# Prosthetics

*Philip Brey*

This is a preprint version of the following article:

Brey, P. (2005). Prosthetics. In C. Mitcham (Ed.), *MacMillan Encyclopedia of Science, Technology and Ethics* (pp. 1527-1532). MacMillan Press.

## 1. Introduction: prosthetics, prostheses and biomedical engineering

In a narrow sense, prosthetics is a branch of medicine, specifically of surgery, concerned with the replacement of missing body parts (upper and lower limbs, and parts thereof) after amputation. It is related to orthotics, which is a branch of medicine that deals with the support of weak or ineffective joints or muscles using supportive braces and splints. In dentistry, prostetics or prosthodontics is that branch concerned with the replacement of missing teeth and other oral structures. In this narrow sense, a prosthesis is a replacement artificial limb or tooth.

In a broader sense, 'prosthesis' is the name for any artifact that is used to restore bodily functions, and 'prosthetics' is the name of a field concerned with the development and fitting of artificial body parts. It is this sense that shall be used in this entry. Prostheses in this broader sense are an important focus of the relatively new field of bioengineering, or biomedical engineering, which is a branch of engineering concerned with the application of engineering techniques to medicine and the biomedical sciences. Bioengineering is a very broad field, with applications ranging from molecular imaging tools to medical radiation devices. The development of prosthetic techniques and devices is only one of its interests.

Several areas in bioengineering have special relevance to prosthetics. Rehabilitation engineering is an area concerned with the application of engineering science to ameliorate the handicaps of individuals with disabilities. It includes prosthetics and orthotics as defined at the beginning of this entry, but also addresses other disabilities, specifically sensory and speech impairments. It does not address functional impairments in internal organs, however. Other relevant areas include tissue engineering, which involves the repair or replacement of organic cells, tissues, or organs with laboratory-grown biological substitutes; biomaterials engineering, which aims at the development of synthetic or natural materials that can replace or augment tissues, organs or body functions; biomechanics, which studies the human musculoskeletal system and its mechanical aspects and includes artificial limb and joint design; cardiovascular engineering, which studies the cardiovascular and blood system and develops techniques and systems for diagnosis, intervention, therapy and replacement, and neural engineering, which studies the nervous system and develops means to repair or replace damaged and nonfunctioning nerves and sensory systems. Neuroprosthetics is a rapidly growing subfield of neural engineering that aims to develop devices or systems that communicate with nerves to restore functionality of the nervous system.

Although research in prosthetics and bioengineering is primarily aimed at restoring damaged human functions, there has been a growing interest in the augmentation of human functions. Human augmentation is a relatively new field in bioengineering directed at developing prosthetic devices that augment normal function, prevent injury to function or rehabilitate injured function.

Bioengineering is, together with artificial intelligence and robotics, the successor of the now-outdated field of bionics (a conflation of "biological electronics"), which was a field that emerged in the 1950s with the aim to use biological design principles to create novel technological devices and to create mechanical substitutes for the extension of biological organs. Bionics was -and is- specifically concerned with the development of bionic devices or bionic implants, which are electromechanical devices that do not merely replace a body part but that closely mimic or surpass the behavior of a replaced organ, and that are often able to communicate with the nervous system. To attain its aims, bionics relied on a feedback-control framework that was provided by cybernetics, the science of communication and control in animal and machine. Cybernetics has been partially superseded by systems theory, a field that studies the general principles underlying the organization of systems of any kind. Cybernetics has yielded the term cyborg, a conflation of 'cybernetic organism,' meaning an organism that is part human, part machine. A cyborg is an individual whose biological functions are aided or controlled by technological devices, particularly by bionic implants.

Currently, a large number of human biological functions can already be restored or improved with the aid of prostheses. Implants and devices that were in use as of 2004 include: artificial limbs, including robotic ones and ones with sensory feedback to the body; artificial muscles made of polymer; artificial skin used to promote healing; artificial joints, hips and vertebrae; artificial bone used to help heal fractures and replace diseased bone; dental implants and false teeth; bracing systems, cervical implants and spinal cages to support the spine; silicone or plastic implants to build bony structures of the face; speech synthesizers and artificial larynxes to restore speech; artificial blood vessels and urological systems; artificial blood (experimental); retinal implants (experimental), intraocular lenses and artificial corneae to restore vision; cochlear implants that replace the inner ear and involve a microphone, speech processor and wiring to the nervous system; artificial nerves (experimental); electrodes implanted in the brain to control seizures or tremor; breast implants; penile implants; orgasmatrons (implants for women that produce orgasms; experimental); cardiac pacemakers, defibrillators, artificial heart valves and heart-assist pumps; artificial hearts (experimental); implanted chips to locate persons or to regulate devices in "intelligent environments"; implanted drug delivery systems (experimental); spinal neuro-implants with handheld remote control to block pain signals; motor neural prostheses based on Functional Electrical Stimulation techniques that stimulate motor nerves for movement, respiration and bladder function; and artificial hippocampi (experimental). Research is underway on bioartificial livers, kidneys, pancreases, lungs, and other organs, as well as on more advanced neural prostheses to restore functions of the brain and nervous system.

## 3. Philosophical and anthropological theories of prostheses and cyborgs

Most philosophical and anthropological theories that refer to the notion of prosthesis are not so much concerned with an understanding of prosthetic technologies as normally defined but with an understanding of technology in general by means of the concept of prosthesis. The notion of prosthesis is then used as a metaphor to understand technology and its relation to human beings. In such prosthetic theories of technology, which have been proposed since at least the late 19th century by a variety of different authors, it is claimed that there is no essential distinction between prosthetic technologies and other technologies, since all technologies in some way aim to replace or augment aspects of human functioning. This view has been proposed, amongst others, by and Marshall McLuhan, Henri Bergson, Arnold Gehlen, Ernst Kapp and Lewis Mumford.

According to the prosthetic view of technology, every technological artifact or system extends the the human organism in that it serve to continue abilities of human faculties beyond the body, in this way amplifying already present abilities of the body. The body is itself a toolbox that its owner uses to do things in the world. Technical artifacts serve to replace, extend or augment tools in this organic toolbox. Weapons and tools like bows, knives and saws are extensions of human hands, nails, and teeth, clothing extends the functions of the skin of bodily heat control and protection, the wheel extends the mobility functions of the legs, bags extend the ability of the hands and arms to carry things, the radio and telephone extend hearing, television and photography extend the visual function, writing and print media extend human language and memory functions, and the computer extends a large variety of human cognitive functions. Prosthesis, in the narrow sense, is therefore only an instance of the general ability of technology to extend or replace functions of the human organism, and all technologies should be understood in terms of their relation to human functioning.

Even if this view is correct, it is recognized by many authors that all artifacts do not extend the human organism in the same way. Some technological artifacts have a more symbiotic relation to the body, whereas others function more independently. A relevant distinction seems to exist between artifacts that serve as direct extensions of human functioning by engaging in a symbiotic relationship with human limbs, senses or other body parts, like telescopes, glasses, hammers and canes, and those artifacts that operate separately from the body and are themselves the object of interaction or perception, like dinner plates, stereo systems and computer screens.

Philosophers Don Ihde and Maurice Merleau-Ponty have claimed that humans are able to engage in embodiment relations with artifacts, in which they are made part of the body schema or body image, meaning that they are integrated with the image that human beings have of their own sensorimotor abilities, an image that defines them as agents and separates them from a world that is to be engaged. This view has found support in psychological studies of body schemas.

Recent years have seen the emergence of cyborg theory, or cyborgology, being the multidisciplinary study of cyborgs and their representation in popular culture (see CYBORG). Studies in cyborg theory tend to use the notion of the cyborg as a metaphor to understand aspects of contemporary - late modern or postmodern - society's relationship to technology, as well as to the human body and the self. In cyborg theory, the notion of cyborg refers to hybrid organisms in science fiction (e.g., The Six Million Dollar Man, Robocop, X-Men, Star Trek's The Borg), contemporary human beings with prostheses or implants, as well as to (contemporary) human beings in general, which are all thought to be cyborgs in the sense of being inherently dependent on technology, as also emphasized in prosthetic theories of technology.

The advance of cyborg theory as an area of academic interest has been credited to Donna Haraway, in particular to her 1985 "Manifesto for Cyborgs". In this essay, Haraway presents the cyborg as a hybrid organism that disrupts essentialist presuppositions of modernist thinking, with its black-and-white dichotomies like nature-culture, human-animal, organism-technology, man-woman, physical-nonphysical and fact-fiction. Cyborgs have no pre-existing nature or stable identity, and cut through modernist oppositions because of their thoroughly hybrid nature. Haraway holds that the modern era ('modernity') is characterized by essentialism and binary ways of thinking that have the political effect of trapping beings into supposedly fixed identities and oppressing those beings (animals, women, blacks, etc.) who are on the wrong, inferior side of a binary opposition. She believes that the hybridization of humans and human societies, through the notion of the cyborg, can free those who are oppressed through modernistic thinking by blurring boundaries and constructing hybrid identities that are less vulnerable to the trappings of modernistic thinking.

Haraway believes, along with many other authors in cyborg theory like Katherine Hayles and Chris Hables Gray, that this hybridization is already occurring on a large scale. This hybridization is a consequence of the transition since the Second World War from an industrial to an information society, as a result of technological advances in biotechnology, information technology and cybernetics. In the new world order that is ensuing, boundaries are constantly being blurred, and our linguistic categories and symbols increasingly reflect this fact. Many of our most basic concepts even, such as those of human nature, the body, consciousness and reality, are shifting and taking on new, hybrid, informationalized meanings. In this postmodern, posthuman age, power relations take on new forms, and new forms of freedom and resistance are made possible.

Sharing the positive outlook of cyborg theorists on the technological transformation of human nature, but otherwise quite distinct from it both politically and philosophically, transhumanism is a recent school of thought or movement that advocates the progressive transformation of the human condition through technological means. Its early inspirational source was FM-2030 (formerly, F. M. Esfandiary), a futurist who wrote on the notion of the transhuman in the early 1970s, and its current main organizing body is the World Transhumanist Association, co-founded in 1998 by Nick Bostrom and David Pearce. Transhumanists want to move beyond humanism, which they commend for many of its values like its orientation on reason and science, its commitment to and belief in progress, and its rejection of faith and worship, but which they fault for its belief in a fixed human nature. Transhumanists want to use modern technology to alter human nature in order to augment human bodily and cognitive abilities and extend human life. They envision that converging developments in genetic engineering, biomedical engineering, artificial intelligence, nanotechnology and cognitive science will make such extensions of human nature possible, thus leading humanity to a transhuman or posthuman condition. They argue that this development should receive full support, because of its potential to enhance human autonomy and happiness and eliminate suffering and pain, and possibly even death.

## 4. Ethical issues

The research, development, application and use of prostheses and implants raises a number of ethical issues, relating to health and safety, distributive justice, identity, privacy, autonomy, and accountability. Special ethical issues are raised by human augmentation research.

*Health and safety*. The functioning of a prosthesis for the remainder of someone's life cannot be predicted reliably on the basis of a couple of clinical trials with human subjects or a few tests with animals. There is a real risk, therefore, that people will be fitted with prostheses or implants that malfunction, have harmful side-effects, or are even rejected by the body's autoimmune system. Negative experiences with silicone breast implants and artificial hearts have already shown the body's resistance to technological interventions. Ideally, prostheses would be tested over many years, decades even, and involve a large number of human subjects. But such extensive clinical trials and experimental uses are often considered too lengthy and costly and raise ethical issues by making guinea pigs out of human beings. Tests on animals often cannot serve as a substitute, and also raise ethical issues of their own.

*Justice*. The development of increasingly sophisticated prostheses and implants raises issues of distributive justice: will there be a division between biological haves and have nots? Will there be a division between those who receive no prosthesis or a low-quality or high-risk one and those who receive the best medical care? Do people have a moral right to a replacement part for a malfunctioning organ, when such parts exist? And will all be able to obtain implants that are attuned to their biological characteristics and their lifestyle? In a 2003 incident in the United Kingdom, a black woman with an amputated foot was told that she would have to be fitted with a white prosthetic limb unless she paid an additional 3000 British pounds for a black one. Although this is a clear instance of discrimination, the situation is not always this clear. Who, for example, should pay the extra costs when a person has mild allergic reactions to a prosthesis and demands a much more expensive version that will not cause such reactions? Do developers have a duty to develop special prostheses for people whose biological features do not fit the norm, and can they charge extra for those?

*Identity*. Acquiring a prosthesis requires people to come to terms with the fact that a part of their body is artificial, and that they are dependent on a piece of technology for their biological functioning. This may be even more of an issue with bionic and neuroprosthetic implants, which may display or induce behaviors only partially controlled by us that one may find it hard to identify with. Even more so, cognitive prostheses, which are neuroprostheses that aid cognitive function, may be developed in the future, and these may undermine identity even more directly as they directly interface with the mind. Some critics of prostheses have argued for the integrity of the human body, with all its defects and flaws, and worry that as we increasingly become cyborgs, the essence of our humanity will be lost. Social identity may be at issue as well; a particular controversy has arisen over cochlear implants, against which deaf advocates have argued that they may place children in between the deaf world and the hearing world, and that they may end up destroying the deaf community with its rich history and culture.

*Privacy*. Privacy issues are at stake when implants process or store information or emit identifying signals that can be registered from a distance. Implantable chips for tracking, already common in pets and livestock, are also being considered for children and adults, and make it possible to trace individuals over long distances. Sensory and neuroprosthetic devices and prostheses equipped with biosensors process and sometimes store information about people's biological states, behaviors and perceptions that may be accessed by third parties.

*Autonomy*. Prostheses can clearly enhance individual autonomy by restoring functions, but it has been argued that they can also reduce it. Having a prosthesis means being intrinsically dependent on technology. A prosthesis may also create dependence on others for maintenance, diagnosis and testing. Bionic and neuroprosthetic implants may not even leave their wearer in complete control of their actions or even thoughts.

*Accountability*. Bionic and neuroprosthetic implants may raise issues of accountability, because the behavior or cognitive processes of their wearers will be determined in part by the workings of machines. If such individuals cause accidents or make bad decisions, who is to blame: they or their implants?

*Ethical aspects of human augmentation*. The field of human augmentation raises a number of special ethical issues in addition to the ones already mentioned. Is it ever morally permissible to destroy or impair healthy human tissue or organs to fit an augmentation, considering that this destruction may be irreversible? Can an employer require an employee to have enhanced functions, or put a premium on the possession of such functions? Part of the debate on human augmentation has focused on military applications, specifically the possibility of creating super-soldiers. Should military research be devoted to the creation of a super-soldier, involving implants, steroids, amphetamines, genetically altered muscles, integrated weaponry and lightning-fast artificial nerves? If certain augmentations get very popular, there is also a risk that they will become accepted as the norm, and people without one will be seen as cripples.

*Conclusion*

Many parts of the human body can already be replaced by prosthetic devices, and revolutionary developments in bioengineering are rapidly expanding the reach or prosthetics. Biomedical engineers and medical specialists have a special, professional responsibility in dealing with the ethical issues that arise as a result, as they are primarily responsible for the development and fitting of prostheses. Many ethical issues also need to be addressed at the level of legislation and public policy. Special moral concerns are raised in the areas of human augmentation and neuroprosthetics.

**Related Topics: Androids; Bioengineering Ethics; Cyborgs**

## References


Brey, P. (2000). 'Technology as Extension of Human Faculties,' In C. Mitcham, ed., *Metaphysics, Epistemology, and Technology. Research in Philosophy and Technology, vol 19*. London: Elsevier/JAI Press.

Gray, C. H. (ed.) (1995). *The Cyborg Handbook*. New York and London: Routledge.
Moor, J. (2004). "Should We Become Cyborgs?" In R. Cavalier, ed., *The Impact of the Internet on Our Moral Lives*. Albany, NY: State University of New York Press.