Special Section: Technology and the Body: Linking Life and Technology

Becoming Borg to Become Immortal: Regulating Brain Implant Technologies

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Revolutions[1] in semiconductor device miniaturization, bioelectronics, and applied neural control technologies are enabling scientists to create machine-assisted minds, science fiction's "cyborgs." In a paper published in 1999,[1] we sought to draw attention to the advances in prosthetic devices, to the myriad of artificial implants, and to the early developments of this technology in cochlear and retinal implants. Our concern, then and now, was to draw attention to the ethical issues arising from these innovations. Since that time, breakthroughs have occurred at a breathtaking pace. Scientists, researchers, and engineers using differing methodologies are pursuing the possibilities of direct interfaces between brains and machines. Technological innovations as such are neither good nor evil; it is the uses devised for them that create moral implications. As there can be ethical problems inherent in the proper human uses of technologies and because brain chips are a very likely future technology, it is prudent to formulate policies and regulations that will mitigate their ill effects before the technologies are widespread. Unlike genetic technologies, which have received widespread scrutiny within the scientific community, national governments, and international forums, brain–machine interfaces have received little social or ethical scrutiny. However, the potential of this technology to change and significantly affect humans is potentially far greater than that of genetic enhancements, because genetic enhancements are inherently limited by biology and the single location of an individual, whereas hybrids of human and machine are not so restricted. Today, intense interest is focused on the development of drugs to enhance memory; yet, these drugs merely promise an improvement of normal memory, not the encyclopedic recall of a computer-enhanced mind combined with the ability to share information at a distance. The potential of brain chips for transforming humanity are astounding. This paper describes advances in hybrid brain–machine interfaces, offers some likely hypotheses concerning future developments, reflects on the implications of combining cloning and transplanted brain chips, and suggests some potential methods of regulating these technologies.

Advances

Presently, pacemaker-like brain implants help Parkinson's patients and those with essential tremors.[2] Vagus nerve stimulators, made by Cyberonics, have shown

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effectiveness in clinical trials for treating depression.[3] Systems for functional neuromuscular stimulation are being used experimentally in cases of spinal cord severage.[4] In March of 1998, a "locked in" victim of a brain-stem stroke became the first recipient of a brain-to-a-computer interface, enabling him to communicate on a computer by thinking about moving the cursor[5]; these bionic brain implants, developed by researchers at Emory University allow a computer interface to be operated by the power of thought. An artificial vision system, announced in January 2000, enables the blind, using a cortical implant, to navigate independently, to "read" letters, and through a special electronic interface to "watch" television, use a computer, and access the Internet.[6] Implanted chips, undergoing experimentation outside the United States (in order to circumvent Institutional Review Board and Food and Drug Administration approval) are now assisting the blind to drive and navigate around spaces.[7]

Initial work on linking the brain directly with both local and remote manipulators has been demonstrated by neuroscientists at Duke University, who trained a monkey to control a mechanical arm just by thinking.[8] In November of 2003, a U.S. company announced plans to request an investigational device exemption from the Food and Drug Administration to test a device that would allow the paralyzed to control a computer through a neural interface to a computer.[9] The device, Braingate, has been tested in animals, and the company initiated human trials on severely paralyzed patients in 2004.[10] The first subject, a quadriplegic 25-year-old, was successfully implanted with a brain chip that enables him to check e-mail, play computer games, control a television, and turn lights on and off by thought alone.[11] The goals of the NASA *Extension of the Human Senses Group* are to develop brain–computer interface technologies for augmentation purposes.[12] The Defense Advanced Research Projects Agency (DARPA) has allotted $24 million to support research into the proposals of six different laboratories for brain–machine systems.[13] The objective of these projects is to control robots and airplanes through thought alone.

Efforts to decode the information processing system that is the brain were jump started by the discovery of Miguel Nicolelis and John Chapin that electrodes with flexible tips did not damage the brain and that enough information to recognize commands could be produced by decoding only a small number of the neurons in a brain.[14] Recently, in a risky procedure aimed at restoring hearing for two deaf women, a penetrating device was inserted directly into the brain stem.[15] The hippocampus functions to "encode" experiences; it stores new memories, so that memories can be stored elsewhere as long-term memories. The team working on replacing these functions of the hippocampus has copied its *behavior*, rather than waiting to *understand its intricacies*. This shift from trying to map detailed neural function and instead exploit the user's ability to learn is expected to increase the pace of development.

Researchers at Caltech have recently succeeded in using implanted electrodes to detect activity in monkeys' "parietal reach region," where higher-level thoughts such as "get the key and use it" are generated.[16] These results are promising for the development of neural prostheses that would enable users to move mechanical devices with thoughts and monitor "not only patients' goals, what they want to reach for, but also their mood and motivation."[17] Researchers at Washington University, using an implanted brain grid, have found that

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patients can imagine moving and thus control a cursor with thought alone; their goal is to create a brain–machine interface for long-term use.[18]

Therapy/Enhancement

A distinction, the therapy/enhancement distinction, is commonly made between interventions that are therapeutic in their intent, used to treat disease or disability, and interventions to enhance or improve on normal species function or to bestow entirely new capacities, nonhealth related improvements—the therapy/enhancement distinction.[19] This seemingly obvious distinction can be highly problematical, because, in reality, there is no bright line separating therapy and enhancement (how poor does my memory need to be to justify a remedial brain chip?), normal is a difficult concept to specify regarding many human capacities (e.g., moral sensitivity), and within a societal context the norm itself may change (as the average IQ score has been rising, the so-called Flynn effect).[20] Nevertheless, as regards brain chip implants, it seems apparent that there are real distinctions between using the technology for therapy and enhancement.

Used for therapy, implantable brain chips are seemingly noncontroversial, enabling those who are paralyzed or naturally less cognitively endowed to achieve on a more equitable level. The issues that arise with therapeutic use of implanted brain chips primarily involve questions of equity, access, and the costs of implementing this technology. However, these concerns will be complicated by the technology's ability to initiate a constantly changing standard of normalcy. This will be made all the more difficult to restrain, as the derivative of change will be positive—thus providing strong feedback leading to increasingly greater expectations.

More problematical technical, ethical, and social questions are raised by this technology's potential for enhancement and control of humans. Brain implants used to provide vision to the blind are seen as highly desirable devices. Extending their use to provide night vision, X-ray vision, and long-range zoom capacities to the normally sighted raises considerably different issues. Enhancement in and of itself is not necessarily objectionable; vaccines, in vitro fertilization, breast enhancement surgery, and Viagra (used as a recreational agent, rather than to alleviate erectile dysfunction) are all instances of readily accepted and widely sought enhancement technologies. However, brain–machine interfaces will put new forms of stress on privacy, autonomy, and justice, and more importantly, on what it means to be human. Brain–machine interfaces will enable humans to be constantly logged onto the Internet, and this augmented human–system interaction can assist not only those with failing memory, but might even bestow fluency in a new language, enable "recognition" of previously unmet individuals, and provide nearly instantaneous access to encyclopedic databases. It promises to change the capacities of humans to such a degree that they become fundamentally different. Humanity itself, at least those (former) members of *Homo sapiens* who have access to the technology, will be substantially different.

Ethical Issues

The presence of an interface also raises issues of privacy and autonomy. Nonimplanted technologies are already being used to track children and those

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with dementia.[21] At present, chips have been implanted in scores of household pets, and the company, Applied Digital Solutions, originally suggested marketing its chip, the "Guardian Angel," for children and those with dementia.[22] Similarly, the emergence of rising numbers of "security cameras" has provided the ability to track people along the streets of several large urban cities. Software is under development to automatically track individuals using images from these cameras. When similar technologies are implanted, significantly novel difficulties arise. The differences are (1) that once implanted there might never be a time or place when the individual could not be tracked, (2) remote stimulation of the brain could be used to cause behavior that the individual might not even be conscious of, and (3) if there are regions where the individual could not be tracked/controlled, then the individual could be "trained" so that they stay out of such areas. With implantable devices, messages and information could be transmitted to the brain, actions could be initiated by remote control, and information could be transmitted both to and from the brain. Remote control of rats has already been demonstrated,[23] and remote control of humans is presumably equally feasible. Because, when chips are connected directly into a brain, signals from another human or a machine could directly impact the individual, there is the potential for power over the subject. Chips could easily be used as a way to monitor the movements of people and to transmit personal information. As noted earlier, some neural researchers believe that present experiments indicate that patients' moods as well as their motivations could be monitored.[24] Although it is often possible with careful observation (and augmented with physiological monitoring) and interviews to discern a subject's mood and motivations, the ability to do so remotely and potentially on a massive scale fundamentally changes the notions of privacy. One can think of a *direct* "Nielsen" style rating of a politician's speech or interview—where the participants might not be able to say, "No, I don't want to participate."

Brain Chips and Cloning

Among the most complex of the ethical uncertainties is that raised by the prospect of combining brain chips and cloning. Cloning involves the asexual reproduction of genetically identical individuals. If the nuclear DNA from a woman were put into her own egg, the resulting child would be a complete replication of the woman.[25] Presumably, it will become possible in the near future to clone an individual and bring it to birth.

Insofar as the self is identified with a particular body, the clone duplicates the self. Cloning the self would ensure a certain type of immortality—genetic. However, insofar as the self is other than the genetic body, fully replicating the self requires more than biological identity. In 30 years, it may be possible to store the data representing all of a human being's sensory experiences in a storage device implanted in the body. These data could be collected by biological probes receiving electrical impulses and would enable a user to recreate experiences or even to transfer (transplant) memories from one brain to another. Another technique for achieving this goal is to implant a chip behind the eye in order to record all of a person's thoughts, sensations, and experiences. British Telecom's Artificial Life Team is working on this device, called Soul

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Catcher 2025, as it is estimated that it will be ready for use in 2025. Dr. Winter's claim is that "by combining this information with a record of the person's genes, we could recreate a person physically, emotionally and spiritually."[26] In actuality it would probably be necessary to implant multiple chips to capture all the sensory data that is sent to the brain. Gordon Bell of Microsoft's Media Presence Group is recording a lifetime's worth of articles, books, cards, CDs, letters, memos, papers, photos, pictures, presentations, home movies, videotaped lectures, and voice recordings and storing them digitally, along with creating software to selectively replay this information.[27] Under the auspices of the Department of Defense, the Defense Advanced Research Projects Agency (DARPA) proposed, but subsequently ended (probably due to public concerns about privacy) the LifeLog project to create a comprehensive database of an individual human life.[28]

It is an open question whether brain–machine interface technology will in the near future enable uploading our memories to a chip. Some researchers argue that as we develop capacities to scan the brain, research that is ongoing, we will learn to scan the brain in order to download it, thus not even needing to store the raw data as it is generated. It is theoretically possible that we will map the locations and interconnections of neurons and synapses and eventually be able to transfer an analog of the brain and its memory to a digital-analog computer.[29] Indeed Ray Kurzweil claims that, "By the end of this century, I don't think there will be a clear distinction between human and machine."[30] Futurologist Ian Pearson of BT posits that at some point it should be possible to make a "full duplex mind link between man and machine."[31] Thought transmission between humans will then be achievable, backup copies of our brains could be made, and a global network will be part of our consciousness. One result of uploading minds is that immortality would be assured because uploaded minds would not age; in addition such humans could travel at the speed of light, have enhanced memory and knowledge capabilities, and communicate from mind to mind.

In this eventuality, psychological continuity of personal identity could be immortalized in a series of cloned selves, bestowing immortality, and raising anew philosophical questions regarding personal identity. If all that is required for the persistence of personal identity is the sustaining of memory and physical continuity,[32] then the clone with a previous or ongoing individual's memories uploaded to a chip, implanted, and activated would be the same person ongoing in time. Arguments minimizing cloning's effects and claiming that cloning is unlikely to affect a person's sense of self or identity[33] become irrelevant when the clone receives all the memories and experiences of a previous individual. In this case, concerns about the loss of an open future for the clone and the impacts upon autonomy and freedom are warranted. Certainly, the cloned individual's individuality and uniqueness could be overwhelmed to such an extent that the new individual might simply be the ongoing previous individual now experiencing a new history; a clone's independent learning might even be suppressed to facilitate this. The extent to which the clone's identity would be impacted by the implant would depend on the age of implantation and the control exerted over the new memories of the host clone. In considering the question of whether such an implant would produce an extension of the same person or a duplicate, one disquieting

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question is: How many can exist at the same time? If only one, then it would be an extension; if more than one, a duplication. It is, in some real sense, the same person and not the same person, just as I am not the same today as I was yesterday, because things have happened in the meantime and this changes who I am. What the ability to transfer memories does is to enable this evolution of "self" across a much longer time than a single body might normally exist, possibly forever.

A multitude of other questions emerge when contemplating this eventuality. When would the chip be implanted? Or enabled? What would it be like to be an already aware individual with an ongoing history imprisoned in a child's body? Would the cloned, implanted entity feel like a unique person? Who would the clone be? These are similar to questions about brain transplants and personal identity considered in a dialogue between Derek Parfit and Godfrey Vesey in 1974, in which Parfit argued that there "isn't anything more to personal identity than what you call psychological continuity in a one-one case."[34]

The question "What is man?" has no definitive answer. Yet, mind is surely the most salient feature of *Homo sapiens*. Once memories can be transferred from one brain to another or perhaps even several others—even to a computer or other species—questions regarding personal identity, the nature of memory, and the meaning of memory will be even more insistent. Neuroscientists, who hold that the mind is essentially computational, that consciousness is an emergent property of complicated information patterns, are comfortable with the notion of uploading the mind to a chip. For they are essentially materialists or physicalists who posit mind as the result of physical processes and challenge the view of dualists who believe that mind is nonphysical, spiritual. Derek Parfit proposes that "on the Reductionist View, each person's existence just involves the existence of a brain and body, the doing of certain deeds, the thinking of certain thoughts, the occurrence of certain experiences, and so on."[35]

At the moment, human intelligence is superior to that of machines, at least in terms of general intelligence. But, as machines improve, they will successfully compete with humans and, given sufficient time, surpass humans. Several researchers in a variety of articles and books have projected the coming superiority of artificial intelligence.[36] Intelligent machines could then supersede mere humans.

> We are re-evolving artificial minds at ten million times the original speed of human evolution, exponentially growing robot complexity. Currently, a guppylike thousand MIPS and hundreds of megabytes of memory enable our robots to build dense, almost photorealistic 3D maps of their surroundings and navigate intelligently. Within three decades, fourth-generation universal robots with a humanlike 100 million MIPS will be able to abstract and generalize–perhaps replace us.[37]

Based on the speed with which computers are gaining processing power, already existent input/output technologies, and the research potential for understanding the principles of operation of the human brain and copying its workings (either through computational neuroscience or emulating "the scanned brain on a computer by running a fine-grained simulation of its neural network"[38]), artificial intelligence and supersmart robots may well be developed

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with a few decades. Unless humanity embraces cyber technology, its hegemony may eventually yield to intelligent machines. If cybernetic technology is guided to allow the development or evolution of a human that is not merely human, cyborg, the supremacy of humans could be ensured, at least until the time when the machines evolve the next generation without our assistance.[39]

Regulatory Procedures

Because of the enormous potential impact of cybernetics, this area of scientific development must be closely linked to ethical guidelines. Developments in cybernetics should be openly debated with accountability to the public, especially for investment of public funds. Advances that can impact society so intensely require public scrutiny. Procedures should be established for evaluating safety and efficacy and for consideration of the need for equitable distribution of the benefits of this new technology. Some call for outright bans, citing the "precautionary principle" on the development of technologies that have the potential to significantly change human nature. Using language that speaks of hubris, and the "giveness" of humanness, they challenge developments that would threaten the "dignity of the naturally human way of activity."[40] George J. Annas, in proposing the "human species protection treaty," has recommended that human/machine cyborgs be banned along with cloning, genetic engineering, and artificial organs.[41] Scientific progress promises to fulfill our desire for improvement; banning that progress is unrealistic and probably futile. In liberal democracies, the actions of persons are generally not interfered with unless they cause harm to others and, in very limited cases, to self. But between the options of unfettered freedom and outright prohibition lies the province of regulation.

Now is the time to consider whether and, if so, how to regulate, rather than ban, the enhancement uses of this technology. Presently, before a medical device can be marketed in the United States it must meet the requirements of the Food and Drug Administration. Implantable brain chips would be listed as Class III devices *because* they are implanted and may present a potential risk of illness or injury. Clinical trials will be used to establish the efficacy of the device and its safety. As with the development of the Activa Dystonia Therapy System, which was approved in April of 2003 for treatment of a movement disorder, the expedited development of therapeutic uses of brain implants may proceed under a humanitarian device exemption process. The development of brain implant technology in the United States is, then, already subject to a layer of governmental scrutiny. Whether this scrutiny is adequate to the task of reviewing brain implants is questionable; even required postmarket safety reviews of devices are rarely done.[42] Moreover, the focus of FDA review is the establishment of indications for use, methods of safe placement, risks to subjects of surgery and anesthesia, and compilation of adverse events, particularly for those requiring device removals. No system exists for consideration of the extraordinary social and policy questions raised by these devices when used for enhancement. This level of scrutiny should be added and considered the equivalent of an environmental impact statement.

Such deliberation is all the more significant because implantable brain chips can be a *positive* and transformative step in the evolution of human. The

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differences in the kinds of humans this future will create need national and international consideration. Although the United States often approaches new technological developments from within an optimistic, ameliorist framework that privileges capitalist innovation and scientific freedom, many areas with social impact are regulated. Unfettered and unregulated scientific activity is a myth; existing regulations govern research on humans, on active infectious agents such as smallpox and Ebola, encryption software, and even research on marijuana.[43] Nations can and should deliberate and pass laws governing technology. The history of the guidelines formulated for recombinant DNA research in the United States suggests possible avenues for regulation and the usefulness of creating a parallel system to the human subjects review process.

Controls need to be pursued on the national and international levels, with self-regulation by the scientific community leading the way. Self-regulation by those involved in brain implant technology should be pursued, in much the way that the Asilomar meeting created guidelines for recombinant DNA research.[44] The Asilomar meeting resulted in a moratorium, one possible method for ensuring that deliberation occurs before innovation. In the present case, development of enhanced humans through brain implants, there is adequate time to formulate guidelines without the use of a moratorium, if the proper forums for reflection can be created or accessed; however, this window will close more rapidly than is the case for strictly biological developments. In the United States, reestablishment of an Office of Technology Assessment would facilitate legislative examination of the complex issues surrounding brain implants. Other committees, such as those at the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine, could conceivably investigate the safety, social, and political implications of cybernetic technologies, but a nonpartisan agency serving in an advisory role to Congress has much to recommend it. Such an agency could commission an analysis of this future technology and provide forums for discussion of its possibilities and perils. Some mechanism such as that used to regulate recombinant DNA research, including the establishment of research guidelines, the holding of public hearings, and the formation of an agency to review protocols is required.[45] Recommending and establishing standards to regulate the enhancement possibilities of cybernetic technology to ensure safety, efficacy, privacy, consent, and justice should not prove as difficult as attempts to regulate reproductive technologies, which entail more deeply held value conflicts.

However, inasmuch as the complexity of enhancement techniques makes providing general policy challenging, a new regulatory body needs to be created to deal with the myriad of knotty issues. Such an agency could provide for a public review process at the national level to facilitate the consideration of risk and benefit. In regard to brain implants, issues of safety, privacy and autonomy, and the societal and transformative effects of uploading memories and implanting in third parties are all concerns that need extensive consideration.

Principles and Standards for Adoption

A discussion of standards for enhancement technologies and drugs is long overdue. A principle, which needs to be considered for possible adoption, is that the risk/benefit ratio applied in evaluating the safety and effectiveness of

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enhancement techniques should be *higher* than that required for therapeutic interventions. Criterion for the use of this technology in the normal individual for purposes of enhancement should be placed at a higher level than the norms for review of devices to heal the sick. Thus, concerns about risks of infection and brain damage are more pressing when the individual is healthy. In the deliberations concerning brain chips, this safety assessment will be complicated by the fact that researchers have demonstrated that, for the monkeys that have been trained to control robot arms, the brain itself actually changes, with more neurons emerging so that "the brain is assimilating the robot. It's creating a representation of it in different areas of the motor cortex."[46] Presumably, human brains will be similarly plastic and change through using an interface. This also raises the issue of removing the device—or even if removing it will revert the patient to the state before the device was implanted (see next paragraph). A safety issue with even wider implications involves achieving control over remembering. Forgetting seems to provide benefits, and brain implant technology will need to be studied for its effects on our ability to deal with a painful past. Another area requiring study will be the effect that constant connection to others would have on our attention abilities and on our needs for isolation.[47]

Likely and reasonable initial standards would ensure that enhancement uses of interface technology include provisions for (1) reversibility in the event of adverse events, (2) informed consent, and (3) limited access for initial studies. The requirement of reversibility would guarantee that if unforeseen risks develop there is a possibility of avoiding permanent problems; it is not altogether clear that superior, even perfect memory, would be a good, nor is high intelligence always beneficial. The requirement of informed consent would restrict usage, for enhancement, to adults with decisional capacity. This provision would eliminate the risks that a clone could be precluded by brain chip implantation in early childhood from the development of personal individuality. Utilizing these principles and initially restricting implantation to a small and controlled group would secure time for evaluation of these technologies before widespread implementation. These requirements, although they may serve to secure the safety and autonomy of individuals, are insufficient to deal with more encompassing concerns, which include the relationship between these superhumans and the inferior species that is unenhanced. Nations and world societies have a stake in assessing the costs to society as a whole from the introduction of novel technologies. Fukuyama's concerns about a "future world in which . . . human homogeneity splinters . . . into competing human biological kinds,"[48] although addressed to genetic technologies, is applicable also to brain–machine interfaces and raises the prospect of diminishing tolerance and democracy.

Nor are such national laws and regulation sufficient to effectively monitor and control technologies that will cross national boundaries. It is necessary and should be possible to create international regulatory bodies for biotechnology developments. As Amitai Etzioni has pointed out, many transnational authorities and structures already exist—the World Trade Organization, the Bank for International Settlements, the World Health Organization's new powers after SARS, and agreements on biodiversity and pollution.[49] The legitimacy of such endeavors relies on the agreements of established governments and is often

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associated with the United Nations. International documents, such as the Universal Declaration on Human Genome and Human Rights (UNESCO) (1997) and the World Medical Association's Resolution on Cloning (1997) have begun the task of addressing enhancement issues, and demonstrate an emerging willingness to regulate biomedical technologies globally.

The scenario envisioned in this paper's analysis where a clone is created and implanted with a brain chip containing all of a previous individual's thoughts and memories could be effectively regulated by national and international bans on human reproductive cloning. However, the effort to pass effective legislation does not appear promising. Presently in the United States, although there appears to be a scientific self-imposed ban and there is a ban on government-funded projects, there is no law outlawing human cloning. Of the 193 countries in the world, 26 have passed laws or moratoriums or have implicitly banned human cloning to replicate an individual.[50] The effort to pass a worldwide ban on human reproductive cloning through an international treaty under the auspices of the United Nations was abandoned in November 2004.[51] Nevertheless, the United Nations is proposing a recommendation that each country pass laws banning human reproductive cloning. In this, as in any efforts to regulate brain machine interfaces, the covenants of the United Nations lack any effective mechanism for enforcement; the system of international law is voluntarist and depends on the consent of each state. Despite this, the United Nations should take the lead in deliberation and policy recommendations concerning brain–machine interfaces. On this issue, although the concerns are real and significant, the international stakes are not so high as to preclude agreement and international regulation.

The efforts to regulate this technology should begin and begin soon.

Notes

1. McGee EM, Maguire GQ. Implantable brain chip? Time for debate. *Hastings Center Report* 1999;29(1):7–13.
2. Ditlea S. Cyborgs of New York. *The Daily News* 2004 Jun 8:1.
3. Vince G. Brain "Pacemaker" has long-term effects on depression. *New Scientist* 2001;10(5). Available from: http://www.newscientist.com/article.ns?id=1665. Accessed January 29, 2005.
4. Study of an implantable functional neuromuscular stimulation system for patients with spinal cord injuries. ClinicalTrials.gov Available from: http://www.clinicaltrials.gov/ct/show/NCT00004445. Accessed January 29, 2005.
5. Headlam B. The mind that moves objects. *The New York Times Magazine* 2000 Jun 11:63–4.
6. Artificial vision system for the blind announced by the Dobelle Institute. Press Release. *Science Daily* http://www.sciencedaily.com/releases\2000\01\000118065202.htm. Accessed January 15, 2001.
7. Port O. Artificial eyes, turbine hearts. *Business Week Online*, March 20, 2000. Available at: http://www.businessweek.com/2000/00_12/b3673025.htm. Accessed March 5, 2007.
8. Lemonick M. Robo-monkey's reward. *Time* 2003 October 27:45–7.
9. Barker A. Approval sought to test brain implant [in humans]. Available at: http://www.bio.net/bionet/mm/neur-sci/2003-November/055874.html. Accessed March 5, 2007.
10. Cyberkinetics. Available at: http://www.cyberkineticsinc.com/content/index.jsp. Accessed May 29, 2005.
11. Hooper S. Brain chip offers hope for paralyzed. Available at: http://www.cnn.com/2004/TECH/10/20/explorers.braingate. Accessed January 4, 2005.
12. Extension of the human senses group. Available at: http://ic.arc.nasa.gov/projects/ne/ehs.html. Accessed February 10, 2004.

https://doi.org/10.1017/S0963180107070326 Published online by Cambridge University Press

13. Zimmer C. Mind over machine. *Popular Science* 2004;Feb. Available at: http://www.popsci.com/popsci/medicine/59b5c4522fa84010vgnvcm1000004eecbccdrcrd/4.html. Accessed March 5, 2007.
14. See note 13, Zimmer 2004.
15. Graham-Rowe D. The first brain prosthesis—an artificial hippocampus—is in development. *New Scientist* 2003;19, Mar 12. Available at: http://www.newscientist.com/article.ns?id=dn3488. Accessed May 2004.
16. Graham-Rowe D. Brain implants "read" monkey minds. *New Scientist* 2004 Jul 8. Available at: http://www.newscientist.com/article.ns?id=dn6127. Accessed August 10, 2004.
17. Begley S. Prosthetics operated by brain activity move closer to reality. *The Wall Street Journal Science Journal* 2004 Jul 9:B1.
18. Fitzpatrick T. Human subjects play mind games. Available at: http://news-info.wustl.edu/tips/page/normal/911.html. Accessed March 5, 2007.
19. Parens E. Is better always good? The enhancement project. In: Parens E, ed. *Enhancing Human Traits: Ethical and Social Implications*. Washington, DC: Georgetown University Press; 1998:1–28.
20. Flynn Effect. In: *Wikipedia, the free encyclopedia*. Available at: http://en.wikipedia.org/wiki/Flynn_effect. Accessed April 17, 2005.
21. GPS personal locator for children. Available at http://www.childlocator.com. Accessed March 5, 2007.
22. Digital Angel Corporation. Available at: http://www.digitalangelcorp.com. Accessed on March 5, 2007; Singer G. Study to look at planting identification chips in dementia patients. *South Florida Sun-Sentinel* February 23, 2007, http://www.sun-sentinel.com/business/local/sfl-zchip23feb23,0,139269.story?coll=sfla-business-headlines. Accessed March 5, 2007.
23. Chapin JK, Moxon KA, Markowitz RS, Nicolelis MAL. Real-time control of a robot arm using simultaneously recorded neurons in the motor cortex. *Nature Neuroscience* 1999;2:664–70.
24. See note 17, Begley 2004:B1.
25. Elliot D. Uniqueness, individuality, and human cloning. *Journal of Applied Philosophy* 1998;15(3):218.
26. This'll chip away at the cost of storage for personal archives, but the arrangement and description could be a bit time-consuming. Archives Society of Alberta 1996;16(2). Available at: www.archivesalberta.org/vol16_2/brain.htm. Accessed January 7, 2005.
27. Gemmel J, Bell G, Lueder R, Drucker S, Wong C. My life bits: Fulfilling the memex vision. Microsoft Research. Available at: http://research.microsoft.com/~jgemmell/pubs/MyLifeBitsMM02.pdf. Accessed January 7, 2005.
28. Schachtman N. Pentagon kills lifelog project. *Wired News* Feb 4, 2004. Available at: http://www.wired.com/news/privacy/0,1848,62158,00.html. Accessed March 5, 2007.
29. Kurzweil R. The coming merging of mind and machine. In: Fritz S, ed. *Understanding Artificial Intelligence*. New York: Warner Books; 2002:90–9.
30. McCullag D, Kurzweil R. Rooting for the machine. *Wired News* 2000 Nov 3. Available at: http://www.wired.com/news/technology/0,1282,39967,00.html. Accessed January 31, 2005.
31. Pearson I. The future of human evolution. Available at: www.bt.com/sphere/insights/pearson/human_evolution.htm. Accessed January 28, 2005.
32. Olson ET. Personal identity. In: Zalta EN, ed. *The Stanford Encyclopedia of Philosophy* (Fall 2002 ed.), Available at: http://plato.stanford.edu/archives/fall2002/entries/identity-personal/. Accessed April 17, 2005.
33. Brock DW. Human cloning and our sense of self. *Science* 2002;296:314–7.
34. Parfit D, Vesey G. Brain transplants and personal identity: A dialogue. In: Burr J, Goldinger M, eds., *Philosophy and Contemporary Issues*, 8th ed. Upper Saddle River, NJ: Prentice Hall; 2000:440.
35. Parfit D. *Reasons and Persons*. Oxford: Oxford University Press; 1986:211.
36. Bostrom N. When machines outsmart humans. *Futures* 2000;35–7:759–64. Available at: http://www.nickbostrom.com. Accessed March 6, 2007; Kurzweil, R. *The Age of Intelligent Machines*. Cambridge, MA: MIT Press; 1990.
37. Moravec R. Robots, Re-Evolving Mind. Kurzweil AI net. Available at: http://www.kurzweilai.net/meme/frame.html?main=/articles/art0145.html?m%3D3. Accessed March 5, 2007.
38. See note 36, Bostrom 2000.
39. See note 29, Kurzweil 2002:99.
40. Kass L. *Beyond Therapy: Biotechnology and the Pursuit of Happiness*. New York: Regan Books; 2003:292.
41. Annas GJ. The man on the moon, immortality and other millennial myths: The prospects and perils of genetic engineering. *Emory Law Journal* 2000;49(3):778–80.

https://doi.org/10.1017/S0963180107070326 Published online by Cambridge University Press

42. Kerber R, Globe Staff. 22% of medical device follow-up studies left undone. *The Boston Globe* 2004 Dec. 24.
43. Regulations do not do away with violations any more than laws against murder eliminate murder.
44. Barinaga M. Asilomar revisited: Lessons for today? *Science* 2003;287(5458):1584–5. Available at: http://www.biotech-info.net/asilomar_revisited.html. Accessed February 3, 2005.
45. Fredrickson DS. *The Recombinant DNA Controversy: A Memoir*. Washington, DC: American Society for Microbiology Press; 2001.
46. See note 13, Zimmer 2004.
47. Dertougos M. Brain implants: A lousy idea. *Technology Review* Jul–Aug 1999;102(4).
48. Fukuyama F. Sensible restrictions, Reasononline. 2002. Available at: http://reason.com/debate/eh-debate 031902.shtml. Accessed August 10, 2004.
49. Etzioni A. *From Empire to Community. A New Approach to International Relations*. New York: Palgrave Macmillan; 2004.
50. Policies on Human Reproductive Cloning and Germline Genetic Engineering. Available at: www.glphr.org/genetic/genetic.htm. Accessed February 6, 2005.
51. Pearson H. UN ditches cloning ban. news@nature.com. 2004. Available at: http://www.nature.com/news/2004/041122/pf/041122-2_pf.html. Accessed February 5, 2005.

https://doi.org/10.1017/S0963180107070326 Published online by Cambridge University Press