Chapter 5
Modifying, Enhancing, and Hacking the Body

Introduction

The first students who took a course in computer science were required to write programs for a massive computer that had a voracious appetite for electricity and a habit for reading punched cards. Since then, much has changed. Now day's wirelessly networked smart phones with the power of a mid-80s Cray supercomputer are in the hands of every student[1]; and over a hundred thousand people with debilitating neurological disease have electrodes implanted in their brain to control tremors and other symptoms.[2] But, as impressive as these uses of technology, in the future, prosthetics, implantable chips, and brain-computer interfaces, will go far beyond treating disease, or providing a tool for students to search the internet. In fact, researchers in neuroscience, artificial intelligence, and robotics, have predicted that well before the end of this century, technology will have advanced to the stage where memories can be implanted in the brain; cyborgs will emerge in full force; and artificially intelligent machines will argue for rights. The technology of brain-computer interfaces, more powerful computers, and advances in artificial intelligence, are all leading the way to what I believe is the major trend for the twenty-first century, a future in which we humans merge with artificially intelligent machines; and as Ray Kurzweil writing in "*The Singularity is Near*" observed, a future that may be only a few decades away.[3]

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[1]The early ENIAC computer used 160 Kilowatts of electric power and had 18,000 vacuum tubes; Vovek Wadhwa, Our Lagging Laws, 2014, MIT Technology Review, v. 117, p. 11.

[2]About 30,000 in the U.S. with Parkinson's disease are treated with an electrode to stimulate their brain and 70,000 more are in need of deep brain stimulation, further 200,000 people use Cochlear implants.

[3]Ray Kurzweil, 2006, The Singularity is Near: When Humans Transcend Biology, Penguin Books.

W. Barfield, *Cyber-Humans*, DOI 10.1007/978-3-319-25050-2_5

In this chapter, I discuss amazing technologies that are being used by individuals to enhance and modify their body, and that are moving humanity directly towards a cyborg age and the possibility of a Posthuman future. These technologies will also bring us a few steps closer to the technical Singularity; that point in time where artificial intelligence reaches and then passes human intelligence. Given the range of technologies described in this chapter, I categorize practices to modify or enhance the body under the general rubric of "body hacking." Efforts by individuals to "hack their body," may include enhancing their senses, creating new senses, modifying the external features of their body, or as discussed below, under the topic of cybersecurity, disrupting the implantable wireless devices worn by other people. In my view of the future, to merge with machines is not to become indistinguishable from a robot, nor to lose every essence of humanity, but to more-and-more integrate technology into the human body, including the brain, essentially creating a cyborg and Posthuman future for humanity. How this future may unfold is discussed throughout this book.

There are many reasons why it would be desirable to hack the body with prosthesis, sensors, and other technologies. In fact, for thousands of years, people have been modifying the external features of their bodies. For example, among some Amazonian tribes, young males traditionally have their lips pierced and begin to wear lip plates when they enter the men's house, so the general idea that the body is malleable and subject to modification is clear from studies in anthropology and sociology.[4] Furthermore, in western society, movie stars and others use cosmetic surgery to modify their body and facial appearance for aesthetic purposes. Based on data from the *American Society of Plastic Surgeons*,[5] in the U.S. alone, millions of plastic surgery procedures are performed yearly, and millions more people have cosmetic procedures done for reconstructive purposes.[6] In addition, medical necessity is often cited as a reason to modify the body or restore the functions of the body to a previous normal state; for example, several hundred thousand people worldwide have cochlear implants and retinal prosthesis, and amazing enhancement technologies are just beyond the horizon.

Another factor leading to a cyborg future is the growing number of people who are beginning to "self-enhance" their body using digital technology in order to go beyond current human abilities. With continuing advances in technology, such people may benefit from the ability to hack the body in amazing ways. For example, in the future, with sufficiently advanced brain-computer interfaces, students with an interest in physics and economics could access the subject by

[4]See generally Victoria Pitts, 2003, In the Flesh: The Cultural Politics of Body Modification, Palgrave Macmillan.

[5]See for example, American Society of Plastic Surgeons, 2014, American Society of Plastic Surgeons Reports Cosmetic Procedures Increased 3 Percent in 2014, at: http://www.plasticsurgery.org/news/2015/plastic-surgery-statistics-show-new-consumer-trends.html.

[6]Reconstructive surgery is surgery to restore function or normal appearance by reconstructing defective organs or parts.

downloading the material directly to a digital storage device in their brain.[7] And health conscious people could buy medical/MD downloads the way they buy nutritional supplements; and for people requiring new skills for the twenty-first century, they could download the appropriate cognitive skills directly to their mind (or upload cognitive skills they have learned to the internet). Of course for any of these possibilities to happen, significant breakthroughs in technology and the life sciences will have to occur, but if anything, this book should convince the reader that we are at least headed in that direction. And as always, in the background of humans hacking their body and becoming more “cyborg like,” it is important to remember, at the same time, artificially intelligent machines are making great strides in becoming more “human-like” in terms of their senses, cognition, physical appearance, and motor abilities. In fact, robotic prosthesis, are now approaching levels of human functionality in many areas. We seem to be becoming more like them (artificially intelligent machines), and they, more like us.

But even with amazing breakthroughs in technology, caution is in order. In an age where science is on the verge of allowing parents to select the features of their babies; and people are integrating faster, smarter, and more powerful technology into their body, body hacking and its consequences warrant significant discussion. An author and member of Singularity University, Ramez Naam wonders what it would be like if our brains were wired together by electronics.[8] Would we be vulnerable to bugs, software crashes, computer viruses, and malware? In a previous chapter I addressed this issue and concluded the answer is definitely yes. And Stanford Professor Francis Fukuyama, writing in *Our Posthuman Future, Consequences of the Biotechnology Revolution*, warned that “the most significant threat” from enhancement technology is “the possibility that it will alter human nature and thereby move us into a ‘Posthuman’ stage of history.”[9] According to Fukuyama, this might happen through the achievement of genetically engineered “designer babies,” but he presents other routes as well: such as research on neuropharmacology, which has already begun to reshape human behavior through drugs like Prozac and Ritalin.

In this chapter I discuss how digital technology may be used to enhance and modify the body as another route leading to a Posthuman future. On the possibility of humanity entering a Posthuman stage, Professor Fukuyama expressed the concern of those who argue for caution in moving towards this outcome, warning of the possibility of “us” becoming something else or losing what he refers to as our “human essence.”[10] Surely, we will want to vigorously discuss the possibility of losing the very characteristics that make us human, rather than passively observing

[7]While downloading information directly to the brain is an amazing possibility, to do so will be an exceptionally challenging and difficult task.

[8]Ramez Naam, 2013, Now Entering the Neurotech Era: Are you Ready for your Hippocampus Chip? at: http://venturebeat.com/2013/01/09/entering-the-neurotech-era/.

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

[10]*Id*.

as technology marches on and invades our body. And as we move toward a Posthuman future, there are many other issues that a public will need to discuss; for example, whether brain-computer interfaces and neuroprosthesis will have an unintended effect on memory and cognition, and therefore, freedom of thought, and if so, how might we regulate "cognitive liberty" the topic of another chapter in this book. And with the advent of body modifications and brain-computer interfaces, how will courts resolve issues fundamental to constitutional law such as free speech and the unfettered practice of religion; or under the United Nations Declaration of Human Rights, liberty. And considering economic and market forces, businesses' will need to know who owns the intellectual property rights of content created by computers claiming to be conscious and alive, and to what extent will artificially intelligent entities be allowed to contract? And where technology goes, so follows crime, not the least of which are issues of cybersecurity for wirelessly connected implantable medical devices and future brain-computer interfaces. These are serious ethical, legal, and policy concerns that the public should discuss while the possibility to shape the future still exits.

Hacking the Body

In the last decade, an interest to hack the body for reasons of art, self-expression, or to enhance the senses, has resulted in a growing movement among some members of the public to not only modify, but to extend the capabilities of their body. I expect the practice of body modification to grow, and to enter the mainstream of society given continuing advances in technology, public acceptance of new forms of body modification, and increased benefits from becoming enhanced. In this chapter, I extend the concept of hacking, from breaking into networks or clever solutions to software design, to the manipulation and enhancement of the human body with digital technology. Generally, hacking is done to understand how something works, so that the hacker can reassemble it into a different purpose for his own use. However, within the field of computer science hacking has a double meaning; it can refer to an expert programmer who creates complex software or efficient algorithms, or someone who breaks into computer networks for his own use. Regardless of the reason for accessing the software or network of another individual, Eric Raymond, compiler of *The New Hacker's Dictionary*, commented that a "good hack" is a clever solution to a programming problem and "hacking" is the act of doing it.[11]

A good place to start when discussing the topic of "body hacking" is to introduce basic terminology. With this goal in mind, in a report written by the U.S. President's *Council on Bioethics*, human enhancement is defined as going "beyond

[11] Eric S. Raymond, 1996, The New Hacker's Dictionary, MIT Press.

therapy;" instead of returning an individual to a healthy or normal state.[12] However, in a report for the European Parliament, the definition of human enhancement focuses more on performance than "beyond therapy." Under the *Science Technology Options Assessment*, the definition of enhancement is "any modification aimed at improving individual human performance and brought about by science-based or technology-based intervention in the human body."[13] Clearly, various types of prosthesis will be important technologies for the cyborg future; for discussion, we can define a prosthesis as an artificial replacement for a part of the body. In addition, an implant can be thought of as a subset of "prosthesis", and can include anything implanted within the body such as an object or material which is inserted or grafted into the body for prosthetic, therapeutic, diagnostic, or experimental purposes.[14] There is even "implant ethics," which is the study of the ethical aspects of the introduction of technological devices into the human body. On the last point, philosophers have taken an interest in human enhancement and body modification, and have written numerous articles and books on the topic.[15]

"Hacking the body" is a concept that can cover the spectrum from "Grinders" who design and install DIY body-enhancements such as magnetic implants (see below), to DIY biologists whose aim is to conduct at-home gene sequencing. DIY biologists engage in a form of hacking termed "biohacking," which refers to the practice of manipulating human biology using a hacker ethic; that is, finding physical, emotional, or intellectual tweaks to the body in order to improve cognitive and sensory performance. Among some people, biohacking can also refer to the practice of managing one's own biology using a combination of medical, nutritional and electronic techniques. Thus biohacking may include the use of nootropics and/or cybernetic devices for recording biometric data. Generally, people who engage in body hacking identify with the transhumanism movement—the belief that it is both possible and desirable to so fundamentally alter the human condition through the use of technologies as to eventually create a superior post-human being. Finally, many who identify with the Grinder movement, practice actual implementation of cybernetic devices in their organic bodies as a method of working towards transhumanism; we can also refer to these people as "cyber hackers."

The idea of enhancing or modifying the body with implants and other forms of technology is not new, but in the twenty-first century an interesting question arises- in response to advances in prosthetics and digital technology, to what

[12]The President's Council on Bioethics, Beyond Therapy (Enhancement), at: https://bioethicsarchive.georgetown.edu/pcbe/topics/beyond_index.html.

[13]European Parliament, Science Technology Options Assessment, at: https://www.itas.kit.edu/downloads/etag_coua09a.pdf.

[14]See generally Sven Ove Hansson, "Implant Ethics", Journal of Medical Ethics, 31:519–525, 2005; Barbro Björkman and Sven Ove Hansson, "Bodily rights and property rights", Journal of Medical Ethics 32: 209–214, 2006.

[15]Allen E. Buchanan, 2013, Beyond Humanity? The Ethics of Biomedical Enhancement, Oxford University Press.

extent will people enhance or modify their bodies? This chapter seeks to address that question by providing numerous examples of recent implantable devices, but a partial answer can be gleaned from people's efforts to manipulate the shape of their own body. In fact, for some time, body implants have been used to change the shape and appearance of specific body areas, especially the buttocks, chest, calf, and bicep. In this case, the implants which in the U.S. have gone through a Federal Drug Administration (FDA) approval process, are made of firm, semi-solid, rubberized silicone material that fits in front of the bones without being absorbed by the body. Since body implants are considered permanent, their removal requires surgery. In addition to body implants, some people choose to sculpt or add volume or contour to certain parts of the body, using liposuction and fat transfer. Then there are people who have modified their body in extreme ways—like the person who used tattoos and surgery to make himself look like a cat,[16] including implanted whiskers, a converted cat nose, teeth filed into the shape of cat teeth, and a head flattened to appear more feline. In the vein of "cat man" another extreme example of self-directed body modification is "lizard man,"[17] and there is even the *Church of Body Modification*,[18] reportedly dedicated to strengthening the bond between "mind, body, and soul". Given these examples of self-directed body modification, whats new in the twenty-first century is the use of engineering science and information technologies that allow people to modify and enhance their body with sophisticated prosthesis; to extend their senses beyond the limits of human nature; and for people suffering from neurological disorders, to have electrodes and/or chips implanted into their brain forming a commensal relationship between patient and machine.

The Risks of Body Hacking and Cyborg Technology

While many people desire to modify their body, the procedures are not always successful, there is a risk associated with body modification, especially for those who self-modify, and sometimes the risk is fatal. On this point, there are reports in the news that women across the U.S. are risking their lives for black market procedures, done by people with no medical training, often by attending "pumping parties" in which multiple people are injected with silicone in hotel rooms. Whatever the reason for seeking the body modification, they are seeking cheaper alternatives to plastic surgery—sometimes with deadly or disfiguring results. Tragically, deaths from black market silicone injections have been reported in several states in the U.S., with felony charges directed against the person performing the procedure. In one incident, the injector was charged with "depraved heart murder" a very serious

[16]Cat Man, at: http://en.wikipedia.org/wiki/Stalking_Cat.

[17]Lizard Man, at: http://www.thelizardman.com/.

[18]Church of Body Modification, at: http://uscobm.com/.

crime signifying an action that demonstrates "callous disregard for human life" that resulted in death. Conviction could be punishable by life in prison. Despite a lack of hard numbers, there's anecdotal evidence that the illegal procedures are becoming more common.

The risk of body implants is not limited to black market procedures. For example, the French firm Poly Implant Prostheses (PIP), once the third biggest global supplier of breast implants, used industrial grade silicone not intended for medical use in its products for years. As a result, many of the breast implants were prone to rupture, causing dangerous leakages of the silicone in women's bodies. And when an implant fails, it normally affects a large number of people. Here the breast implant fraud case affected 100,000 women in Europe and 300,000 women globally; thousands of the women are now seeking compensation for harm caused by the implants which under French law are generally limited to actual losses and to lost opportunities (*perte d'une chance*). However, the French court may also impose general damages not linked to a specific loss, called "moral damages" (*dommages moraux*) to compensate the victim for mental anguish or distress. If one wants to mass market technology to hack the body, they better get it right—the founder of the company received a four year prison sentence for fraud, which under French law can be an element of various criminal provisions arising under the Criminal Code (*Code Pénal*).

Given the possibility of disfigurement and other dangers from body hacking, I advocate that a debate among the public on the desirability of modifying the body occur before body hacking becomes more mainstream in popular culture. For example, it is popular among the youth to get a temporary tattoo to mark an occasion, often in an act of rebellion. Temporary tattoos typically last from three days to several weeks, depending on the product used for coloring and the condition of the skin. Unlike permanent tattoos, which are injected into the skin, and digital tattoos (described below) which serve as sensors, temporary tattoos marketed as "henna" are applied to the skin's surface. At first glance these tattoos seem harmless; however, according to Linda Katz, director of the FDA's Office of Cosmetics and Colors, "just because a tattoo is temporary it doesn't mean that it is risk free."[19] In fact, some recipients of temporary tattoos have reported severe reactions that may outlast the temporary tattoos themselves. Of course, technology implanted under the skin, and even within the brain, has the potential to offer tremendous capabilities to a person, but poses far more danger to recipients, and extreme caution should be taken to protect our future cyborgs.

As a response to defective implants, the *European Commission* has proposed updating the existing legislation on medical devices. Currently, the term 'medical device' in Europe, covers a wide range of products both used internally and externally by patients and doctors. They can include everything from contact lenses and

[19]Linda Katz, 2013, FDA warns about hidden dangers of 'temporary' henna tattoos that burn, blister and leave skin scarred for life, Daily Mail, at: http://www.dailymail.co.uk/news/article-2299140/FDA-warns-hidden-dangers-temporary-henna-tattoos-burn-blister-leave-skin-scarred-life.html.

pregnancy tests, dental filling materials, to, "cyborg technology" such as pacemakers and hip replacements. Similarly, in the U.S. medical devices are regulated by the FDA with the intensity of the regulation depending on the complexity, usage, and potential danger of the device. A thermometer, for example, might have rather minimal regulations, while a pacemaker is very heavily regulated. And in Europe (and likewise in the U.S.), medical devices are ranked from Class I, a low-risk category that would include spectacles, to high-risk Class III items such as hip replacements and pacemakers, which are fitted inside the body. In its proposal for regulating implants, the Commission wants to improve the product evaluation process, enhance the traceability of products in the marketplace and place more scrutiny on notified bodies once an issue with a medical device has manifested itself.

As we move toward the cyborg future, unique safety and health issues for those with implants and other types of "cyborg technology" will arise. For example, when we consider the possible health problems associated with being equipped with prosthesis and implants, there is concern among pathologists and other experts that there are safety issues with the materials and devices implanted into the human body. We can think of these concerns as challenges which must be overcome if humanity is to merge with machines. For example, although implantable materials are generally considered inert or ''biocompatible,'' there is a body of evidence which suggests that many metals, plastics, gels, rubbers and combinations of materials fashioned into implantable devices can produce chronic and potentially harmful effects on human tissue in some people. It is possible that people with implants could suffer persistent inflammation, infection, blood clots, bone erosion, diseases of connective tissue and, in rare instances, cancer, depending on the materials and the location in the body. And with brain implants, the biocompatibility of implanted electrodes and chips is of particular concern in device design. Already, the development of scar tissue at the site of implantable electrodes for people being treated with Parkinson's disease is a concern.

As we head towards a cyborg future, the emerging evidence on the safety of implants, ranging from their software to hardware, is viewed by some experts as a caution sign for people planning to undergo an implant, particularly one that would be used early in life for purely cosmetic purposes. The potentially troublesome devices seems to run the gauntlet of current "cyborg technology"; including artificial hips, knees, elbows, wrists, ligaments and fingers, breast implants, heart valves, pacemakers, shunts, intrauterine devices, dental implants and a variety of other objects that meet either medical or cosmetic needs.

What are some of the specific reactions of the body to implants? Generally, the body is designed to attack foreign objects that invade it. When a material is implanted under the skin, it sits in a protein-rich bath found throughout body tissues. Immediately, proteins begin sticking to the surface of the implanted device and, it is soon coated in a mixture of proteins. Depending on the type of material used in the implant, physical interactions may involve charged particles and magnetic fields occurring between the implant's surface and the proteins. The interaction is sufficiently energetic to alter the shape of proteins sticking to the implant, so that the proteins expose binding sites that attract other circulating proteins designed to recognize trouble. One set of circulating proteins initiates blood clots and covers the implant with thick layers of scar tissue called fibrin. Some implant recipients suffer chronic, intermittent low-grade fevers whereas, initially, some people seem highly tolerant of their implants but then experience flare ups years later. And implants can also become infected with bacteria many years after surgery. To some extent, problems can be treated with antibiotics, pain-killers and anti-inflammation drugs; but clearly, a cost-benefit analysis should be performed for any implant procedure. Another solution to the body's reaction to implantable devices is to coat such devices with antibiotics, blood thinners, and other agents—but these eventually dissolve, limiting their longevity and effectiveness.

As a response to the body's reaction to implants, some companies are developing novel biomaterial for implanted devices that permanently barricade troublesome microbes from the device's surface. One material when applied to an implant device sprouts a thicket of polymers that attract water, creating an impenetrable barrier for microbes. Its chemical makeup also mimics that of cells important to homeostasis, potentially reducing the body's natural rejection of implanted devices. Essentially, the solution is aimed at making the implantable devices look more like the human body.[20] However, even with advances in biomaterials, given efforts by Grinders to self-modify their body without the assistance of a physician, the reader should keep in mind the potential health problems associated with implantable devices, as they read further in this chapter about the body hacking movement.

In thinking about our cyborg future, it is instructive to consider the above discussion in light of a current FDA approved sensor (radio frequency identification, or RFID sensor), that is being implanted in the body for reasons of security, art, and body hacking. While the FDA has "reasonable assurance" that an implanted RFID sensor is safe; neither the company manufacturing it, VeriChip Corp., nor the regulators openly discuss a series of veterinary and toxicology studies, dating back to the mid-1990s, which indicated that chip implants had "induced" malignant tumors in some lab mice and rats. Some researchers have indicated that they would not allow family members to receive RFID implants, and many have urged further research before the glass-encased transponders are widely implanted in people. With these warnings in mind, several thousand RFID devices have still been implanted in humans worldwide. VeriChip Corp., which sees a target market of forty-five million Americans for its medical monitoring chips, insists the devices are safe. However, when the FDA approved the device, it noted some risks: The capsules could migrate around the body, making them difficult to extract; they might interfere with defibrillators, or be incompatible with MRI scans, causing burns.

If we compare an RFID chip to another implantable device, a heart pacemaker, we see that the RFID device isn't vital to keeping someone alive as is a pacemaker, so from a medical perspective, we have to ask—does the cost for RFID

[20]Rob Matheson, 2013, Creating a permanent bacteria barrier, MIT news, at: http://newsoffice.mit.edu/2013/semprus-biosciences-1010.

implants justify the benefits? For a class of people the answer is clearly "yes." Currently, RFID chips have been approved for human patients with Alzheimer's and other dementia sufferers; the idea being that if they become lost, the chip will make it easier for them to be reunited with their caregivers; here the benefits of an implanted sensor outweigh the costs. But the general idea that a class of people could benefit from implantable technology, while others may not, raises fascinating questions of law and policy. Not the least of which is whether courts should view cyborgs as a protected class, and thus eligible for special protection under the law; which could include required access to software updates and next-generation hardware replacements and possibly broad protection under a federal statue granting a cause of action for discrimination.

Prosthesis, Implants and Law

Many who have reservations about the cyborg future, often advocate for appropriate government regulations and statues to protect those who have become enhanced with technology. In the future, advances in neuroscience and robotics will change the way that society views the human body, reinforcing the concept of the body as a machine with interchangeable, replaceable, and upgradeable parts. As these cyborg technologies become more advanced, they will approach and then surpass ordinary human function, rising the prospects of enhancing human capabilities well beyond the current baseline standard; this may lead society to view the healthy, yet unenhanced human as disabled.[21] Therefore, in the cyborg future, the disabled, equipped with cyborg technology, may prove more "abled," and average abilities could become almost akin to defects, in need of elimination. With these possibilities in mind, this section gives the reader a flavor of what I think is part of a developing field of cyborg law.

Numerous cases of discrimination against those equipped with "cyborg technology" revolve around employment disputes and in the U.S. are brought forward by the Equal Employment Opportunity Commission (EEOC). One such case involved a woman who was terminated because she had a prosthetic leg and her employer was concerned she would be "knocked down" at work due to her disability.[22] The case, which was won by the woman, was decided under the American with Disabilities Act (ADA) which prohibits discrimination against people with disabilities in employment.[23] The court ruled that it was illegal to fire a disabled employee due to a baseless fear they may injure themselves or others. Another

[21]Collin R. Bockman, 2010, Cybernetic-Enhancement Technology and the Future of Disability Law, 95 Iowa Law Review, 1315–1340.

[22]*EEOC v. Staffmark Investment LLC and Sony Electronics, Inc.*, No. 12-cv-9628, on Dec. 4, 2012 in U.S. District Court for the Northern District of Illinois.

[23]Americans With Disabilities Act, 42 U.S.C. Section 12101 et seq.

employment dispute with implications for a "cyborg law," dealt with a person equipped with a hand prosthesis, and was brought under the Rehabilitation Act of 1973.[24] In this dispute a veteran who had lost his hand and replaced it with a prosthesis, was dismissed from the FBI academy because they alleged that during his training he could not safely fire a handgun with his prosthesis. However, a jury finding that the FBI instructors at the academy were hostile toward the veteran, ruled in his favor and the court awarded him monetary damages, back pay, and reinstatement to the FBI academy. The statue used for this "cyborg discrimination case," deals with federal jobs and federal agencies, and thus does not cover discrimination against those with prosthesis in other situations; this seems like an area ripe for legislation.

Another case with implications for cyborg law was heard in 1999 by the U.S. Supreme Court and involved the issue of whether a person with a corrected disability would still be considered disabled under the ADA.[25] This is an interesting case for "cyborg law" given the aim of becoming equipped with technology (i.e., becoming a cyborg) is often to restore, or go beyond, normal human abilities. The case involved twin sisters who suffered from acute visual myopia. When they applied to United Airlines for a job as a commercial pilot, they met the requirements for employment except for the vision requirement which was uncorrected visual acuity of 20/100 or better.[26] Each sister was able to correct their myopic vision to 20/20 with glasses and contact lens, and could function normally in their daily lives. However, in their ADA claim, the Suttons argued that they were disabled within the meaning of the ADA because, under the statute they suffered from a physical impairment that "substantially limits … major life activities," or because, they were regarded as having such an impairment. The question for the Court to decide was whether the determination of disability under the ADA could be made without reference to corrective measures that mitigated the impairment. That is, would a person with a disability, but restored to "normal" with technology, still be considered disabled? The Court determined that a disability must be determined with reference to corrective measures. Thus, the Court reasoned that once an impairment is corrected, the impairment does not substantially limit a "major life activity." Based on this court decision, a person would not be considered disabled if cyborg technology brought the person to normal functioning (or beyond normal?). But a court's decision may be overturned by legislators, lets continue the discussion.

The law on mitigating disabilities with technology, has much to say for cyborg discrimination and acceptance into society, and raises serious questions

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[24]Rehabilitation Act of 1973, 29 U.S.C. § 791 *et eq*; Matt Zapotosky, 2013, Disabled veteran's discrimination lawsuit rankles FBI, spurs investigation of agent, at: http://www.washingtonpost.com/local/disabled-veterans-discrimination-lawsuit-rankles-fbi-spurs-investigation-of-agent/2013/07/27/d3d1d8f6-f3b2-11e2-9434- 60440856fadf_story.html.

[25]*Sutton v. United Airlines*, *Inc.*, 527 U.S. 471 (1999).

[26]*Id*.

concerning who should be considered disabled as people become equipped with technology. On this question, Congress passed the *American with Disabilities Amendments Act* in 2008 which explicitly states that the determination of whether an impairment substantially limits a major life activity is to be made without regard to the ameliorative effects of mitigating measures such as—prosthetic limbs, cochlear implants, or an implantable hearing device.[27] The amendment revealed the thinking of Congress; that no additions or modifications are relevant in the eyes of the law to the determination of whether someone is disabled; so, for example, the very act of getting a prosthesis for the upper arm doesn't automatically qualify a person as disabled under the amendment. The determination of whether an impairment substantially limits a major life activity is to be made without regard to the beneficial effects of mitigating measures such as medication, prosthetics, mobility devices, hearing aids and cochlear implants—to name just a few ways to mitigate a disability. For example, a person with one leg may be equipped with a prosthesis but when he wears his prosthetic leg he can walk fine, but without the prosthetic leg he has great difficulty walking. This person has a disability under the ADA because the determination of whether he is substantially limited in the major life activity of walking is made without considering the prosthetic leg. However, when determining whether someone has a disability, the rule concerning mitigating measures does not apply to people whose vision is corrected with eye glasses or contact lens. For example, a woman with myopia whose visual acuity is fully corrected when she's wearing eyeglasses, is not substantially limited in seeing, because the determination is made when she's wearing the glasses. This is a public policy decision—just think of how many people would be considered to have a disability under the ADA if we did not take into account the beneficial effects of ordinary eyeglasses and contact lenses.

However, the amended ADA raises several conceptual problems in an age of cyborgs. For example, under the amended ADA, if a women chose to replace her right leg with a far superior cybernetic limb, the limb would fall under the category of prosthetics (limbs and devices), and since the statute bans such mitigating factors from consideration in determining disability, this woman would be legally disabled, even though her new leg is actually better than the old one. And paradoxically, if everyone at a particular work site except for one person upgraded a limb with a superior cybernetic prosthesis, the unenhanced "normal" person would be the only non-disabled employee, even though all her colleagues enjoyed superior capabilities. In fact, the more prosthetic upgrades a person receives, the more disabled they may be considered under the Amended ADA. And nothing in the ADA protects those with enhancements from comparative discrimination, where enhanced individuals may discriminate against an otherwise ordinary individual whom they consider "disabled" due to his lack of upgrades. As more enhancements become available, and result in humans with superior capabilities, the law will need to change how it conceptualizes those who are disabled to account for cyborg technology and enhanced cyborgs living amongst us.

[27]ADA, *id.*, note 23.

There are other legal and policy issues that are relevant for a developing field of cyborg law. For example, public policy dictates that materials needed for life-saving medical procedures are available to manufactures of medical devices, including implants. So, for suppliers of implant materials the U.S. Congress enacted the *Biomaterials Access Assurance Act of 1998* (BAAA).[28] The BAAA applies to all implant raw materials and components for implants except the silicone gel and the silicone envelope utilized in a breast implant. Essentially, the BAAA shields suppliers of raw materials and component parts used in medical implants from virtually all civil liability, thereby ensuring the availability of materials for lifesaving and life-enhancing medical devices. However, the BAAA does not apply if the supplier also manufacturers the device, sells the device, or fails to meet applicable contractual requirements relating to the component part or material. But suppliers of raw materials and component parts of medical devices can use the BAAA not only to avoid liability but also to extricate themselves from personal injury suits in which they are named as defendants.

Since the *Biomaterials Access Assurance Act* is limited to suppliers of material, it doesn't shield negligent physicians and manufactures of implantable devices from liability if the device harms the recipient.[29] As long as they are protected under current law schemes, future cyborgs will have a range of legal options if they are harmed. To begin the discussion, what happens if the device, implanted by a physician, fails and the person suffers harm? If the harm can be traced to the physician's actions, the person equipped with the implant may pursue a legal action for malpractice. In the U.S. medical malpractice is derived from English common law. To establish a case for medical malpractice, the injured person must show that the physician acted negligently in implanting the device, and that such negligence resulted in injury. Specifically, four legal elements must be proven: a professional duty owed to the person receiving the implant; breach of such duty; injury caused by the breach; and resulting damages. Given the number of implantable devices and types of prosthesis people may be equipped with, medical malpractice lawsuits are not uncommon in this area particularly with hip and knee replacements which are among the most common surgical procedures performed in the U.S. These surgeries, along with revision surgeries that are performed to correct problems that develop after the original procedure, are increasing in part due to new implant devices and the advancing age of the baby boom generation receiving the implants.

There are other ways in which an implant may cause harm, other than that caused by a physician performing a particular procedure. For example, if the implant fails, a cyborg could sue under a products liability theory. In this case any entity in the chain of manufacture and sale of a defective implant can be sued if harm to the implant recipient occurred. In this case not just the manufacturer of the implant would be liable, but also the manufacturers of the product's

[28]Biomaterials Access Assurance Act of 1998 (BAA98) (21 U.S.C. 1601–1606).

[29]*Id.*

component parts, the wholesaler, and the retailer. Whether a cyborg sued to protect its right to seek compensation for defective parts is done under malpractice or products liability is an important distinction because medical negligence focuses on whether the physician's actions were reasonable (when measured against the medical standard of care); while products liability focuses on whether the product was reasonably safe or not. Generally a product manufacturer or seller is liable under products liability law if the product contains an inherent defect that is unreasonably dangerous and that causes injury to a foreseeable user of the product. I would think that a Grinder using an off-the-shelf sensor as an implant is not foreseeable to a manufacturer; whereas, a person receiving an implant under the supervision of a physician for a medical condition is. However, a foreseeable plaintiff or not, sensors (a main cyborg technology), when used as a medical device, are regulated by the FDA.

Under tort law, there are three types of products liability: a manufacturing defect, a marketing defect, or a design defect. A manufacturing defect occurs during the manufacturing process. A marketing defect usually refers to a problem with the product's instructions or advertising, for example, a failure to warn the purchaser about hidden dangers in an implant device. In addition, a design defect occurs when the product is simply dangerous and defective due to the way it was designed, for example, a prosthetic leg not able to bear the weight of the recipient. Actually, design flaws are not uncommon with "cyborg technology" for example, a few years ago, 93,000 DePuy hips replacement systems were found to have a design flaw and subsequently recalled; many other recalls occur for other implantable devices.[30]

What if the person performing the implant is not a trained physician, instead, a tattoo artist, or a person working at a "body shop"? An action for negligence, which is a failure to exercise the care that a reasonable prudent person would exercise in like circumstances is possible. The elements of negligence are similar to a medical malpractice suit, and likewise include duty, breach, causation, and damages. The fundamental difference between an ordinary suit for negligence and a suit for malpractice lies in the definition of the prevailing standard of care. If someone sues for ordinary negligence, they compare the defendant's behavior to what any reasonable person would have done under the circumstances. If they sue for malpractice, they will compare the physician's behavior to what a reasonable member of the profession would have done. Professional standards are much higher and much better documented; thus, it is generally easier to establish negligence in a professional capacity. In an age of self-directed body modification, when the person doing the implant is a friend or someone who works at a Tattoo parlor, I wonder what the definition of "reasonable person" is?

To hack the body often involves implanting a sensor, magnet, or some other form of technology under the skin, or more generally, piercing the skin to implant

[30]Hip Replacement Lawsuits and Hip Recalls, at: http://www.lieffcabraser.com/Personal-Injury/Devices/Hip-Implant-Recall.shtml.

a device beneath its surface; surprisingly, in some jurisdictions, a physician is not required for the procedure. In the U.K. body piercing is an unregulated industry and only requires the studio to be registered with the Environmental Health Department of their local Council. There are also, unlike tattooing, no minimum age requirements for the piercee in the U.K. whereas there are in the U.S. Furthermore, in the U.K. there are no regulations covering the training of body piercers and there are also no regulations covering those who teach body piercing. However, in the U.S. the body modification culture has caught the attention of some state governments. For example in the State of Arkansas, a state senator sponsored the 2013 bill entitled "*An Act To Limit Body Art Procedures*," aimed at making body modifications limited to "traditional" tattoos and piercings." The state senator's proposal would essentially ban scarification procedures and dermal implants, as well as certain tattoos which remain yet to be defined due to the vague language of the sponsored bill. Scarification is a non-ink skin marking that forms scars for decorative purposes, while dermal implants refers to placing ornamental objects beneath the skin. In my view, the proposed bill is unconstitutional under the First Amendment to the U.S. Constitution which clearly prohibits government efforts at "abridging the freedom of speech," which U.S. courts have repeatedly found includes forms of artistic expression.[31]

In addition, for some, to modify the body is a form of religious practice and thus should be a basic human right. Not far from my home, a North Carolina high school student was dismissed from school because her nose piercing violated the schools dress code.[32] In fighting against the dismissal, the student argued that the nose piercing was part of her religious faith based on her membership in the *Church of Body Modification*. Although her school dress code prohibits facial piercings, a federal judge ruled that the student could return to school, piercing and all. The North Carolina chapter of the American Civil Liberties Union, which represented the student, said the settlement with the school was a vindication of the family's right to determine its own religious practice. Under the terms of the resolution, the student is allowed to wear the nose stud as long as she remains a member of the *Church of Body Modification*, a religious group that claims a few thousand adherents and considers practices like tattooing and body piercing to be elements of spiritual practice.

However, the law is far from an exact science, as another case based on a religious exemption for a person who modified her body, produced a different outcome. Kimberly Cloutier was a Costco employee when she alleged that her employer failed to offer her a "reasonable accommodation" for her facial jewelry which she wore as part of her religious beliefs supported by the *Church of Body Modification*.[33] Even though Kimberly had received a copy of the Costco employ-

[31] *Mattel v. MCA Records*, 296 F.3d 894 (9th Cir. 2002).

[32] Sarah Netter, 2010, Student's Body Modification Religion Questioned After Nose Piercing Controversy, at: http://abcnews.go.com/US/students-body-modification-religion-questioned-nose-piercing-controversy/story?id=11645847.

[33] *Cloutier v. Costco Wholesale Corp.*, 390 F.3d 126, 12 (1st Cir. 2004).

ment agreement, she decided to ignore the dress code provisions and instead engaged in various forms of body modification, including body piercings and skin cutting. After being terminated for failure to adhere to the dress code, she filed a complaint with the *Equal Employment Opportunity Commission*, which was appealed to the U.S. First Circuit Court of Appeals which subsequently held that it would place an undue hardship on Costco to allow a cashier to wear facial jewelry due to their "legitimate interest in presenting a reasonably professional appearance to customers."[34] Interestingly, since there was no direct legal protection for body piercings in the statutes, Cloutier, unsuccessfully tried to link her unprotected characteristic to a protected category, by claiming facial piercings were part of religious practices encouraged by the *Church of Body Modification*. Given a different result in the two cases above dealing with the practice of religion, an issue for the public and legislators to debate, is whether specific legislation needs to be enacted to address the needs of those who modify their bodies, argue for rights, and in the future appear as a cyborg.

Body Hacking in the Digital Age

Generally, in an age of cyborgs, the term body hacking refers to a practice that's part body modification, and part computer hacking. This dichotomy between corporeal body and computer, suggests to me that issues of law and public policy need to be directed at each component of the cyborg. For example the laws which relate to software (e.g., contracts, licenses, tort) would apply to the "brains" of the implantable device; whereas, other laws would apply to the corporeal body. In some cases, the same law would apply to both, but I think new law and policy will have to be enacted to account for the combination of human and machine.

The body hacking movement, especially with regard to implantable sensors within the body, gained momentum from the pioneering work of Professor Kevin Warwick starting in 1998 at the University of Reading. Professor Warwick was one of the first people to hack his body when he participated in a series of proof-of-concept studies involving a sensor implanted into the median nerve of his left arm; a procedure which allowed him to link his nervous system directly to a computer. Most notably, Professor Warwick was able to control an electric wheelchair and an artificial hand, using the neural interface. In addition to being able to measure the signals transmitted along the nerve fibers in Professor Warwick's left arm, the implant was also able to create artificial sensation by stimulating the nerves in his arm using individual electrodes. This bi-directional functionality was demonstrated with the aid of Kevin's wife using a second, less complex implant connected to her nervous system. According to Kevin this was the first solely electronic communication between the nervous systems of two humans; since then,

[34] *Id.*

many have extended Kevin's seminal work using RFID chips and other implantable sensors; such work is discussed in further detail below.

Considering Kevin's surgical procedure to have a sensor implanted in his body; obviously Kevin and his wife volunteered to be implanted with the sensor, an act many might consider to be inherently dangerous. Thus, if any injury attributed to the surgeon resulted during and after the implant, under tort law, there could be a bar to liability based on the assumption of risk theory. This legal doctrine states that a person who knowingly exposes him/herself to hazards with potential for bodily harm cannot hold others liable if harm occurs. Further, under the assumption of risk doctrine, a person who consents to a procedure, with knowledge that injury is a foreseeable, albeit uncommon, result, waives the right to a future complaint that any 'foreseeable' injury was caused by negligence, assuming the procedure was performed with proper care. However, if the physician performing the implant procedure committed malpractice, they may still be sued for medical malpractice. In addition, depending on the jurisdiction, a court could examine this situation using the secondary assumption of risk doctrine. For example, in California, if a physician performed the "experimental implant", and was found to owe Kevin a duty of care, given Kevin volunteered for the procedure (not warranted by medical necessity), if harm occurred, a comparative fault scheme could be used, and the trier of fact, in apportioning the loss resulting from injury, could consider the relative responsibilities of the parties.

Sensors and Implantable Devices

We live in a time when tremendous progress is being made developing sensors and implantable technology to control and monitor different functions of the body (Fig. 5.1). For example, researchers at MIT are developing an implantable sensor

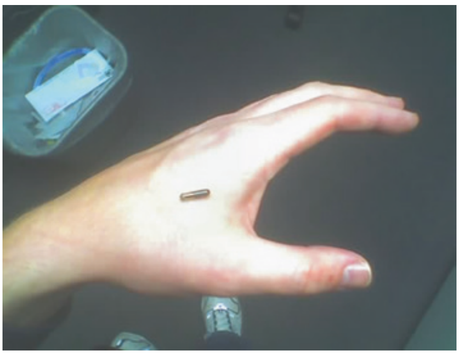

Fig. 5.1 An RFID sensor implanted in the hand. The microchip contains stored information which can be transmitted to a reader and then to a computer. RFID's can be passive, semi-passive or active. Active RFID's have an internal power source such as a battery, this allows the tag to send signals back to the reader. Image from Amal Grafffstra, Wikipedia Commons

which uses carbon nanotubes to monitor nitric oxide (NO) in animals. In humans, the sensor could be useful for detecting cancer cells and for monitoring glucose levels. Then there's research at Boston University[35] that involves "brain-reading" software designed to transform thoughts into speech, starting with vowels. The system uses implanted electrodes to pick up nerve signals related to movement of the mouth, lips, and jaw; these signals are then sent wirelessly to a computer, where software analyzes them for speech patterns.

Further, researchers at Brown University and *Cyberkinetics* in Massachusetts, are devising a microchip that is implanted in the motor cortex just beneath a person's skull that will be able to intercept nerve signals and reroute them to a computer, which will then wirelessly send a command to any of various electronic devices, including computers, stereos and electric wheelchairs. And consider a German team that has designed a microvibration device and a wireless low-frequency receiver that can be implanted in a person's tooth. The vibrator acts as microphone and speaker, sending sound waves along the jawbone to a person's eardrum. And in another example of an implantable device, *Setpoint*, is developing computing therapies to reduce systemic inflammation by stimulating the vagus nerve using an implantable pulse generator. This device works by activating the body's natural inflammatory reflex to dampen inflammation and improve clinical signs and symptoms. Thus far, the company is developing an implanted neuromodulation device to treat rheumatoid arthritis, a disease currently afflicting over two million people in the U.S.

Since Warwick's seminal results, sensors have been implanted into the human body for many reasons such as individual security or to monitor a person's health. For example, due to the risk of being kidnapped, some people have had a tiny transmitter implanted under their skin so that if necessary satellites could track and locate their position. From a different security perspective, courts may require people convicted of a crime to participate in an electronic monitoring program, requiring wearable sensors, as an alternative to incarceration. There are two types of electronic monitoring bracelets: the Radio Frequency Bracelet, which is used as a form of house arrest, and the GPS Bracelet, used to track an offender's whereabouts in real time. As with other wearable technology, the use of the GPS bracelet raises serious legal and policy issues. One such issue occurred when it was discovered that a GPS ankle bracelet was able to listen into conversations between a lawyer and his client, a violation of attorney-client privilege. I would argue that this is also a violation of the Fourth Amendment (prohibiting an unreasonable search and seizure), as well as a violation of the U.S. Federal Wiretapping Act (a federal law that is aimed at protecting privacy in communications with other persons).

The above examples show the benefits of wearable and implantable technology to perform important tasks on the body's surface or within the body; essentially, these are technical tools in the arsenal to assist humans. But continuing a point

[35]Patrick L. Kennedy, 2011, The Mind Reader How Frank Guenther turns thoughts into words, at: http://www.bu.edu/today/2011/the-mind-reader/.

being made throughout this book; the more we become enhanced with technology, the closer we are to becoming a cyborg and laying the groundwork for a future merger with artificially intelligent machines. I also conclude that much of what we learn about integrating sensors within the body is useful information for engineers designing the next generation of artificially intelligent machines as they too will need sensors to perceive the world.

If we consider the range of sensors being developed, and their potential to collect data about the internal state of the body, it's easy to conclude that the human body is becoming the subject of extensive data mining. In fact, Google is doing just that, in a program to determine what a healthy person should look like. The project, dubbed Baseline Study, involves researchers collecting anonymous genetic and molecular information from initially 175 people, and later thousands more, in a bid to help detect diseases, such as cancer and heart disease, much earlier.[36] Baseline will not be limited in scope to certain diseases but will use state-of-the-art diagnostic tools to collect hundreds of different samples that will be plugged into computer systems and compared with others. To collect the data participants could, for example, wear Google's smart contact lenses, to monitor glucose levels. After the data is collected, Google will use its computing power to find patterns or 'biomarkers' that could help medical researchers detect a disease at a curable stage.

Interestingly, as implants collect data about the inside of our bodies, our bodies are becoming the equivalent of open books like those that have been scanned by Google; this raises serious privacy concerns. To me it is problematic that in the future companies which sell and provide services to support neural devices may have unique access to private information stored in the human brain. The data derived from the ability to peer into the brain, is in need of special protection similarly to that provide by Title II of the *Genetic Information Nondiscrimination Act of 2008* (GINA).[37] This act prohibits genetic information discrimination in employment and is enforced by the Equal Employment Opportunity Commission (EEOC). Genetic information is often used to determine whether someone has an increased risk of getting a disease, disorder, or condition in the future. Similarly, access to information in the brain could be used to determine whether a person had a predisposition to commit a crime, a propensity for violence, or is a candidate for mental illness. The ability to collect information about the body and brain and to analyze it with algorithms designed to predict the future, raise serious privacy and policy concerns and the possibility of a dystopian future. A prior chapter explored the law and policy of brain technology and cognitive liberty in some detail.

To manage debilitating disease, diabetes for example, is another reason to become equipped with cyborg technology. In fact, millions of people worldwide

[36] Alistair Barr, 2014, Google's New Moonshot Project: the Human Body, The Wall Street Journal, at: http://www.wsj.com/articles/google-to-collect-data-to-define-healthy-human-1406246214.

[37] Genetic Information Nondiscrimination Act of 2008, Pub. L. 110–233, 122 Stat. 881, enacted May 21, 2008.

with diabetes could benefit from implantable sensors and wearable computers designed to monitor their blood sugar level; because if not controlled people are at risk for dangerous complications, including damage to the eyes, kidneys, and heart. To help people monitor their blood-sugar level *Smart Holograms*[38] a spinoff company of Cambridge University, Google, and others are developing "eye worn" sensors to assist those with the disease. Google's technology consists of contact lens built with special sensors that measures sugar levels in tears using a tiny wireless chip and miniature sensor embedded between two layers of soft contact lens material. Interesting and innovative as this solution to monitoring diabetes is, these aren't the only examples of "eye oriented" cyborg technology within the hacker movement; in fact, hacking the eyes is a subject of body modifiers. In the future, we may see cyborgs equipped with contact lens or retinal prosthesis that monitor their health, detect energy in the X-ray or infrared range, and have telephoto capabilities (see "hacking the eyes," below). I should point out that any device containing a contact lens is regulated by the FDA; the point being that much of cyborg technology comes under government regulation.

Issues of Software

Software is becoming increasingly important in the functioning of implants, thus the law which applies to code and algorithms should be of interest to cyborgs and to those designing them. Consider an artificial pancreas using an intelligent dosing algorithm to simulate the functioning of a normal pancreas by continuously adapting insulin delivery based on changes in glucose level. What happens if the software in the artificial pancreas fails? If the software does fail, there are numerous parties in the "chain of liability" which may be subject to a lawsuit, including software manufacturers, equipment manufacturers, program distributers, programmers, consultants, companies using the software, and software operators. To protect themselves from liability claims, software developers often use disclaimers (through a software license) with their products which may limit clients' claims.

But briefly, a professional programmer could be negligent when writing code, if they failed to act as a reasonably prudent programmer would. The deviation from normal programming practices is often proven through the testimony of another expert programmer. Negligent programming claims are similar to malpractice claims in that both types of claims are based on duty, breach of duty, causation, and damages. To win on a programming malpractice claim the cyborg would have to prove that the negligent programmer was a programming professional that had a duty or legal responsibility to exercise reasonable care in providing computer programming or services, that the negligent programmer breached this duty by

[38]Smart Holograms, at: http://www.cam.ac.uk/research/news/holographic-diagnostics-0.

failing to provide programming or design services that a reasonable programmer would provide in this situation, and that this breach of duty caused damages. In addition to programming negligence claims, given that the design of software and its maintenance is usually covered under contract law, most contracts include safe guards and clauses that protect businesses from computer software, programming, and networks that do not work or are flawed.

Some lawyers in defending their client have attempted to create a "computer malpractice" claim for software errors and crashes. But the courts seem to reject this theory, even stating no such cause of action exists. The early case of *Chatlos Systems v. National Cash Register Corp.* (1979) is an example.[39] Here an NCR salesman did a detailed analysis of Chatlos' business operations and computer needs, and advised Chatlos to buy NCR equipment. Relying on NCR's advice, Chatlos bought a system that they alleged never provided several promised functions; Chatlos sued and NCR was held liable for breach of contract. However, in a footnote, the court discussed Chatlos' claim of computer malpractice: "The novel concept of a new tort called 'computer malpractice' is premised upon a theory of elevated responsibility on the part of those who render computer sales and service. Plaintiff equates the sale and servicing of computer systems with established theories of professional malpractice. Simply because an activity is technically complex and important to the business community does not mean that greater potential liability must attach. In the absence of sound precedential authority, the court declines the invitation to create a new tort."[40]

Lacking a computer malpractice claim, cyborgs suing for defective software can still use contract law and negligence, or possibly an appropriate statue from criminal law to defend their rights. With the coming age of cyborgs, there are many disputes that will involve them, and which will wind their way to the courts. As discussed in Chap. 1, regarding the law of the horse, or in this case, the law of cyborgs, will it be sufficient to rely on the fundamental principles of law found in contract, tort, criminal law, and constitutional law, or will a new set of rights for cyborgs be warranted and in the future for artificially intelligent machines? The answer will be clear by midcentury.

Machines Hacking Machines

In my view, the necessity for humanity to merge with artificially intelligent machines is based on another accelerating trend in technology—efforts among computer scientists and engineers to create machines with the ability to become the architect of their own design or at least to program themselves. Once machines begin to hack their own hardware and software, they may direct their own

[39] *Chatlos Systems, Inc. v. National Cash Register Corp.*, 479 F. Supp. 738 (D. N.J. 1979), *aff'd*, 635 F.2d 1081 (3rd Cir. 1980).

[40] *Id.*

evolution at such a speed that we humans may be quickly surpassed, and insignificant to them. Surely, this possibility should provide strong motivation for humanity to consider moving beyond biological evolution to a self-directed merger with our future technological progeny.

That machines may direct their own evolution comes from recent examples in which they are beginning to design, repair, and program themselves. For example, an International Space Station robot repaired its cameras while in orbit making it the first robot to self-repair in space. Then there's the work of MIT researchers Daniela Rus and Erna Viterbi,[41] on the design of self-assembling robots. Such robots consist of printable robotic components that, when heated, automatically self-assemble into prescribed three-dimensional configurations. One example of their research is a system that takes a digital specification of a three-dimensional shape, such as that generated from a 2D pattern that would enable a piece of plastic to reproduce it through self-folding. Other research by Daniela Rus and her team is focused on building electrical components from self-folding laser-cut materials. These designs include resistors, inductors, and capacitors, as well as sensors and actuators; that is, the electromechanical "muscles" that enable robots' movements.[42] If artificially intelligent machines become the master of their own architecture, is there any doubt that they will use technology such as 3D printers to quickly improve and move beyond the capabilities of their human masters?

Some argue that techniques in artificial intelligence,[43] with sufficient machine intelligence, will give software the potential to autonomously improve the design of its constituent software and hardware. Having undergone these improvements, it would then be better able to find ways of optimizing its structure and improving its abilities further. It is speculated that over many iterations, such an artificial intelligence would far surpass human cognitive abilities and lead to the Singularity.[44] One type of research direction on this topic is machine learning, a branch of artificial intelligence, which is concerned with the construction and study of systems that learn from mining data.[45] I envision a future where cyborgs and artificially intelligent machines mine data, share information, and collectively make decisions. Generally, artificial intelligence has been progressing steadily

[41]Sharon Gaudin, 2014, These origami robots can fold up and walk, at: http://www.computerworld.com/article/2490973/emerging-technology/scientists-create-self-assembling-working-robots.html.

[42]*Ankur Mehta, Joseph DelPreto, Daniela Rus*—Integrated Codesign of Printable Robots, ASME Journal of Mechanisms and Robotics 7(JMR-14-1221), 05 2015; *Ankur M. Mehta, Daniela Rus*—An End-To-End System For Designing Mechanical Structures For Print-And-Fold Robots, IEEE International Conference on Robotics and Automation (ICRA) , Hong Kong, China, June 2014.

[43]Eliezer Yudkowsky, 2015, Rationality: From AI to Zombies, Machine Intelligence Research Institute.

[44]Robin Hanson and Elizer Yudkowsky, 2013, The Hanson-Yudkowsky AI-Foom Debate, Machine Intelligence Research Institute.

[45]Ian H. Witten, Eibe Frank, and Mark A. Hall, 2011, Data Mining: Practical Machine Learning Tools and Techniques, Third Edition, Morgan Kauffman.

over the years, along with advances in computer technology, hardware, memory, and CPU speeds. As computers get faster, more computations can be performed per unit time, allowing increasing power for the computation-intensive processing required by many artificial intelligence algorithms and data mining techniques.

Hacking the Brain

While many of the examples presented in this chapter represent current efforts by people to hack their body and a discussion of legal issues that such acts implicate, the future may be even more amazing in terms of how the body may be manipulated and modified. Ultimately, given that the brain operates by performing computations and that tremendous progress is being made deciphering the way the brain computes,[46] I believe the fundamental processes of how the brain processes and stores information will be discovered; and by doing so, information essential for the cyborg future and a human-machine merger will be gleaned. However, I should make the point clear that uncovering the secrets of the brain will be an extraordinarily difficult task (orders of magnitude more difficult than the Human Genome project) due to the complex neuro-chemistry and neuro-circuitry (wiring) of the 100 billion neurons comprising the human brain, because the brain uses distributed processing to compute, and because there are many distinct classes of neurons in the brain whose coding system for information remains to be discovered and converted into algorithms. Unfortunately, even given the complexity of the brain, due to the significant developments unfolding in the world of wireless networks, brain-computer interfaces and neuroprosthetics, I anticipate that in the cyborg future a wide variety of criminal threats will be directed at the human brain itself.

If we consider the raw processing power of a supercomputer (able to perform trillions of floating point operations per second), and compare that to the brain, estimates put the processing power of a supercomputer within that of a brain's, so with a few iterations of Moore's law, processing power will not be the limiting factor for creating human-like intelligence it once was. Within 10–15 years, the biggest obstacle in creating an artificial intelligence with similar capabilities as the human brain, will be the fact that biological based neural computing, differs in fundamental ways from silicon's. For example, the human brain is massively parallel, it contains billions of neurons that can individually synapse with thousands of other neurons; but the individual neurons each have limited processing ability.[47] In contrast, supercomputers have tremendous processing power as measured by the number of arithmetic operations performed per second, but typically have

[46]Michio Kaku, 2014, The Future of the Mind: The Scientific Quest to Understand, Enhance, and Empower the Mind, Doubleday.

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

limited parallel connections; however, research is directed at just this issue, to make computers compute in parallel. In fact, much of the progress in unlocking the complexity of the brain, can be credited to advances in technology. As theoretical physicist Michio Kaku recently discussed in "*The Future of the Mind: The Scientific Quest to Understand, Enhance, and Empower the Mind*,"[48] the revolution in modern neuroscience has been triggered by the widespread use of MRI technology starting in the 90s, fMRI technology more recently, and culminating in optogenetic techniques in the last few years.[49]

Advances in Optogenetics, by scientists at Stanford University, is an important technology with respect to studying how the brain functions. The reason is that optogenetics allows scientists to study how different neuronal circuits interact and influence each other. The relevancy of this technology for the future human-machine merger is that if we are to build software that can communicate directly with the brain we need to crack its codes. One way to do this is to select a set of neurons of interest, measure how they are firing, reverse engineer their message, and write the appropriate algorithm(s) (this is a simplification!). Historically, scientists knew that proteins, called opsins, in bacteria and algae generated electricity when exposed to light. Fast forward—optogenetics exploits this mechanism for brain science. Opsin genes are inserted into the DNA of a harmless virus, which is then injected into the brain of a test subject. By choosing a virus that prefers some cell types over others, or by altering the virus's genetic sequence, researchers can target specific neurons, or regions of the brain known to be responsible for certain actions or behaviors.[50] To study neuronal activity, an optical fiber- a spaghetti-thin glass cable that transmits light from its tip, is inserted through the skin or skull to the site of the virus. The fibers light activates the opsin, which in turn conducts an electrical charge that forces the neuron to fire.

Even with the brain's tremendous complexity progress is being made towards the integration of the human brain with machines and sensors. For example, researchers at the Rehabilitation Institute of Chicago, have developed a thought-controlled bionic leg which uses neuro-signals from the upper leg muscles to control a prosthetic knee and ankle. The prosthesis uses pattern recognition software contained in an on-board computer, to interpret electrical signals from the upper leg as well as mechanical signals from the bionic leg. When the person equipped with the prosthesis thinks about moving his leg, the thought triggers brain signals that travel down his spinal cord, and ultimately, through peripheral nerves, are read by electrodes in the bionic leg, which then moves in response to the initial thought. Further, hackers are beginning to enter the fray. Take body hacker and inventor Shiva Nathan, a teenager from India. After being inspired to help a family member who lost both arms below the elbow, Shiva created a robotic arm

[48] Michio Kaku, *id*., note 46.

[49] Stuart S. Hall, 2014, Neuroscience's New Toolbox, MIT Technology Review, V. 117, 20–28.

[50] *Id.*

controlled by thought. The technology uses a Mindwave Mobile headset to read EEG waves and Bluetooth to send certain types of thought to the arm which then translates them into finger and hand movements. This is a remarkable achievement for a 15 year old using technology accessible to anyone.

In fact, research on prosthesis, is truly international in scope. For example, in Sweden, researchers at Chalmers University of Technology are developing a thought-controlled prosthesis for amputees in the form of an implantable robotic arm. And in the U.S., the FDA has approved a thought-controlled prosthetic limb that is realistic and more human-like than other devices on the market.[51] The DEKA Arm prosthetic, invented by Dean Kamen, can detect up to ten movements, is the same size and weight as a natural human arm, and works by detecting electrical activity caused by the contraction of muscles close to where the prosthesis is attached. The electrical signals, initially generated by thought are sent to a computer processor in the DEKA Arm, which triggers a specific movement in the prosthesis. In FDA tests, the artificial arm/hand has successfully assisted people with household tasks such as using keys and locks, preparing food, feeding oneself, brushing hair and using zippers.

The above examples causes me to wonder, in the future when an arm or leg prosthesis appears to be as realistic to people as a natural limb, but is more powerful and dexterous than natural limbs, with greater freedom and movement in joints and with additional degrees of articulation, would "normal" humans opt for the superior prosthesis, if the surgical risk was minimal? The answer is unknown, but I have my suspicions. Just consider the following data. According to the American Society of Plastic Surgeons, in 2011 there were 307,000 breast augmentations in the U.S., a surgical procedure done to alleviate no medical condition, and unlike most implantable technology, breast implants lack sensors and artificial intelligence, they are purely cosmetic.

And who needs sight to get around when you've got a digital compass in your head? A neuroprosthesis that feeds geomagnetic signals into the brains of blind rats has enabled them to navigate around a maze. The results demonstrate that the rats could rapidly learn to deploy a completely unnatural "sense". And it raises the possibility that humans could do the same, potentially opening up new ways to treat blindness, or even to provide healthy people with extra senses. "I'm dreaming that humans can expand their senses through artificial sensors for geomagnetism, ultraviolet, radio waves, ultrasonic waves and so on," says Yuji Ikegava of the University of Tokyo in Japan.[52] "Ultrasonic and radio-wave sensors may enable the next generation of human-to-human communication," he says. The

[51]Dean Kamen, DEKA prosthesis, at: http://www.dekaresearch.com/founder.shtml.

[52]Andy Coghlan, 2015, Brain compass implant gives blind rats psychic GPS, New Scientist, at: http://www.newscientist.com/article/dn27293-brain-compass-implant-gives-blind-rats-psychic-gps.html#.VXiVL-_bJjo; See generally, Takahashi, N., Sasaki, T., Matsumoto, W., Matsuki, N. and Ikegaya, Y., 2010, Circuit topology for synchronizing neurons in spontaneously active networks. PNAS, 107:10244–10249.

neuroprosthesis consists of a geomagnetic compass—a version of the microchip found in smartphones—and two electrodes that fit into the animals' visual cortices, the areas of the brain that process visual information.

Returning to Michio Kaku's observations on the future of the mind, he reveals other fascinating research being done using sensors to read images stored in the human brain and on downloading artificial memories into the brain to treat victims of strokes and Alzheimer's.[53] Kaku also lists telepathy and telekinesis; artificial memories implanted into our brains; and a pill that will make us smarter as future technologies that will emerge this century. Extending Kaku's observations on the future, imagine being able to replace the anatomy and physiology of the brain with 3D printed parts. For the brain's skull, doctors in the Netherlands have done just that in a first successful replacement of most of a human skull using a 3D printed plastic one. The surgery to replace the skull took place at University Medical Center Utrecht[54] with a woman who was suffering from severe headaches due to a thickening of her skull. As a result she slowly lost her vision, her motor coordination was affected, and without surgical interdiction, other essential brain functions would have atrophied. The 3D implant did its job, pressure on the brain was reduced, and the patient regained sensory and motor functions. I view the use of 3D printed parts for humans, androids, and artificially intelligent robots, as a transformative technology that will proliferate in the next few decades and play a major role in leading to our cyborg and ultimately human-machine merger.

Hacking Memory

If we can replace the anatomical structure protecting the brain, can we repair, replace, or enhance parts of the brain's wetware with digital technology? Certainly not now, but how about in the future, or even in the next few decades? Enter biomedical engineer Theodore Berger[55] at the University of Southern California and his team who have developed an experimental artificial hippocampus that they are testing with rats. Their artificial hippocampus is a silicon substitute for the part of the brain that neuroscientists believe encodes experiences as long-term memories. While Berger and his team are motivated by the desire to fight debilitating neurological disease, for example, epilepsy and other disorders that result in damage to the hippocampus (which prevent a person from retaining new memories), an

[53]Michio Kaku, *id*., note 46.

[54]University Medical Center Utrecht, 2014, 3D-printed skull implanted in patient, at: http://www.umcutrecht.nl/en/Research/News/3D-printed-skull-implanted-in-patient.

[55]Rebecca Boyle, 2011, Artificial Memory Chip, discussing the work of Theodore Berger, at: http://www.popsci.com/technology/article/2011-06/artificial-memory-chip-rats-can-remember-and-forget-touch-button.

artificial hippocampus will also be a major advance towards the cyborg future and human-machine merger.

To build an artificial hippocampus, Berger created mathematical models of the neuronal activity in a rat's hippocampus and designed a chip (located external to the brain) to mimic the signal processing which occurred in different parts of the hippocampus. Interestingly, the researchers modeled neuronal activity by sending random pulses into the hippocampus, recorded the signals at various localities to see how they were transformed, and then derived equations describing the signals.[56] Berger and colleagues also connected the chip, which contained the algorithms, to the rat's brain by electrodes. Using the chip, Berger was *not* able to "put individual memories back into the brain," but he *was* able to put the capacity to generate memories in the brain.[57]

To see if the chip could serve as a prosthesis for a damaged hippocampal region, the researchers performed a study to determine whether they could bypass a central component of the pathways in the hippocampus. Berger's team tested the device in rats trained in a simple memory task. Each rat (with the prosthesis) was placed in a chamber with two levers. First, the lever on just one side of the chamber was presented, and the rat pushed it, after a short waiting period, the levers on both sides of the chamber appeared, and if the rat pushed the opposite lever from the one it pushed before, the rat was rewarded with a sip of water. However, to perform the task successfully required the rat to remember which lever it pushed originally.

To test if the memory prosthesis worked as expected, Berger and his team injected some of these rats with a drug that impaired their natural memory, and then tested the animals in the lever experiment. The rats (with the prosthesis) were still able to push the correct lever to receive their drink, suggesting they were able to form new memories and that the rats' brain implant was remembering for them. Remarkably, the researchers found that the prosthesis could enhance memory function in rats even when they hadn't been given the drug that impaired their memory.

Going up the phylogenetic scale, at Wake Forest University School of Medicine, Robert Hampson and his team successfully tested a hippocampal prosthesis on non-human primates. While the device is far from a fully implantable hippocampus "chip," these tests, from rat to monkey, demonstrate the "proof-of-concept" effectiveness of the artificial hippocampus as a neural prosthetic; and in the near future, Robert Hampson plans to begin human trials. While Hampson's and Berger's work is a long way from a hard drive for the brain, it's a step in the direction of being able to "back up," or hack, memory, and once this is possible, the next step will be to transmit information into the artificial hippocampus, a major step in the direction of a cyborg future. Of course, once an artificial

[56] *Id.*

[57] *Id.*

hippocampus is implanted within the brain it could be hacked by third parties, a topic discussed in the chapter on *Cognitive Liberty*.

Implanting False Memories

The legal and policy implications of being able to manipulate memory are immense: If humans can control memories, can they also alter them? Could memories be decoded against a persons will and used as evidence in a courtroom, and could people erase memories and replace them with new ones altogether?[58] And for artificially intelligent machines, will manipulating their memory be nothing more than changing the lines of their code? Would this be ethical, would a future law need to be enacted to protect against this possibility? If an artificially intelligent machine used computer vision and algorithms to view the world, would changing its software be the equivalent of tampering with a witness or performing a digital lobotomy? And when examining the prospect of memory enhancement, some who worry about the ethics of cognitive enhancement point to the danger of creating two classes of human beings—those with access to enhancement technologies, and those who must make do with an unaltered memory that fades with age.

Planting false memories in the brain may seem like science fiction, until, that is, we see that it's already being done, at least with a research subject commonly picked on by scientists, the laboratory mouse. Using genetically engineered mice, Susumu Tonegawa, MIT Picower Professor of Biology and Neuroscience, Dr. Xu Liu,[59] and colleagues at the *Riken-MIT Center for Neural Circuit Genetics*, used the technique of optogenetics to access neurons in the brain of a mouse. Basically they implanted a fiber optic in the mouse's brain allowing them to reactivate neuronal circuitry that had previously been recorded.[60] According to Dr. Liu, our memory changes every single time it's being recorded, which is why we can incorporate new information into old memories and this is how a false memory can form. Interestingly, by implanting a false memory, the MIT team was able to make the mice wrongly associate a benign environment with a previous unpleasant experience from different surroundings.

How they did this was to first condition a network of neurons to respond to light based on optic fibers implanted in the mouse's brain in a specific region.[61] Then the scientists placed the mouse in a red chamber, which was harmless. The following day, they had the mouse explore a blue-walled chamber, and gave it a

[58]See generally, Nita Farahany, 2012, Incrimination Thoughts, Stanford Law Review, Vol, 64. 351.

[59]RIKEN Brain Science Institute, RIKEN-MIT Center for Neural Circuit Genetics (CNCG), see the references to Xi Liu, at: http://www.riken.jp/en/research/labs/bsi/rmc/.

[60]Optogenetics, MIT Technology Review, at: http://www.technologyreview.com/tagged/optogenetics/.

[61]*Id.* note 59.

mild jolt while simultaneously inducing neuronal recall of the red room. This was done so that the mouse would artificially associate the memory of the shock-free red room with the fear of being shocked. On the third day, the researchers wanted to see whether this false association had successfully been implanted. To determine this, they placed the mouse in the red room, where it froze even though nothing bad had happened to it there.[62] Based on the fear response, the MIT team concluded that a false memory had been formed and recalled. Attesting to the importance of the work, cognitive scientist Neil Burgess[63] from University College London, told BBC News the study was an "impressive example" of creating a fearful response in an environment where nothing fearful had happened. Although using an implant to plant a memory in a human brain won't be possible in the next few years, in principle, it should be possible to isolate a human memory and activate it given difficult technical problems are overcome.

The phenomenon of false memory has implications for law and policy and has been well-documented by psychologists. In many court cases, defendants have been found guilty based on testimony from witnesses and victims who were sure of their recollections, but DNA evidence later overturned the conviction. In a step toward understanding how these faulty memories arise, material presented in this chapter has shown that at the level of neuronal circuitry, false memories can be modeled and implanted in the brains of mice. But importantly, neuroscientists have also found that many of the neurological traces of these memories are identical in nature to those of authentic memories. According to MITs Susumu Tonegawa, "Whether it's a false or genuine memory, the brain's neural mechanism underlying the recall of the memory is the same."[64]

That we should be concerned with the possibility of false memories being implanted in the brain is not a recent concern motivated only by the arrival of brain-computer interfaces and a cyborg future. For example, a Wisconsin jury awarded $1 million to a couple who claimed that malpractice by therapists caused their daughter to have false memories of childhood abuse. In fact, several patients have won settlements or jury awards of millions in false memory lawsuits against therapists. But the case of Dr. Charles Johnson and his wife Karen is the first in which the parents of a patient brought negligent therapy claims—over the objections of the patient. The case took years to get to trial, prompted by a key breakthrough in 2005 when the Wisconsin Supreme Court ruled that the therapist-patient privilege did not apply to the daughter's treatment records.[65] The

[62] *Id*. note 59.

[63] Melissa Hogenboom, 2013, Scientists can implant false memories into mice, at: http://www.bbc.com/news/science-environment-23447600.

[64] Anne Trafton, 2013, Neuroscientists plant false memories in the brain, quoting Susuma Tonegawa, at: http://newsoffice.mit.edu/2013/neuroscientists-plant-false-memories-in-the-brain-0725.

[65] Linda Greenhouse, 1996, The Supreme Court, Confidentiality, Justices Uphold Patient Privacy With Therapist, New York Times, at: http://www.nytimes.com/1996/06/14/us/the-supreme-court-confidentiality-justices-uphold-patient-privacy-with-therapist.html.

Johnsons used those records to support their claim that the therapists practiced the controversial "recovered memory" technique on their daughter. What to make of this? There is a public policy exception to the therapist-patient privilege and to the confidentiality in patient health care records where negligent therapy causes false accusations to be made against the parents for sexually or physically abusing their child, the court concluded.[66] Would a similar privilege be necessary for brain-computer interfaces?

Thinking more broadly, I can't help but see a connection between the science and technology of implanting memories, false memories implanted by a therapist, and a case heard before the Court of Justice in the European Union which decreed that human beings have a solemn right to make mistakes and then to erase them, that is, "The Right to be Forgotten." The concept stems from the desire of an individual to 'determine the development of his life in an autonomous way, without being perpetually or periodically stigmatized as a consequence of a specific action performed in the past.'[67] If memories can be implanted in a person's mind, not only would it be difficult to forget the past, but a person could be stigmatized by actions that never took place. Among legal scholars, there are concerns that creating a right to be forgotten would lead to censorship and a possible rewriting of history—I share this concern.

Hacking the Skin

If we can hack the brain, can we hack the skin, the largest sense organ? Surprisingly, the answer is yes, but first a digression into popular culture. A recent Pew study showed that nearly forty percent of Americans under the age of forty have at least one tattoo, creating a $1.65 billion industry. Like any industry, however, the tattoo industry must innovate to expand and gain new clients. In an analog world, one way to innovate is to make the switch to digital technology.

Rather than being passive as are current tattoos, digital tattoos are active, they *do* things, and they are getting smart. That is, now days, digital tattoos have the potential to do more than serve the function of art or self-expression, even though these are laudable goals, they will become digital devices as useful as smartphones and will monitor our health. This is not the distant future, the technology to create digital tattoos already exist. It's possible, for instance, to use a type of ink in a tattoo that responds to electromagnetic fields, which raises a host of opportunities. In fact, Nokia patented just this technology, ferromagnetic ink that can interact with a device through magnetism.[68] The basic idea is to enrich tattoo ink with metallic

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[66] *Id.*

[67] Factsheet on the "Right to be Forgotten" Ruling, at: http://ec.europa.eu/justice/data-protection/files/factsheets/factsheet_data_protection_en.pdf.

[68] Adam Clark Estes, 2014, The Freaky Bioelectric Future of Tattoos, at: http://gizmodo.com/the-freaky-bioelectric-future-of-tattoos-1494169250.

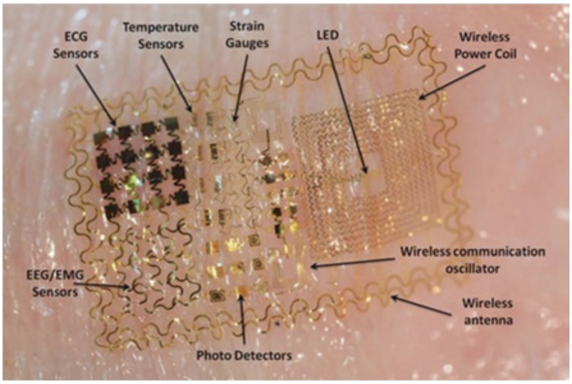

Fig. 5.2 Electronic sensor tattoos can be "printed" directly onto human skin. Image courtesy of Professor John Rogers, University of Illinois

compounds that are first demagnetized (by exposing the metal to high temperatures) before the ink is embedded in a person's skin. Once the tattoo has healed, the ink is re-magnetized with permanent magnets. The procedure is strikingly similar to that of getting a 'normal' tattoo—only the ink is special. The resulting tattoo is then sensitive to magnetic pulses, which can be emitted by a device such as a cellular phone. Interestingly, a digital tattoo would allow a person's ringing phone to result in a haptic sensation experienced by the body; that is, the person would experience the phone ringing literally through the tattoo. And since the phone should be able to send a variety of pulses, different degrees of tingling could be used to indicate whether a phone battery was dying, or whether a person had a text or voice message.[69] A sub-dermal phone call makes me wonder if a deliberate wrong call should be considered an assault and battery?

If the tattoo consists of putting electronics on the surface of the skin, many possibilities for body hacking exist. Materials scientist, and University of Illinois Professor John Rogers and his company are developing flexible electronics that stick to the skin to operate as a temporary tattoo.[70] These so-called "epidural electronics" (or Biostamp) is a thin electronic mesh that stretches with the skin and monitors temperature, hydration and strain, as well as monitoring a person's body's vital signs (Fig. 5.2). The latest prototype of the Biostamp is applied directly to the skin using a rubber stamp. The stamp lasts up to two weeks before the skin's natural exfoliation causes it to come away. Rogers is currently working on ways to get the electronics to communicate with other devices like smartphones so that they can start building apps. Google isn't far behind in developing digital tattoos, as the company's Advanced Technology and Projects Group patented the idea of a digital tattoo consisting of various sensors and gages, such as strain gauges for tracking strain in

[69] *Id.*

[70] Liz Ahlberg, 2014, Off the shelf, on the skin: Stick-on electronic patches for health monitoring, at: http://news.illinois.edu/news/14/0403microfluidics_JohnRogers.html.

multiple directions (how the user is flexing), EEG and EMG (electrical impulses in the skeletal structure or nerves), ECG (heart activity), and temperature.

As with other implantable technology, initially, hacking the skin will most likely be done for health reasons. In fact, by 2016, there could be 100 million wearable wireless medical devices used by people.[71] As an example, Roger's digital tattoo described above can track a person's health and monitor healing near the skin's surface. Then there's a wearable sensor that tells people when it's time for a drink. Sandia National Laboratories researcher Ronen Polsky has built a prototype of a microneedle fluidic chip device able to selectively detect and measure electrolytes in the fluids around skin cells.[72] The device consists of an array of microneedles on the underside of a watch-like device that protrudes into a person's skin to measure interstitial fluid levels—broadly speaking, the water that sits between a person's cells. Whenever this figure falls below a certain limit, a person is alerted. Placing sensors on the skin is an interesting idea, with great potential for monitoring a person's health, but sensors on the skin will also serve other functions—for example, to detect information in the environment that is of interest to a person and to wirelessly connect a person to the billions of items that will be networked together in the future.

But the skin isn't being hacked only to monitor our health, artists are combining the surface of the skin with technology in unique ways. Consider body hacker Moon Ribas who is a Catalan contemporary choreographer and the co-founder of the *Cyborg Foundation*, an international organisation which promotes "cyborgism" as an artistic and social movement. In an interesting use of technology and choreography, she attached a seismic sensor to her elbow that allows her to feel earthquakes through vibrations resulting from ground tremors.

In a more extreme example of performance art, Professor Stelarc, through a series of surgeries, created an artificial ear on the skin of his left arm.[73] Stelarc's philosophy for body hacking is to use technology in a way that extends the body's physical abilities, allowing a person to do what they previously could not due to physical limitations—this he plans to accomplish by implanting a microchip and microphone in the artificial ear. To build the artificial ear, excess skin was created with an implanted skin expander in the forearm. By injecting saline solution into a subcutaneous port, a kidney shaped silicone implant stretched the skin, forming a pocket of excess skin that was used in surgically constructing the ear. In a second surgery a Medpor scaffold was inserted and skin was suctioned over it. The Medpor implant was shaped into several parts and sutured together to form the ear shape. During the second procedure a miniature microphone was positioned inside

[71]Robert N. Charette, 2012, Wearable Computers the Size of Button to Monitor Health, at: http://spectrum.ieee.org/riskfactor/biomedical/devices/wearable-computers-the-size-of-buttons-to-monitor-health.

[72]Prototype electrolyte sensor provides immediate read-outs, 2014, at: https://share.sandia.gov/news/resources/news_releases/electrolyte_sensor/#.VXjhNO_bJjo.

[73]Paolo Atzori and Kirk Woolford, Extended-Body: Interview with Stelarc, at: http://web.stanford.edu/dept/HPS/stelarc/a29-extended_body.html.

the ear. But while the inserted microphone was tested successfully, later it had to be removed due to infection. Once the hacking is complete, wherever Stelarc may be, using the appropriate technology, a person could remotely listen into what his artificial ear "hears." Summarizing Stelarc' body hacking philosophy, he comments that as technology proliferates and microminiaturizes it becomes biocompatible in both scale and substance and thus can be incorporated as a component of the body; his artificial ear represents this idea.

Hacking the Eyes

For many people, vision is the most important sense, its loss is so deleterious to functioning in everyday life, that major efforts are underway to develop technology to restore sight to those who have lost it. The visual sense is also the subject of body hackers. Meet Neil Harbisson who was born with a rare condition (achromatopsia) that allows him to see only in black and white and shades of grey (Fig. 5.3). After viewing a talk in 2003 on cybernetics, in the spirit of a hacker, Neil wondered if he could turn color into sound, based on the idea that a specific frequency of light could be made equivalent to a sound wave. When Neil first thought of the idea, he wasn't aware that in 2014, research would eventually show that the visual cortex processes auditory information detected by the ears. To become a cyborg, Neil had a sound conducting chip implanted in his head, along with a flexible shaft with a digital camera on it, permanently attached to his skull (the Eyeborg). With his latest software upgrade, Neil says he is able to hear ultraviolet and infrared frequencies, can have phone calls delivered to his head, and has a Bluetooth connection which allows him to connect his Eyeborg to the Internet.[74]

Interestingly, the addition of the Eyeborg to his passport photo has led some to dub Neil the first cyborg officially recognized by a sovereign state. In a harbinger of future bioethical debates about cyborg technology, Neil had to convince a surgical team to perform the procedure; that is, to implant the chip in his head. Since the purpose of medicine is to restore the body to its normal state, Neil had to convince the doctors that his device could help restore function to those who had lost it, not just allow him to have a sixth sense through the perception of objects in his visual field via bone-conducted sounds. This brought up the second ethical issue. Whether Neil should receive an implant which allowed him to perceive outside the normal range of human vision and human hearing (hearing via the bone allows a person to hear a wider range of sounds, from infrasounds to ultrasounds), again, not typically a reason to receive an implant. But in theory, if a person was equipped with a different type of chip, say one that translated words into sound, or distances into sound, for instance, then the same electronic eye implant could be used to read or to detect obstacles, thus restoring function to those who had

[74]Eyeborg: The Man Who Hears Colours, 2014, at: https://artselectronic.wordpress.com/2014/12/19/eyeborg-the-man-who-hears-colours/.

Fig. 5.3 Neil Harbisson hearing color, image curtesy of Lars Norgaard

lost it. This argument convinced the surgical team that the implant could have a restorative effect, and the procedure was done. However, this example raises an interesting policy question- which kinds of cybernetic implants will society find to be ethical and legal, and which ones they will not. Let the debate begin.

Amazing technology to assist people with visual impairments is creating a whole new population of cyborgs, some of whom never thought they would see again. In fact, different types of prosthesis for the eyes are starting to emerge from research laboratories. For example, in the U.S. the FDA approved a retinal implant, for those experiencing the effects of retintis pigmentosa. The implant doesn't completely restore vision, but is meant to partially restore useful vision to people who have lost their sight due to degenerative eye conditions.

In a healthy eye, the photoreceptors (rods and cones) in the retina convert light into tiny electrochemical impulses that are sent through the optic nerve and into the brain, where they are decoded into images. If the photoreceptors no longer function correctly—due to conditions such as retintis pigmentosa—the first step in this process is disrupted, and the visual system cannot transform light into images. Enter the Argus II Retinal Prosthesis System (Argus II) which was approved in Europe in 2011, and the U.S. in 2013. This prosthesis is designed to bypass the damaged photoreceptors altogether. With the prosthesis, a miniature video camera housed in the patient's glasses captures a scene, and the video of the scene is sent to a small patient-worn computer where it is processed and transformed into instructions that are sent back to the glasses via a cable. These instructions are then transmitted wirelessly to an antenna in the implant which then sends the instructions to an electrode array in the retina. The small pulses of electricity are intended to bypass the damaged photoreceptors and stimulate the retina's remaining cells, which transmit the visual information along the optic nerve to the brain. This process is intended to create the perception of patterns of light which patients can learn to interpret as visual patterns.

If we can begin to restore vision, can we enhance it? What about the idea of telephoto vision (Fig. 5.4)? For the approximately 20–25 million people worldwide who have the advanced form of age-related macular degeneration (AMD), a disease which affects the region of the retina responsible for central, detailed vision,

Fig. 5.4 Implantable telescopic eye. Image provided courtesy of VisionCare Ophthalmic Technologies

and is the leading cause of irreversible vision loss and legal blindness in people over the age of 65, a relatively new device, essentially an implantable telescope, is offering hope. In 2010, the U.S. FDA approved the implantable miniature telescope (IMT), which works like the telephoto lens of a camera.[75] The IMT technology reduces the impact of the central vision blind spot due to end-stage AMD and projects the objects the patient is looking at onto the healthy area of the light-sensing retina not degenerated by the disease.

The Implantable Miniature Telescope (IMT) technology reduces the impact of the central vision blind spot due to End-Stage AMD and projects the objects the patient is looking at onto the healthy area of the light-sensing retina not degenerated by the disease.

The surgical procedure involves removing the eye's natural lens, as with cataract surgery, and replacing the lens with the IMT. The tiny telescope is implanted behind the iris, the colored, muscular ring around the pupil. While telephoto eyes are not coming soon to an ophthalmologist office, this is an intriguing step in that direction. As always the law is part of the picture, as the procedures to equip a person with telephoto eyes will be subject to tort law if harm occurs, products liability law if the implant fails, and the implant technology will be regulated by the FDA as a medical device.

Hacking the Body with Sensors

In an extension of Professor Warwick's early work involving a sensor implanted under his skin, body hacker Anthony Antonellis implanted an RFID chip into his hand which can be wirelessly accessed by a smartphone.[76] While the chip holds

[75]FDA-Approved Implantable Miniature Telescope for End-Stage Age-Related Macular Degeneration, at: http://www.visionaware.org/info/your-eye-condition/age-related-macular-degeneration-amd/new-fda-approved-implantable-telescope-for-end-stage-amd/125.

[76]Anthony Antonellis, Net Art Implant (and video), at: http://www.anthonyantonellis.com/news-post/item/670-net-art-implant.

only about 1–2 KB of data, it allows Antonellis to access and display an animated GIF on his phone that is stored on the implant. Since the RFID chip can transfer and receive data, Antonellis can swap out 1 KB files as he pleases. Antonellis views the implant as a "net art tattoo", something for which quick response codes (QR, or matrix barcode), are commonly used. Instead of a visible QR code, the RFID chip will allow the art to be easily changed with an increase in storage capacity to the chip, further the convenience of a subdermal wireless hard drive would be an interesting development for the body hacking movement. Similarly, Karl Marc, a tattoo artist from Paris designed an animated tattoo that makes use of a QR code and a smartphone.[77] The code basically activates software on the phone that makes the tattoo move when seen through the phone's camera.

In addition, others have also implanted RFID chips for various reasons. For example, Dr. John Halamaka, of Harvard Medical School, chose to be implanted with an RFID chip in 2004 which is used to access medical information.[78] His implant stores information which can direct anyone with the appropriate reader to a website containing his medical information. He believes that chips such as these can be valuable in situations where patients arrive at the hospital unconscious or unresponsive. Another person with an RFID implant, Meghan Trainor has a much less practical but highly creative application than many of the others who have gotten them. Trainor had the implant put in as part of her master's thesis for NYU's Interactive Telecommunications Program.[79] Her implant serves as part of an interactive art exhibit. RFID tags are embedded in sculptures which can be manipulated to play sounds stored in an audio database. Trainor can use the implant in her arm to further manipulate these sounds. Considering a digital tattoo designed for a medical monitoring purpose, University of Pennsylvania's Brian Litt, a neurologist and bioengineer, is implanting LED displays under the skin for medical monitoring purposes.[80] These tattoos consist of silicon electronics less than 250 nm thick, built onto water soluble, biocompatible silk substrates. When injected with saline, the silk substrates conform to fit the surrounding tissue and eventually dissolves completely, leaving only the silicon circuitry. The electronics can be used to power LEDs that act as photonic tattoos. Litt is perfecting a form of this technology that could be used to build wearable medical devices—say, a tattoo that gives diabetics information about their blood sugar level.

But in what I consider to be a remarkable effort to hack the body, "grinder" Tim Cannon, implanted a Circadia 1.0 biometric sensor under his forearm skin to track changes in his temperature.[81] The sensor/computer can connect wirelessly to an

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[77] QR Code Tattoos, at: http://www.qrscanner.us/qr-tatoos.html.

[78] Life as a Healthcare CIO, 2007, at: http://geekdoctor.blogspot.com/2007/12/chip-in-my-shoulder.html.

[79] RFID Implants: 5 Amazing Stories, at: http://www.rfidgazette.org/2007/04/rfid_implants_5.html.

[80] *Id.*

[81] Biohacking/Grinder Update: Tim Cannon Implants Circadia 1.0, 2013, at: http://hplusmagazine.com/2013/10/21/grinder-update-tim-cannon-implants-circadia-1-0/.

Android device, produce readouts of the temperature changes, and send Cannon a text message if he's experiencing a fever. To insert the device, an incision was made on Cannon's forearm above an existing tattoo. His skin was lifted and separated away from his tissue and the device was inserted into the pocket that was created before being sutured shut. The LEDs act as 'status lights' that can be used to light up a tattoo on Cannon's arm, under which the sensor is fitted. The first version of the sensor reads temperature changes but, in theory, later versions could be used to track other vital signs and body changes. Some critics have argued that Tim's implanted technology does not realistically measure body temperature—but entering that debate is not a purpose of this chapter, other than to use this dispute as an introduction to how the law, in general, will have to deal with defective implantable devices a subject covered in this and other chapters throughout this book.

Sensory Substitution and a Sixth Sense

With regard to hacking the body, can a new sense be created? If by "new sense" one meant to enhance a current sense in such a way that sensory information beyond the range of its sensory receptor(s) can be detected, then yes. Actually, substituting one sense for another is a well-researched topic and represents another way to hack the body and create a cyborg future. Increasing and/or extending the range of our senses may be desirable given we see and hear across certain frequencies, and that the eyes and ears can only detect information within a given distance to the sensory receptors. In the future, by hacking the body, X-ray or telephoto vision, and greater sensitivity to olfactory, gustatory, or haptic information, may be possible.

Duke University neuroscientist Miguel Nicolelis, and his team claim that they have created a "sixth sense" through a brain implant in which infrared light is detected by lab rats.[82] Even though the infrared light can't be seen, lab rats are able to detect it via electrodes in the part of the brain responsible for the rat's sense of touch- so remarkably, the rats feel the light, not sees it. In order to give the rats their "sixth sense", Duke researchers placed electrodes in the rat's brains that were attached to an infrared detector.[83] The electrodes were then attached to the part of the animals' brains responsible for processing information about touch. The rats soon began to detect the source of the 'contact' and move towards the signal.

Sixth sense or not, in my view, the study by Nicolelis and his team is another step toward integrating brain-computer technology into the human body; and thus contributing to a cyborg future.[84] Eric Thomson, who worked on the project, said

[82]Miguel Nicolelis, *Id*. note 47.

[83]Miguel Nicolelis, *Id*. note 47.

[84]Miguel Nicolelis, *Id*. note 47.

past brain-machine studies have focused on restoring function to damaged areas of the brain, not creating it. "This is the first study in which a neuroprosthetic device, was used to augment function—literally enabling a normal animal to acquire a sixth sense."[85] In addition to these fascinating findings, the Duke scientists found that creating the infrared-detecting sixth sense did not stop the rats from being able to process touch signals, despite the electrodes (providing input for the infrared detection system) being placed in the tactile cortex.

Hacking the Ear

Grinders have also shown an interest in hacking the ear. For example, Rich Lee, a self-described Grinder, implanted sound-transmitting magnets in his ears to extend his auditory sense.[86] Part of his system contains a coil that creates an electromagnetic field that vibrates magnets implanted in his ears which produces sound. Lee says the quality of the sound is similar to a cheap pair of earbuds. The phenomenon at work is known as electromagnetic induction, and is also the reason we can both generate electricity with mechanical motion (i.e. generators) and turn sound into electrical currents (i.e. microphones). Showing the true hacker spirit, one of Rick's interests is to use the implant to connect with other devices to augment his own senses and abilities. But a main part of his interest in hacking his auditory sense deals with necessity, Rick is losing his sight. With his headphone implants, and other technology, Rich could compensate for his loss of vision by learning to echolocate and to interpret the shape and dimensions of his surroundings based on how they react to emitted sound waves transmitted to his implanted magnets. Aside from just listening to music or podcasts, Lee plans to use the earlobe-implants in conjunction with his phone's GPS so he can get directions beamed right into his head. And Lee plans to hook up the earlobe-phones to a directional microphone in order to listen in on conversations; clearly there are privacy issues associated with this.

Hackers are not the only one interested in restoring or enhancing audition. According to the FDA, as of 2012, approximately 324,200 people worldwide have received a cochlear implant, designed to improve hearing. A cochlear implant helps to provide a sense of sound to a person who is profoundly deaf or severely hard-of-hearing. The implant does not restore normal hearing, instead, it can give a deaf person a useful representation of sounds in the environment and help him or her to understand speech. The typical implant consists of: an external portion that sits behind the ear and a second portion that is surgically placed under the skin and has a microphone, which picks up sound from the environment; a speech

[85]See generally, Miguel Nicolelis, *Id*. note 47.

[86]Zoltan Islvan, 2014, Interview with Transhumanist Biohacker Rich Lee, The Transhumanist Philosopher, at: https://www.psychologytoday.com/blog/the-transhumanist-philosopher/201407/interview-transhumanist-biohacker-rich-lee.

processor, which selects and arranges sounds picked up by the microphone; a transmitter and receiver/stimulator, which receive signals from the speech processor and converts them into electric impulses; and an electrode array, a group of electrodes that collects the impulses from the stimulator and sends them to different regions of the auditory nerve. A cochlear implant is very different from a hearing aid which amplifies sounds so they may be detected by damaged ears. Instead, cochlear implants bypass damaged portions of the ear and directly stimulate the auditory nerve

In the U.S. the FDA enforces regulations that deal specifically with the manufacture and sale of hearing aids because these products are recognized as medical devices. The most notable federal regulation is the FDA's Hearing Aid Rule which requires that prior to the sale of a hearing aid, the practitioner advice the patient that it is in their best health interest to see a physician, preferably one specializing in diseases of the ear, before purchasing a hearing aid. As with other implant technology, with cochlear implants problems may occur which prompt legal action. For example, in Kentucky a jury awarded $7.24 million to a Kentucky girl and her family, after her cochlear implant failed and caused her to suffer excruciating shocks and convulsions.[87] The jury found that Advanced Bionics, a medical device company, was responsible for knowingly selling defective cochlear implants.

Sensing Electromagnetic Fields

In an extension of the work by Duke's Miguel Nicolelis (feeling light) and University of Reading's Kevin Warrick (implantable chip), Grinders are hacking their body by inserting magnets under their fingertips in order to detect a source of energy that is beyond our normal perception, electromagnetic fields. Similarly, robots are also becoming equipped with the ability to sense objects before it touches them by using magnetic fields in a way that in their case, mimics the sensory perception of sharks.

Electromagnetic fields are all around us, whether we perceive them or not. In fact, anything that uses a transformer or direct current (as do household appliances) gives off an electromagnetic field. With implantable magnets, things like power cord transformers, microwaves, and laptop fans became perceptible to a cyborg. According to Grinders equipped with the implanted magnets, each object has its own unique field, with a different strength and "texture." Body hacker, Tim Cannon has extensive experience detecting magnetic fields through his neodymium magnetic implant. Interestingly, when Tim first received his implant he reports

[87]David Kirkwood, 2013, Jury awards $7.2 million in case of a girl harmed by a defective cochlear implant, at: http://hearinghealthmatters.org/hearingnewswatch/2013/jury-awards-7-2-million-in-case-of-a-girl-harmed-by-a-defective-cochlear-implant/.

that he could literally feel the invisible field of a cash register, with the strength of the vibrations of his implanted magnet varying depending on where he held his finger in relation to the machine.[88] However, not all of Tim's perceptions of magnetic fields have been positive, as Tim reports an uncomfortable feeling when he handles other magnets which can flip the magnet inside his finger.

In an extension of his body hacking efforts to create a magnetic sense, Cannon is working on an implantable device called Bottlenose which is an echo location unit, giving a person a sonar sense. The device which is about half the size of a pack of cigarettes slips over a person's finger. Named after the echolocation used by dolphins, it sends out an electromagnetic pulse and measures the time it takes to bounce back. If a person is equipped with a finger magnet, the implant is able to react to the sonar information translating it into distance information. A final example of hacking the skin involves implanted magnets in the arm of tattoo artist Dan Hurban, the purpose of which is to hold an iPod Nano to his arm.[89] While a strap would have done the job, none-the-less, this is an interesting proof-of-concept example.

Cybersecurity and the Cyborg Network

As humans become equipped with wirelessly networked sensors and implants, the body is becoming a local area network requiring dedicated spectrum. And as with any wireless network, it can be hacked. In the U.S. the Federal Communication Commission specifically allocates spectrum for a medical body area network, or MBAN for short, which consists of devices worn on, or implanted in, the human body that communicate with a programmer/controller device outside the body using a wireless communication link. The spectrum allocated to MBANs is solely for the purpose of measuring and recording physiological parameters and other patient information, or for performing diagnostic or therapeutic functions, primarily in health care facilities. There are a number of restriction with MBANs—they can be used only for diagnostic and therapeutic purposes; they must be provided to a patient only under the direction of an authorized health care professional; an MBAN body-worn device may not communicate directly with another MBAN body-worn device; and are only allowed a maximum emission bandwidth of five megahertz.

With wirelessly implantable devices, there are several weaknesses to the network which includes those resulting from unintentional signal interference, to threats characterized as "unauthorized accessing of a device," or hacking. Medical devices exhibit a number of potential vulnerabilities—such as untested firmware and software, and unsecured wireless connectivity. This could happen in a number of ways: limited battery life, remote access vulnerabilities, interruptible wireless signals,

[88]See generally, Dan Berg, 2012, Body Hacking: My Magnetic Implant, at: http://www.iamdann.com/2012/03/21/my-magnet-implant-body-modification.

[89]Guy Gives Himself Magnet Implants to Attach iPod To Arm, at: http://geekologie.com/2012/05/guy-gives-himself-magnet-implants-to-att.php.

unencrypted data transfers, susceptibility to interference, faulty warning mechanisms, reliance on outdated and obsolete technologies and the inability to download security patches. These vulnerabilities, in turn, could lead to hackers tampering with a device's settings, disabling key functions of the device without a user's knowledge, obtaining sensitive data about a patient or causing a complete device malfunction.

Conclusions

In an age where technology allows people to augment their body, without the confines of evolution by natural selection, human development will continue to leap forward bringing fundamental changes to the very nature of humanity. Body hacking, augmentation, cyborgization, call it what you like, the movement towards implanting technology in the body, is a ripe ground for legislation as new advances in sensors, prosthetics, and brain-computer interfaces are being developed. Law and technology must work hand-in-hand as we move into this new age of human development. Under current laws, such as the ADA, the baseline "able" person is the average functioning human, with all original parts intact, and no addition or modification are relevant in the eyes of the law to determine whether someone is disabled. But this paradigm doesn't work in an age of cyborgs where neuroscience and robotics is leading to an updated division between disabled, able, and "better abled" as both disabled and healthy humans increasingly chose to augment their bodies, and even their brains, with technology. In fact, the use of brain-computer interfaces in the future will go far beyond restoration and enhancement to literally adding new functions to the mind. The ability to hack the body raises the question of what kind of autonomy do we have with our bodies?[90] Is it the autonomy that individuals possess over a piece of property? Or is the autonomy under a right of privacy?

In this chapter I showed that body hackers, Grinders, and self-made cyborgs, are taking advantage of widely available technologies such as tracking chips, LEDs, magnets, and motion sensors to imbue themselves capabilities no other human has. Professor Warwick's initial RFID implant was a turning point in the history of transhumanism not because it represented a great technological leap in implants, but because it required mostly imagination and the courage to try something new, as the technology he used already existed. What he did, anyone could have done. What it undeniably did was pave the way for people with far fewer resources to experiment with enhancements of their own—often without the aid of medical professionals- and many of those explorers have been discussed in this chapter.

In the beginning of the chapter, I stated that caution was in order as we approach the cyborg future. Stanford's Fukuyama's warnings are worth noting again—"What is that human essence that we might be in danger of losing?" "For a

[90]Radhika Rao, Property, Privacy, and the Human Body, 2000, 80 B.U.L. Rev. 359.

religious person, it might have to do with the divine gift or spark that all human beings are born with. From a secular perspective, it would have to do with human nature: the species-typical characteristics shared by all human beings qua human beings. That is ultimately what is at stake in the biotech revolution."[91] Fukuyama argues that state power, possibly in the form of new regulatory institutions, should be used to regulate biotechnology and also cyborg technology. I agree and gave examples in this chapter of how the FDA and other government agencies are starting to show an interest in cyborg technology and that there is a fledgling field of cyborg law related to body modification and enhancements beginning to emerge.

[91]Francis Fukuyama, *id*., note 9.