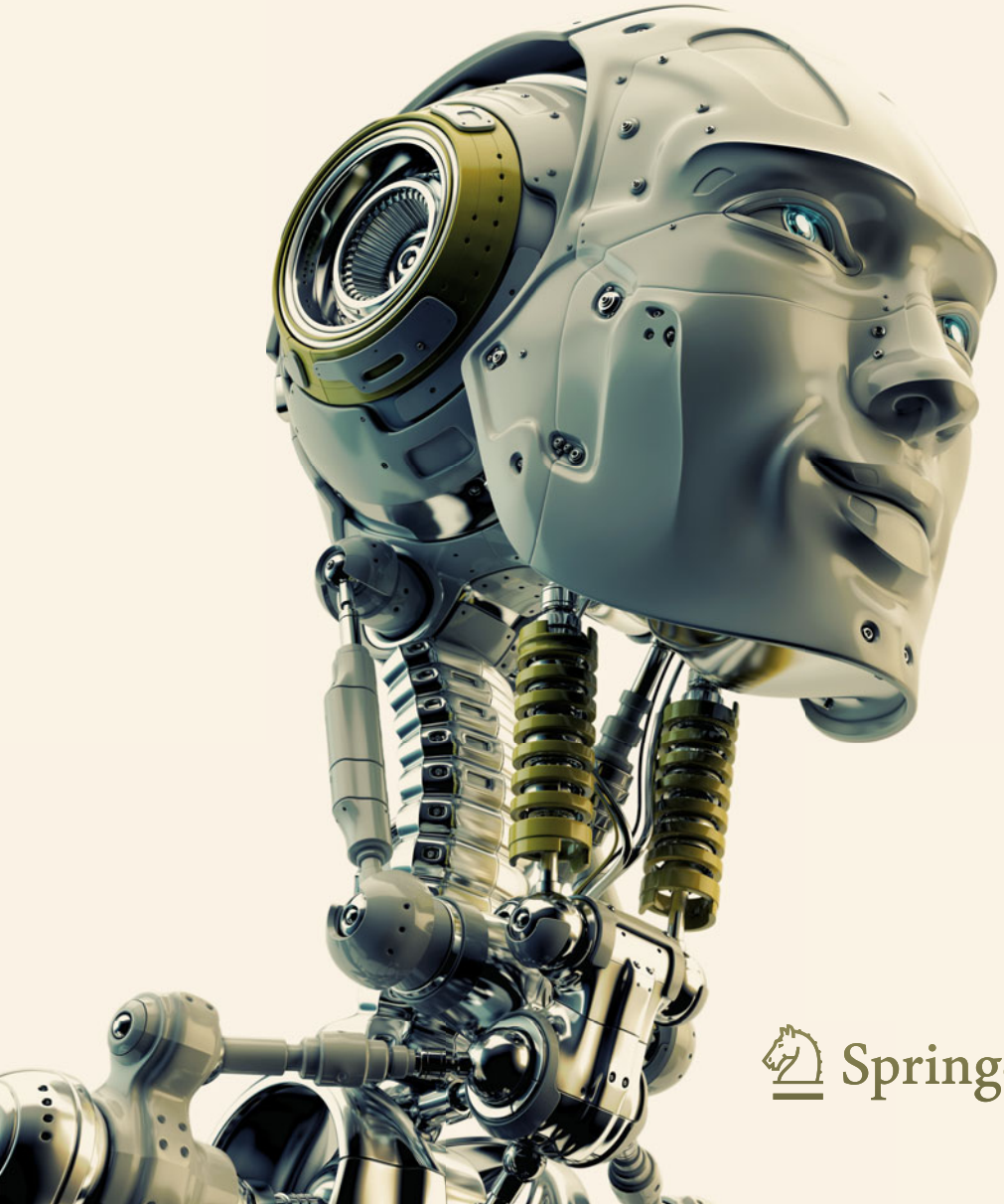
Woodrow Barfield

Cyber-Humans

Our Future with Machines



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This book is dedicated to my daughter, Jessica, both athlete and scholar; to the memory of my wonderful and supportive parents, my sister Linda, to my nieces Melissa and Sky, Cousin Paula, and all the relatives in South Florida, Oregon, Virginia, and California. Dr. Conrad Kraft is also remembered for his friendship, scholarship, and mentorship. I also dedicate this book to Watson, and all other artificial intelligences that will follow, and I look forward to their book review and to the books they will write and to the science they will discover.

Preface

In the mid-1980s I was a graduate student of Industrial and Systems Engineering at Purdue University in Indiana. My research revolved around the topic of how to make computers easier for people to use. At that time the fields of artificial intelligence and robotics were still in their infancy; and a human was a component of every system, either providing manual input or performing supervisory control. With a human brain containing about 85–100 billion neurons and approximately 100 trillion synapses, and with sensors containing remarkable capabilities, determining how technology could best serve humans was a challenging research topic. The theme that the purpose of technology was to serve as a tool for humans, was the dominant view when I was a graduate student in engineering and still is. But later my thinking about technology with regard to its role in serving humanity was to change, and eventually led to the writing of this book. While at Purdue, with limited space for graduate students, I shared an office with other students who were studying aeronautical engineering, manufacturing, and robotics. As I engaged my fellow graduate students in conversation about the topic of their research, I realized that while I was trying to design systems that were easier for humans to use, the other graduate students were trying to design systems that were completely automated; that is, had no human in the system at all. These fascinating and wide ranging discussions were my first introduction to robotics, artificial intelligence, and automation.

After graduation, I took a faculty position and did work primarily in the area of virtual reality, augmented reality, and wearable computers and taught a course on the supervisory control of robots. As my career developed, I became interested in more of the big picture of how technology, science, and policy interrelated. This new line of thinking led me to papers in the area of human rights (for artificial intelligence) and intellectual property, which then led me to law school and later to the LLM program in intellectual property law and policy at the University of Washington. This book details much of my engineering knowledge regarding the design of systems for human use, my formal training in law, and from years of

research and scholarship on the design of virtual and augmented reality systems and wearable computers.

While in graduate school I became aware of another accelerating trend occurring in technology—the enhancement of humans using techniques that were just being discovered in genetics, and the practice of equipping humans with biotechnology to treat a range of disabilities. For frame of reference, in the early 1980s, William DeVries implanted an artificial heart, the Jarvik-7, in a patient with the intention that the implant be long-lasting (it worked for a few months). More recently, French heart transplant specialists developed a prototype of the world's first fully implantable artificial heart, designed to beat for at least five years. Since the first attempts at using technology to enhance humans, advances in technology have led to the ability to replace or enhance a surprising amount of human physiology and anatomy. In fact, over the coming decades, humankind will, for the first time in the history of our species, be able to actively supersede our own physiology and anatomy. And as the nascent technology of prosthetics and neuromorphic chips develops, sometimes this century we may be able to bolster our memory and recall with brain implants; and to think faster, focus our attention better, react faster, run more swiftly, and possibly have superhuman strength. When I consider the enhancement of the human body with technology, my conclusion is that we are in the process of becoming the technology, and not just the passive recipient of its benefits.

For a host of reasons, technology is being developed and used for many purposes thought not possible even a few years ago: for example, assisting the handicapped and disabled (restoring sight for the blind, sound where there is a hearing deficit, or equipping people with exoskeletons to enable movement for those lacking mobility); for those who want to hack their body (a term used for people who seek to self-modify their body to extend the range of their senses, the topic of a chapter in this book); and ominously, for the cyborg-soldier of the future. However, while humans are being equipped with more-and-more technology, our cognitive abilities, which derive from our genetic blueprint, have remained relatively the same for thousands of years. In contrast, operating under the law of accelerating returns, which states that the rate of technological change is exponential, machines are quickly gaining in intelligence, sensory, and motor capabilities.

While technology is being used to enhance human capabilities, fight disease, and to allow new forms of expression, technology itself is becoming smarter, more human-like (i.e., an android, which is a robot designed to have a human appearance), and before midcentury could exceed humans in intelligence (referred to as the Singularity, the topic of Chap. 2). If so, a number of policy and legal issues will ensue regarding the relations between humans and our intelligent machines. Often when challenged by advances across many areas of human endeavor, our relevant laws and governmental policies have lagged behind technological breakthroughs. Consider the ethical, policy, and legal issues raised by the use of drones, or with autonomous robotic soldiers should they enter the battlefield. How about tort law and specifically negligence and strict liability when robots harm humans, or from

a social justice perspective, the deep digital divide which may result when some humans are physically and cognitively enhanced by technology and others are left behind? Further, consider how humanity should respond if artificially intelligent machines attain or surpass human levels of intelligence and argue for rights. For example, should we extend the rights that humans receive in most industrialized nations—such as political rights and liberties, to artificially intelligent machines; or would it be prudent to deny such rights to nonhuman beings? And finally, consider the main theme of this book—should we merge with artificially intelligent machines, or risk being surpassed and becoming inconsequential or even extinct?

One significant impact that will be made by developments in enhancement technology and the emergence of machines with artificial intelligence will be on the law—specifically creating motivations for the passage of new laws and also discovering novel ways to use existing laws to apply in a human society intertwined with smart machines. The law can be found in Constitutions, statutes, government and industry regulations, and the judge-made decisions resulting from cases argued in court. When writing a law review article, the author is comforted when cases have been decided on the issue of interest. This is because the court will have heard the facts, examined the issues, listened to witnesses, and decided how the law applies. However, when dealing with the topic of cyborgs and artificially intelligent machines, we are just now at the stage where disputes are beginning to occur. For example, in 2012 Professor Steve Mann one of the first human–machine "cyborgs" living amongst us, was assaulted at a restaurant in Paris based on his appearance and technical capabilities as a cyborg. Since Steve has natural personhood status (a legal status granting him a range of rights), he could initiate a civil lawsuit on his own behalf (possibly for assault and battery). However, artificially intelligent machines have not yet reached a level of cognitive development to argue for personhood status, thus, they currently lack individual rights and the ability to defend their interests. But if in the future an artificially intelligent machine claimed to be sentient and subsequently argued for rights (at the time of this writing, it has been argued that an AI software bot posing as a teenage boy has passed the Turing test), the public should stay tuned, a tipping point would have been reached and it will get interesting.

To indicate the widespread interest in the topic of this book, let me briefly introduce some of the comments of renowned Cosmologist Sir Martin Rees, by conveying some of his highly interesting observations about our future—what some have termed the Post-Human era. Professor Rees rightly notes that there are chemical and metabolic limits to the size and processing power of organic brains which results in issues of bandwidth limitations and speed of information processing for humans. Furthermore, he notes that such limitations are not competitive with the raw processing power of computers and their march toward artificial general intelligence. But while some think that artificial intelligence is becoming our competition, prominent scientists such as Hans Moravec think of artificial intelligence as humanity's natural future evolutionary path. Agreeing with Rees, I conclude that the potential for further development of artificial intelligence could

be as dramatic as the evolution from single-celled organisms to the humans that exist today. So, looking beyond the horizon, Rees eloquently states that "in the far future, it won't be the minds of humans, but those of machines, that will most fully understand the cosmos—and it will be the actions of autonomous machines that will most drastically change our world, and perhaps what lies beyond."

This book is about the technical, legal, and policy issues which are raised when humans and artificially intelligent machines are enhanced by technology. I discuss cyborgs, bionic humans, and machines with increasing levels of intelligence by linking a chain of fascinating subjects together—the technology of cognitive, motor, and sensory prosthetics; biological and technological enhancements to humans; and body hacking and brain–computer interfaces. Each of these technologies combines to tell the story of where we are going as a species, what policies to consider, and how the law and policy must adapt to accommodate the future of human-technology combinations. My goal in writing this book is to inform the public of what may be coming this century in terms of human cybernetic enhancements, artificially intelligent machines, and the development of cyborgs. I also aim to initiate debate among academicians on a range of scholarly topics, which often receive inadequate coverage in law and technology courses. In the coming decades, the decisions we make as a society, or more generally, as a species regarding how we enhance ourselves and create machines that may replace us, will affect the very essence of what it means to be human, nothing could be more compelling and important for humanity.

Chapel Hill, USA Woodrow Barfield

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Contents

About the Author

Woodrow Barfield headed the Sensory Engineering Laboratory at the University of Washington where he was a Professor of Industrial and Systems Engineering. His research revolved around the design and use of wearable computers and augmented reality systems. He received the Presidential Young Investigator Award from the National Science Foundation, and served as a senior editor of Presence: Teleoperators and Virtual Environments. Dr. Barfield is currently an associate editor of the Virtual Reality Journal and is the senior editor of the first and second editions of "*Fundamentals of Wearable Computers and Augmented Reality*." Dr. Barfield earned a Ph.D. in Engineering from Purdue University and the JD degree and an LLM in intellectual property law and policy, serving as an editor of the *Journal of Law, Technology & Arts*. He has over 350 publications and major presentations, including keynote addresses and articles in engineering and law review journals. He currently lives in Chapel Hill, North Carolina.

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Majchrzak, A., Chang, T-C., Barfield, W., Eberts, R. E., & Salvendy, G., 1987, *Human Aspects of Computer-Aided Design,* London: Taylor and Francis, Ltd.

A Brief Comment About Predictions and Examples Used in the Book

The most important question posed by books on the Singularity, and discussed by futurists and authors such as Ray Kurzweil, Rodney Brooks, Kevin Warwick, Hans Moravec, Nick Bostrom, James Barrat, and Martine Rothblatt, is whether artificial intelligence will eventually pass humans in general intelligence, and gain consciousness. I don't profess to know the answer with any certainty, but I do have the opinion that it will happen. I find it interesting that many of the debates on whether humans may be surpassed in intelligence by an artificial intelligence focuses on *when* it could happen (not *if*)—with predictions that this transformative event will occur by midcentury, the latter half of this century, or sometime next century. However, if one considers the age of this planet (over 45 million centuries), or the amount of time that has passed since humans evolved to live on this planet, or even since humans started recording history, being off by a century or two is insignificant, some would even say a rounding error. But in my view Ray Kurzweil's argument that the Singularity is near, is convincing, so I wrote this book to add to the conversation on how humanity should respond to the emergence of cyborgs and artificial intelligence. Further, to make a specific point about technology, law, and policy in an "age of cyborgs," in several chapters I often used existing "cyborgs" Steve Mann, Neil Harbisson, and Kevin Warwick as examples. They certainly aren't the only cyborgs living amongst us, you, or your neighbor may be equipped with cyborg technology in the form of a heart pacer or artificial limb. In fact, cumulatively, millions of people worldwide are equipped with cochlear implants, retinal prosthesis, and artificial limbs. However, I consistently used Steve, Neil, and Kevin as examples because they are not only pioneers in "wearable and implantable computing technology," they have also been the subject of the popular media and in Steve's case a documentary (Cyberman, 2002). In several chapters I also discuss the work of Dr. Theodore Berger of the University of Southern California on the design of an artificial hippocampus; this is because his work cuts across several topics discussed in this book and I view his work as essential for our cyborg future. In terms of examples of cutting-edge cyborg technology, and start-up companies developing amazing technologies in artificial intelligence, robotics, and neuroprosthesis, I expect some of the companies discussed

in this book will have failed by the time this book is in the hands of the reader, or that some of the projects discussed in this book will have not met the initial promise and are no longer being developed. But if that is the case, there is no doubt that other companies and projects will have started, which the reader will surely read about in the news and that will lead to the amazing future described in this book.

Further Reading

Cyberman (2001) Based on the "Cyborg Experiences" of Steve Mann, Directed by Michael Allder, Written by David Wearer and Bridgot Newsom, distrubted by Canadian Broadcasting Corperation (CBC)

Chapter 1
The Technological Future

Introduction

Let me start the book with a controversial and bold statement—our future is to merge with artificially intelligent machines! How I reached that conclusion is the subject of this book. I don't mean to imply that in the coming decades we humans will look and act like robots on an assembly line, rather, that we will be equipped with so much technology, including computing devices implanted within the brain itself, that we will have been transformed from a biological being into a technology-based being, evolving under laws of technology, more so than under the laws of biological evolution. At the same time that we are becoming more "machine like" (or "cyborg like"), advances in robotics, artificial intelligence, neuroscience, and materials engineering are allowing scientists to create intelligent machines that have sophisticated human—like functionality and are rapidly gaining in intelligence—"they" are becoming like us. I see the logical outcome of technological advancements in robotics, artificial intelligence, prosthesis, and brain implants, as a future merger between humans and machines.[1] This will not be a conscious decision made by humanity, but will be a gradual process, and inevitable. But not so gradual as to take centuries, but in all likelihood something that will happen this century or early next.

As a confession, I may have played a small role in this outcome (our future merger with machines), because as a faculty in engineering, I headed a research laboratory whose goal was to design wearable computing and sensor technology that was fully integrated with the human body. In the early 1990s, I began to formalize my thinking about the future direction of technology, and wrote about it in

[1]Of course, while seminal robot experts and artificial intelligence pioneers such as Hans Moravec hold the view that our future is to merge with machines, many experts disagree, and others argue that humanity should stop this outcome from occurring.

W. Barfield, *Cyber-Humans*, DOI 10.1007/978-3-319-25050-2_1

2001, in a chapter 1 co-authored, *Computing Under the Skin*, in which my colleagues and I argued for the use of sensors and cyborg implants to fix, repair, replace, and enhance damaged human anatomical and physiological systems.[2] At the time, my colleagues and I also mused about the future directions of "wearable" devices, making predictions about technology that are being implemented today. But in hindsight, it seems that we didn't go far enough predicting the future that has unfolded and we were too conservative in stating how close we are to the Singularity and afterwards Posthuman age.

Much of my work on the design and use of "wearable" technology was published in two books I co-edited, *Virtual Environments and Advanced Interface Design,* and *Fundamentals of Wearable Computers and Augmented Reality.*[3] Since the publication of the first edition of these books over a decade ago, the landscape in human enhancement technology and artificial intelligence has changed dramatically. To address these changes, I wrote this book to present an up-to-date summary of recent advances in genetics, prosthesis, and brain-computer interfaces; and to discuss current efforts to create artificially intelligent machines that learn and solve problems in ways not predicted by humans. Another goal in writing this book was to generate discussion among the public on the law and policies which should be enacted as humans are enhanced by technology, and as artificially intelligent machines gain human, or beyond human, levels of intelligence. Given the nature of the topics presented in this book, the discussion will be wide ranging cutting across diverse fields such as biology, engineering, ethics, and law.

As often stated by Google's Ray Kurzweil, the rate of technological change in engineering, medicine, and computer science is accelerating.[4] In some areas, what was science fiction just 10–20 years ago is now mainstream science. If advances in several key technologies continue to accelerate, the twenty-first century will indeed be a time of great change, amazing developments, and unique challenges for humanity. As predicted by computer scientists, engineers, and philosophers, by the end of the twenty-first century, advances in science and engineering will have led to such significant changes in the structure of our bodies that the very nature of what it means to be human will be questioned. On this point, the science fiction writer William Gibson, who coined the term "cyberspace" in the short story "*Burning Chrome,*"[5] sees a "cyborg" future for humanity which includes implantations of silicon chips into the human brain modified with DNA. Fast forward to Professor Theodore Berger's

[2]Dwight Holland, Dawn J. Roberson, and Woodrow Barfield, 2001, Computing Under the Skin, in Woodrow Barfield and Thomas Caudell (eds), *Fundamentals of Wearable Computers and Augmented Reality*, CRC Press.

[3]Woodrow Barfield and Thomas Caudell, *id*.; Woodrow Barfield and Thomas Furness (eds.), 1995, *Virtual Environments and Advanced Interface Design*, Oxford University Press.

[4]Perhaps Ray Kurzweil is most recognized for his ideas about the Law of Accelerating Returns discussed in his seminal book, Ray Kurzweil, 2006, The Singularity is Near, When Humans Transcend Biology, Penguin Books.

[5]William Gibson, 2003, Burning Chrome, Harper Voyager Press. Gibson coined the term "cyberspace" in the 1980s.

laboratory at the University of Southern California, where our cyborg future is being designed now in the form of remarkable neuroprosthetic devices.

Enhancing Humans

According to Sidney Perkowitz writing in "*Digital People: From Bionic Humans to Androids,*"[6] there are two main ways to categorize artificial enhancements of humans: firstly, as functional prosthetic devices and implants, such as artificial limbs, replacement knees and hips, and vascular stents (which aid in the flow of blood in blocked arteries); and secondly, as cosmetic or vanity implants, like hair plugs, false teeth, artificial eyes, and breast implants. This book concerns both categories of enhancements, and it is interesting to note that the efforts of some researchers to develop human-like robots, could be thought of as cosmetic or vanity enhancements to the machine, as such enhancements may be nonfunctional. Enhancement technologies may also occur in a multitude of ways, supported by a variety of technologies, in which human beings enhance their looks, abilities, features, or functions. In fact, enhancements to the human body range from performance enhancing drugs, plastic surgery and silicone implants for (perceived) beauty purposes, to bionic limbs and chip-enhanced cognition in humans. While the distinguishing feature of "cyborg" enhancement technology is to improve human functioning above 'normal' or 'average', many technologies for enhancement are being used for medical or regenerative purposes; for example, plastic surgery for burn victims or prostheses for lost limbs; the purpose in these cases being to bring the people 'back to normal'.

In addition to efforts to enhance the human body with a range of technologies, other important progress is being made in robotics and artificial intelligence that is also setting the stage for a human-machine merger. Due to major improvements in algorithms and sensors, machines are becoming more autonomous, software is becoming 'smarter', and robots are being developed that are beginning to look and act more like humans than machines (see Chaps. 3, *The Law of Artificially Intelligent Brains*, and 7, *The Law of Looks and Artificial Bodies*). In fact, one area of research in robotics is towards developing realistic looking robots that mirror human appearance (i.e., androids); another strand is towards developing facial features that cause a robot to appear as if expressing emotions; in particular, facial expressions like smiling or raising eyebrows. Once 'humanoid' robots are equipped with artificial intelligence—and thus acquire more autonomy from their human masters—the vision of an android in the spirit of Star Trek's "Data" might become a reality. At this point one can imagine two interesting scenarios: firstly, that the world may become populated by different types of species than those we see around us today: non-enhanced and enhanced humans, cyborgs, robots, and

[6]Sidney Perkowitz, 2004, Digital People: From Bionic Humans to Androids, Joseph Henry Press.

androids among them, all of which will function, in different but perhaps also in similar ways, in day-to-day social life.[7] And secondly, from advances in technology there could emerge one intelligent species, based on the merger of human and machine. In my view, before humanity could eventually merges with machines, there will be several intermediate forms of human-machine combinations, some of which we will term cyborgs. Again, when I speak of "merging with machines," I mean equipping humans with the technology (typically information technologies) to enhance the human body and mind, to go beyond current capabilities, essentially, to become more "cyborg-like." Throughout this book, I refer to the technology to enhance the human body and mind as "cyborg technologies." And I refer to the "cyborg future," "cyborg age," or coming "age of cyborgs," to refer to the future in which we will become equipped with technology to repair, replace, and extend our senses, and cognitive functions. An "emerging cyborg law," then is the legal issues which will be important to consider for our technological future. Further, whether a complete machine body containing a human consciousness uploaded to a machine architecture is a human or machine, is an interesting philosophical question, and the subject of discussions by various authors (see Chap. 7: *The Law of Looks and Artificial Bodies*).[8]

The vision of a future world populated by humans, cyborgs, intelligent robots, and androids raises many interesting questions. One such question is what this development means for fundamental or constitutional rights for the range of intelligent beings that may exist in the near future. Will cyborgs be considered human enough to still be bearers of 'human' rights? Can androids claim 'human' rights if they look and function in the same way in society as humans or cyborgs? And can human beings keep robots under control as they become increasingly autonomous; in other words, will robots comply with Asimov's three laws of robotics, or will they, like HAL in *2001—A Space Odyssey*, revolt and try and control humans? Society has been warned of this very outcome by physicist Stephen Hawking and entrepreneur and CEO of Telsa Motors Elon Musk.[9] Some argue that since cyborgs will evolve in gradual steps from the human species, they will most likely be considered humans by future generations. The scenario may work out as follows—as soon as different enhancement technologies are adopted by a critical mass, after the initial pioneers, enhanced humans will simply be the new appearance of the human species. As a result, it is argued that cyborgs will be the

[7]See Human enhancement, at: http://www.fidis.net/resources/identity-use-cases-scenarios/human-enhancement-robots-and-the-fight-for-human-rights/.

[8]Patrick Lin and Keith Adney, 2014, Robot Ethics: The Ethical and Social Implications of Robotics, MIT Press.

[9]Rory Cellan, Stephen Hawking Warns Artificial Intelligence Could End Mankind, BBC News, at http://www.bbc.com/news/technology-30290540; Ellie Zolfaghariford and Victoria Woollastan, 2–15, Could robots turn people into PETS? Elon Musk claims artificial intelligence will treat humans like 'labradors', at: http://www.dailymail.co.uk/sciencetech/article-3011302/Could-robots-turn-people-PETS-Elon-Musk-claims-artificial-intelligence-treat-humans-like-Labradors.html.

inheritors of human rights that exist today.[10] Now suppose that robots and artificially-intelligent machines perform similar functions as cyborgs do, and perhaps even become androids who are in looks and functions equivalent to cyborgs, then should they not have the same catalogue of rights? This issue will require substantial debate in society and legal academia.

Another issue that technologically enhanced people may raise is whether a social, or digital divide will develop between enhanced and non-enhanced humans. Human rights can play an important part in this debate: because they lay down the basic rules for treating people. At first sight, the right to non-discrimination will provide substantial guidance: non-enhanced people should not be treated unequally. However, what is 'unequal', if in the future enhanced humans are different in important ways from non-enhanced humans? For example, if an employer can choose between an unenhanced person with an IQ of 120 and a cyborg with an IQ of 260 or beyond, does he discriminate if he chooses the cyborg? This is just one example of questions concerning specific human rights in relation to human enhancement that merit public debate.

Humans, Bionics, and Cyborgs

As we become equipped with prosthesis and brain implants, we are moving beyond the human capabilities provided by our evolutionary history and coded in our genes. Since I believe technological advances are leading humanity towards a "cyborg" future and an eventual merger with machines; I should define some basic terms. Let's start with one of the main characters in this book—a "cyborg". Generally, a cyborg is a human-machine combination that has certain physiological and intellectual processes aided or controlled by mechanical, electronic, or computational devices. "Cyborg," is actually a compound word derived from cybernetics and organism, and was coined by Manfred Clynes[11] in 1960 to describe the need for mankind to artificially enhance biological functions in order to survive in the hostile environment of Space.

To introduce some other basic terms, "transhuman" is a term that refers to an evolutionary transition from the human to the Posthuman. To transhumanist thinkers, a Posthuman is a hypothetical future being "whose basic capacities so radically exceed those of present humans as to be no longer unambiguously human by our current standards."[12] The difference between the Posthuman and other hypothetical sophisticated non-humans is that a Posthuman was once a human, either in

[10]Human enhancement, robots, and the fight for human rights, at: http://www.fidis.net/resources/identity-use-cases-scenarios/human-enhancement-robots-and-the-fight-for-human-rights/.

[11]M. E. Clynes and N. S. Kline, 1960, Cyborgs and Space, *Astronautics*, 26–27, 74–75.

[12]Posthuman, Wikipedia, https://en.wikipedia.org/wiki/Posthuman.

its lifetime or in the lifetimes of some or all of its direct ancestors.[13] As such, a prerequisite for a Posthuman is a transhuman, the point at which the human being begins surpassing his or her own limitations, but is still recognizable as a human person. In this sense, the transition between human and Posthuman may be viewed as a continuum rather than an all-or-nothing event.

The field of cybernetics is concerned with communication and control systems involving living organisms and machines. The artificial parts used to create cyborgs do more than replace the main functionality of an organ or limb, they add to, enhance, or replace the computational abilities of biological systems. In a typical example of a cyborg, a human fitted with a heart pacemaker might be considered a cyborg, since s/he is incapable of surviving without the mechanical part whose computational capabilities are essential. As a more extreme example of a cyborg, some would view clothing as a cybernetic modification of skin; because it enables us to survive in drastically different environments by the use of materials that aren't naturally existing in those environments. In my conceptualization of a cyborg, if the clothing had computational capabilities that aided the wearer,[14] then I would conclude that the "clothing enhanced human" was a cyborg. However, in almost every case, throughout this book the "cyborgs" I discuss are the result of being enhanced with technology worn on or integrated into the body.

In the popular culture the terms "bionic human" and "cyborg" are often used interchangeably to refer to any human enhanced with technology. However, I draw the distinction that while a bionic human is a person that has been enhanced by mechanical or biological means; going a step further, a cyborg has computational processes enhanced or aided by technology, the goal being to go beyond current human sensory and cognitive abilities. Interestingly, while there are clearly many bionically enhanced people, there are also cyborgs living amongst us now. If we want to determine how many cyborgs or bionic humans there are, the number will depend on the definition used. For example, if by using the term "bionic human," one means to signify a person who is artificially enhanced in some way, then the digestion of medicine would create a bionic human and there would be literally hundreds of millions of such beings alive today. If, however, one meant that to be a "bionic human" a certain number of human parts were replaced by mechanical implants and prosthesis, then the number of such humans would not number in the hundreds of millions, but in the millions. According to one commentator, many current people could be defined as "bionic," in that eight to ten percent of the U.S. population, that is, approximately 25 million people, currently have some sort of artificial part- a number expected to grow as the population ages. In fact, just considering the sense of audition, thousands of cochlear implants are currently in use, including some placed in deaf children.

Finally, if one meant that to be a "cyborg" that a brain function was artificially enhanced or replaced, then the number of such people would likely be in the

[13] *Id.*

[14] Kate Hartman, 2014, Make: Wearable Electronics: Design, Prototype, and Wear Your Own Interactive Garments, Maker Medic Inc. Publisher.

thousands, a number expected to increase dramatically in the next 10 years. As an example of brain implant technology currently being used, starting in the late 1990s physicians have implanted electrodes into the brains of patients in the hope of developing a computer-brain interface which would allow those "locked-in " their bodies to operate a robotic arm or move a cursor on a screen. Further, technology that may allow memories to be digitally stored in the brain is under development. The neuroprosthesis (artificial hippocampus) referred to earlier and that is being designed and tested by Theodore Berger and his team at the University of Southern California[15] and by Dr. Sam A. Deadwyler and Dr. Robert Hampson of Wake Forest Baptist Medical Center could serve this purpose.[16]

In many discussions of enhanced humans, whether a person equipped with technology is termed bionic or cyborg, is not an important distinction—most people use the terms interchangeably to refer to any person equipped with technology. But under the law, the degree to which a person is enhanced by technology could matter. For example, under disability law a person with a given handicap may need to be accommodated by an employer; but the type of disability and what technology is used to address it, would matter in the legal analysis of the disability and the rights afforded the disabled person. And consider athletes who have lost their legs yet still compete against athletes without prosthesis. Competitors often raise concerns about the unfair advantage the "cyborg" would have over them due to the lightness of their carbon-fiber prosthetics. While this example may appear to be something of an outlier, as prosthetic technology improves, the potential for prosthetic limbs to equal or even surpass the capabilities of natural limbs is great.[17] Further, prosthetic limbs may be stronger, and allow the user to carry heavier loads than they may normally be able to carry. Alternatively, they may be more flexible, or allow for greater accuracy in certain tasks—how many people can boast of having a wrist that rotates 360°? While this may seem an inane example, the possibilities nevertheless exist for people once considered 'disabled' to become 'over-abled' in comparison to non-enhanced individuals. Will this give those individuals a competitive advantage over others that are non-enhanced in employment? As with some enhanced people, will a perceived superiority of the artificial over the natural create resentment between 'enhanced' and 'non-enhanced' people? As a result, will new categories of discrimination law be necessary? Under the U.K. *Equality Act*, someone is 'disabled' if they are considered to have an impairment that has a substantial and long-term adverse effect on their ability to carry out normal day-to-day activities; if someone is able to surpass the ability of

[15]Theodore Berger, Artificial Hippocampus, in Memory Implants, MIT Technology Review, at: http://www.technologyreview.com/featuredstory/513681/memory-implants/.

[16]Theodore W. Berger, Dong Song, Rosa H. M. Chan, Vasilas Z. Marmarelis, Jeff LaCoss, Jack Wills, Robert E. Hampson, Sam A. Deadwyler, and John J. Granacki, A Hippocampal Cognitive Prosthesis: Multi-Input, Multi-Output Nonlinear Modeling and VLSI Implementation, IEEE Trans Neural Syst Rehabil Eng. 2012 Mar; 20(2): 198–211, doi: 10.1109/TNSRE.2012.2189133.

[17]Human Enhancement Technologies—Edging towards the Cyborg? at: http://www.scl.org/site.aspx?i=ed31780.

fully-able people to undertake those activities through the use of enhancement technologies, can we truly consider them to be disabled?[18]

Interestingly, one jurisdiction may have already recognized a person as a cyborg. Artist, Neil Harbisson,[19] is completely color blind suffering from a visual impairment called achromatopsia, which means he sees the world in shades of grey. To perceive colors, Neil wears a sensory augmentation device in the form of a head-mounted antenna attached to a chip at the back of his skull. As a form of sensory substitution, the "Eyeborg" turns colors into sounds, allowing Neil to "hear" electromagnetic energy representing color. After a long dispute with the U.K. authorities, Neil's passport photo now includes a picture of him with his cyborg device, a recognition by the authorities that his cyborg enhancement is a permanent part of his appearance. With a passport photo that shows the Eyeborg as part of Harbisson's face, it will be difficult for people to argue that his Eyeborg is an optional accessory, like a camera or a hat, and somebody trying to take his augmentation off could be committing an assault and battery equivalent to injuring his face. Interestingly, under the law, a "battery" may occur even if the aggressor does not touch the plaintiff (i.e., cyborg) directly, but instead touches something closely related to his or her person (like a cybernetic enhancement attached to the body).[20] For example, courts have held that touching the cane a person uses to walk may be battery, even if the defendant never touches the person herself. In this case, the cane is like an extension of the person's body, so touching it is the same thing as touching the person's body. In many situations, clothing, hats, and bags may also count as part of a person enough for the person wearing them to prove battery. However, as we will see in a later chapter, the law in this area is evolving in response to cyborg technologies.

A major point to make early in this book is that while humans are becoming equipped with prosthesis and implants, and thus becoming more cyborg-like, during this century, robots will continue to get smarter and at a speed defying human imagination (actually our bias towards linear thinking see Chap. 3: *The Law of Artificially Intelligent Brains*). In fact, robots equipped with artificial intelligence, and a host of sensors, actuators, and algorithms are leading the way to the creation of machines that may surpass humans in intelligence and motor capabilities by the middle, and almost certainly, the end of the twenty-first century. As technology advances, new forms of humans may evolve from different techniques to enhance human physiology, anatomy, and cognitive structures. All this may create a continuum of intelligent beings from human to machine, progressing from human, bionic human, cyborg, android, robot, software bot, and machine; how artificial intelligence may add to, or "disrupt" this continuum is discussed throughout this book.

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[18]UK Equity Act of 2010.

[19]Neil Harbisson, BBC News, The Man Who Hears Color, at: http://www.bbc.com/news/technology-29992577.

[20]Gowri Ramachandran, Against the Right to Bodily Integrity: Of Cyborgs and Human Rights, 2009, Denver Law Review, Vol. 187, 1–57.

Advances in artificial intelligence may also result in disembodied software beings that roam the internet, possibly downloading their consciousness to remote robots or to androids to gain mobility at particular locations around the world. One commentator has even used the term "digital people" to refer to entities that include artificial and partly artificial beings, from mechatronic robots (mechanical plus electronic) to humans with bionic (biological plus electronic) implants. In addition, Martine Rothblatt in her book, *Virtually Human: The Premise and the Peril of Digital Immortality*, argues that the brain can be simulated using software and computer technology. From this discussion, the impression is conveyed that different types of artificially intelligent beings may coexist in the future.

Brain-Computer Interfaces

Based on medical necessity, enhancement technologies are being used to repair and replace human anatomy and physiology, and to repair and enhance human cognitive and perceptual abilities. For example, brain-computer interfaces are assisting people suffering from debilitating neurological disorders, such that they are "locked-in" their own body. A brain-computer interface which consists of recording electrodes placed on a person's scalp or implanted into their brain, allows those locked-in the capability to communicate and interact with the world, by thought alone.

Additional progress is being made in other areas of brain-computer interface design. For example, scientists have used brain scanners to detect and reconstruct the faces that people are thinking of, according to a study published in the journal *NeuroImage*.[21] In the study, Yale scientists hooked participants up to an fMRI brain scanner—which determines activity in different parts of the brain by measuring blood flow—and showed them images of faces. Then, using only the brain scans, Professor Marvin Chun and his team were able to create images of the faces the people were looking at.[22] One can imagine in the future that a witness to a crime might reconstruct a suspect's face based on "extracting" the image from his mind. Yale researchers pointed out that an important limitation of the technology as it exists now, is that this sort of technology can only read active parts of the brain, it couldn't read passive memories—to do this you would have to get the person to imagine the memory to read it. Interestingly, at the University of California-Berkeley, scientists are moving beyond "reading" thoughts to predicting what

[21]Bill Hathaway, 2014, Yale Researchers Reconstruct Facial Images Locked in a Viewer's Mind, http://news.yale.edu/2014/03/25/yale-researchers-reconstruct-facial-images-locked-viewer-s-mind; also in Neuroimage. 2014 Jul 1;94:12–22. doi: 10.1016/j.neuroimage.2014.03.018.

[22]Bill Hathaway, Yale researchers reconstruct facial images locked in a viewer's mind, at: http://news.yale.edu/2014/03/25/yale-researchers-reconstruct-facial-images-locked-viewer-s-mind.

someone will think next.[23] And at Carnegie Mellon University, in Pittsburgh, cognitive neuroscientist Marcel Just from the *Center for Cognitive Brain Imaging* has a vision that will make Google Glass and other similar technologies seem very last century.[24] Instead of using your eye to direct a cursor, Just envisions a device that will dial a number by interpreting your thoughts.[25] However, what if all of our thoughts were public? Dr. Just envisions a terrifying version of the future, where officials read minds in order to gain control over them. But more optimistically, Marcel also envisions a more positive future, with mind reading devices offering opportunities to people with disabilities—and to those not disabled.

According to Duke University neuroscientist Miguel Nicolelis, microchips implanted into the brain could also allow brain-to-brain communication, that is, telepathy.[26] Thus far, brain-wave sensing machines have been used to 'telepathically' control everything from real-life helicopters to characters in a computer game. In its most recent incarnation, the science of telepathy has gone a step further by allowing someone in India to send an email to his colleague in France using thought. To perform this feat, researchers used electroencephalography (EEG) headsets which recorded electrical activity from neurons firing in the brain to convert words into binary. Once the initial thoughts were digitized in India, they were sent to a person's mind in France where a computer translated the message, and then used electrical stimulation to transmit the thought to the receiver's mind. Ultimately, telepathy chips and related brain-computer devices could lead to the emergence of new forms of intelligence, for example, "mindplexes."[27] This is a term used by artificial intelligence researcher Ben Goertzel, which represents a collection of independent human minds, yet also possessing a coherent self and consciousness at the higher level of the telepathically-interlinked human group. Mindplexes could lead to the benefits associated with crowd sourcing in which the combined wisdom of a crowd has in some cases been shown to solve problems beyond the reach of experts. In fact, the characteristics of "wise crowds," which are diversity of opinion; independence of members from one another; decentralization; and a good method for aggregating opinions would be a feature of networked brain-to-brain communication.

Surely, the reading of thoughts would raise a host of legal and policy issues. Not the least of which is privacy law. On this point, courts in the future may have to decide whether listening to and recording a person's thoughts is protected

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[23]Yasmin Anwar, 2011, Scientists Use Brain Imaging to Reveal the Movies in Our Mind, at: http://newscenter.berkeley.edu/2011/09/22/brain-movies/.

[24]Karen Weintraub, 2014, Scientists explore possibilities of mind reading, at: http://www.usatoday.com/story/tech/2014/04/22/mind-reading-brain-scans/7747831/.

[25]*Id.*

[26]Miguel Nicolelis, 2012, Beyond Boundaries: The New Neuroscience of Connecting Brains with Machines-and How It Will Change Our Lives, St. Martin's Griffin Press.

[27]Ben Goertzel, 2014, Between Ape and Artilect: Conversations with Pioneers of Artificial General Intelligence and Other Transformative Technologies, CreateSpace Independent Publishing Platform.

speech, or an unlawful search and seizure of the activity (i.e., cognition) generated by the prefrontal cortex (a topic discussed in Chap. 3). As to implanting microchips, a few states in the U.S. have already enacted anti-chipping statutes which prohibit the "chipping" of vulnerable populations and raises the bar of consent for implanting an identification or tracking device in any person. I will return to this important topic again.

With the ability to hack the brain comes compelling problems of law and policy. If it becomes technically possible to communicate brain-to-brain by thought alone, could the wirelessly networked brains be hacked into by a corporation or government agency that could implant an advertisement, subconscious thought, or memory into one's mind? If you are annoyed by pop-up ads which appear now on a website, imagine the nuisance of a pop-up ad appearing in your mind. Further, the ability to implant a "telepathy chip"—a neural implant that would allow the wearer to project their thoughts or feelings to others, and receive thoughts or feelings from others, raises a huge number of questions philosophically, legally, psychologically, and socially. For example, what would happen, if an implanted computer chip should "crash" after it is in place? What kinds of health and behavior problems might arise in such a case?

Biological Enhancements

While much of this book discusses enhancement technology in the form of hardware, software, and algorithms, to present a more comprehensive picture of what the future may hold, I briefly present here material on current efforts to enhance human abilities by modifying their DNA, and by performance enhancing drugs. In addition, DNA nanobots in 15–20 years could allow humans to access the internet with their mind, in fact, the U.S. agency DARPA, is researching this possibility now. Until recently, human genetic engineering was the material of science-fiction novels and blockbuster Hollywood films. However, genetic engineering of DNA is not confined to books and movies, scientists and doctors are already attempting to genetically alter human beings and our cells. To understand the choices that humanity must confront this century as a result of the ability to genetically enhance a human, it is critical to understand an important distinction under the umbrella of genetic engineering: the difference between therapy and enhancement. Gene therapy and genetic enhancement are technically both genetic engineering, but there are important moral differences.

For decades, researchers have worked toward using genetic modification called gene therapy to cure devastating genetic diseases. Gene therapy works by delivering a copy of a normal gene into the cells of a patient in an attempt to correct a defective gene. This genetic alteration would then hopefully cure or slow the progress of that disease. In many cases, the added gene would produce a protein that is missing or not functioning in a patient because of a genetic mutation. However, genetically engineering a normal person who wants, for example, more muscle to

improve his athletic ability is no longer gene therapy; instead, it is genetic enhancement.[28] Genetic enhancement would take an otherwise healthy person and genetically modify him to be more than human, not just in strength, but also in intelligence, beauty or any other desirable trait. So why is the distinction between gene therapy and genetic enhancement important? Gene therapy seeks to return a patient to normal human functioning. Genetic enhancement, on the other hand, intentionally and fundamentally alters a human being in ways not intended by nature (note cyborg technologies may perform the same function).

When considering biological enhancements to humans, there is another important distinction to discuss. Somatic enhancements are those that affect one person, and therefore, the genetic alterations occur in only one individual, they do not enter the human genome generally. While single-person enhancements may have a dramatic impact on a solitary individual's life, since those changes are not passed on to that individual's children; they do not become part of the larger human genome. In contrast, germline changes are genetic modifications that can be passed on to one's descendants and thus can become permanent components of the human genome; affecting the person receiving the intervention and, at least indirectly, affecting every other human being. Such changes would constitute alterations of the entire complement of genetic traits found within the species, and many people believe that such steps should be taken with great caution, even trepidation, if not banned altogether.[29]

One form of enhancement technology that has great promise for engineering a healthier person, but at the same time, has the potential to impact the very nature of humanity is nanotechnology. The long-term goal of nanotechnology is to manipulate molecular and atomic structures to design and create machines at the atomic level; for example, nanobots to repair the body. Since humans are made of the same basic building blocks as the natural world, nanotechnology will enable the ability to change human tissues and cells at the molecular level. This will open doors in medicine previously thought impossible, and it will enable us to extend the length and quality of human life. It will also open the door to "enhancements" of the body; including better IQ, appearance, and capabilities. These enhancements will undoubtedly benefit many, but they also bring up important moral, ethical, and legal questions that human society is just beginning to face.

Biological enhancements to humans already exist in many forms; for example, according to Maxwell Mehlman, director of the *Law-Medicine Center* at Case Western Reserve School of Law,[30] the U.S. Federal Drug Administration (FDA)

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[28]See generally, Gene Therapy, 2008, at: http://www.marymeetsdolly.com/index.pl?%7C%7Cac=marymeetsdolly&%7C%7Ccm=2c&%7C%7Ccv=1&%7C%7Cpp=20&%7C%7Crp=1&%7C%7Crv=titledescription&%7C%7Csi=00ZKNPHS3VX33PA0I3Z5&%7C%7Csrt=t&%7C%7Csrtin=a&%7C%7Ctr=OIP8JNM0ME&%7C%7Cudid=15&go=50.

[29]Francis Fukuyama, 2003. Our Posthuman Future: Consequences of the Biotechnology Revolution, Picador Press.

[30]Maxwell Mehlman, 2012, Transhumanist Dreams and Dystopian Nightmares: The Promise and Peril of Genetic Engineering, John Hopkins University Press.

recently approved a drug which has the cosmetic effects of lengthening and darkening eyelashes. The drug, Latisse, or bimatoprost, was already on the market as a treatment for glaucoma. And to gain a competitive edge, athletes use everything from steroids and blood transfusions to recombinant-DNA—manufactured hormones. Students have been known to supplement caffeine-containing energy drinks with Ritalin and the new alertness drug modafinil. Further, the military also spends millions of dollars every year on biological research to increase the war-fighting abilities of "cyborg" soldiers. All of these are examples of biomedical enhancements: interventions that use medical and biological technology to improve performance, appearance, or capability in addition to what is necessary to achieve, sustain, or restore health.[31]

One of the recent enhancement movements is the phenomena of DIY biology which advocates open source of DNA information (see Chap. 5, discussing the movement to self-modify the body). This movement emphasizes DIY genetic experiments and open access to scientific and specifically, genetic material. The DIY biology movement attempts to make available the tools and resources necessary for anyone, including non-professionals, to conduct biological engineering of their own body. For example, low-cost thermocyclers (instruments to amplify DNA and RNA samples via polymerase chain reaction) have been created to make a crucial technology more widely available to the public. What about biological enhancements and public policy? An interesting relationship between genetic enhancements and public policy was highlighted by Matthew Liao, a professor of philosophy and bioethics at New York University.[32] Liao explored ways humanity can change its nature to combat "climate change." One of the suggestions Liao discussed was to genetically engineer human eyes to function more like cat eyes so we can see better in the dark. Liao remarked that this would reduce the need for lighting and reduce energy usage. Considering the available pool of resources to feed the planet's rising population, Liao also discussed genetically modifying our offspring to be smaller so they eat less and consume fewer resources. In the face of such suggestions, the NBA, and humanity has much to talk about.

Over the next several decades, it is possible that genetic engineering and other cognitive enhancement techniques could significantly increase human abilities such as intelligence. However, as Ronald Bailey author of works on ecology, economics, and biotechnology points out, critics on both the right and the left worry that the ability to enhance a person's cognitive abilities will undermine political equality.[33] Francis Fukuyama, a strong opponent of engineering DNA for purposes

[31]Maxwell J. Mehlman, Tapping Talent in a Global Economy: Biomedical Enhancements: Entering a New Era, Issues in Science and Technology, Volume XXV Issue 3, Spring 2009, at: http://issues.org/25-3/mehlman/.

[32]See generally Matthew Liao, et al. 2015, Designer Biology: The Ethics of Intensively Engineering Biological and Ecological Systems, Lexington Books.

[33]Ronald Bailey, 2005, Liberation Biology: The Scientific and Moral Case for the Biotech Revolution, Prometheus Books.

of human enhancement, in his 2002 book *Our Posthuman Future: Consequences of the Biotechnology Revolution*, asserted, "The political equality enshrined in the Declaration of Independence rests on the empirical fact of natural human equality".[34] The idea he opposes is that biological enhancements could "allow inequality to be inscribed in the human genome." Fukuyama's argument is that biotechnology could allow a class of "super beings" to be engineered such that "normal" humans would be orders of magnitude less on scales of intelligence, aggression, drive, and so on.[35] While this criticism certainly deserves public debate, some have argued that this is a very weak reason to oppose the enhancement of such important attributes as intelligence. Those in favor of cognitive enhancements point out that cognitive inequality is already inscribed in the human genome, as there is already large difference in intellectual ability between people with low versus high IQs.[36] They also argue that cognitive enhancement could help alleviate political ignorance and increase political equality—at least in so far as political equality is enhanced by cognitive equality.[37] As for the equality issue, cognitive enhancement may follow the same trajectory as numerous previous information-spreading technologies, such as books, radio, television, and computers.[38] Some argue that while at first they may be available mostly to the rich (first adopters), over time costs could go down due to marketplace competition, and the rest of society will then be able to take advantage of them as well. Ultimately, according to some commentators, cognitive enhancement might actually reduce the large "natural" gaps in cognitive ability that currently exist. Again, we humans need to talk about this.

New Opportunities in the 21st Century

Future technological developments leading towards a human—machine merger will also lead to new opportunities for entrepreneurs. For example, according to data from *Global Industry Analysts*, worldwide markets for prosthetics, include the design, manufacturing and fitting of artificial limbs. At the time of this writing a "typical" prosthesis may cost $10,000 to $65,000, and the market is projected to grow from $15.3 billion to $23.5 billion by 2017. The wearable technology market may grow to $6 billion by 2016, and the demand for real-time data, including

[34]Francis Fukuyama, *id.,* note 29.

[35]Francis Fukuyama, *id.,* note 29.

[36]Francis Fukuyama, *id.,* note 29.

[37]Illya Somin, 2013, The Case for Designer Babies, The Volokh Conspiracy, at: http://volokh.com/2013/10/21/case-designer-babies/.

[38]*Id*.