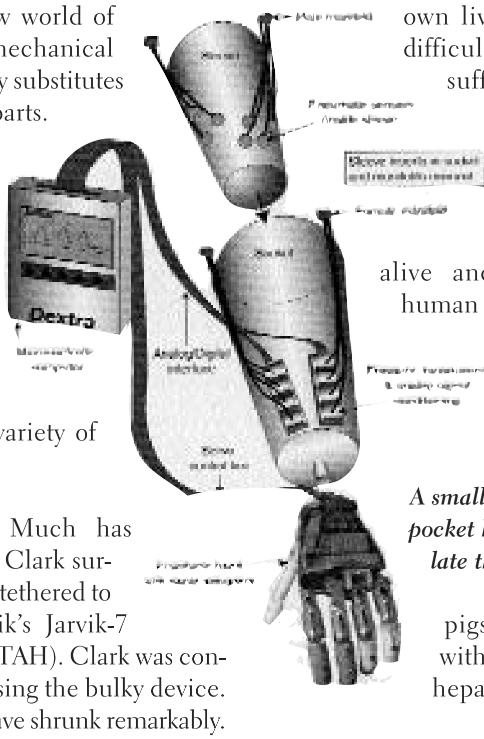
Replacement Parts

A Survey of Recent Articles

"We can rebuild him. We have the technology. We have the capability to make the world's first bionic man. Better than he was before. Better, stronger, faster." The mantra of television's old *Six Million Dollar Man* series voices the long-held dream to replace failed human parts with mechanical or bioengineered devices. Aside from some ingenious prosthetic devices, such as artificial limbs, the reality has fallen short of the dream. But that may be about to change. Spurred by a steadily aging population—and a scarcity of donor organs for transplants—medical science is exploring a brave new world of bionics in which mechanical devices are not the only substitutes for failed human parts. Controversial stem cell research figures in some, but not all, of this work. Seventeen articles on the new research in *Science* (Feb. 8, 2002) reveal a tantalizing mix of achievement, promise, and frustration on a variety of fronts:



A small computer that fits in the pocket helps the user to manipulate the Dextra artificial hand.

Artificial organs. Much has changed since Barney Clark survived 112 days in 1982 tethered to inventor Robert Jarvik's Jarvik-7 Total Artificial Heart (TAH). Clark was confined to the room housing the bulky device. Today's TAH devices have shrunk remarkably. The need for them is tremendous. Two thousand patients per year with end-stage heart failure get transplants, yet an additional 30,000 to 100,000 could benefit from them. Jarvik himself is among those pursuing alternatives, such as the Ventrical Assist Device, designed to ease the pumping strain on a patient's heart while giving it a chance to heal itself. "Removing the natural heart is an obsolete approach," Jarvik says. He is developing a thumb-sized device that can be sewn into (and eventually removed from) the left ventricle.

Other organs, such as the liver, are even more problematic. As Alastair Strain and James Neuberger, both affiliated with the medical school at Britain's University of Birmingham, point out, "many patients with acute liver failure die while waiting for a transplant, and those with chronic disease often deteriorate so much that their survival rate after transplantation is low." A viable bioartificial liver could prolong the lives of patients awaiting donor organs or, in some cases, allow the patient's own liver to regenerate. The difficulty comes in securing a sufficient supply of hepatocytes, the liver cells responsible for most critical liver functions, and keeping them alive and viable outside the human body. The most promising recent research involves using "hepatocytes from other species, particularly pigs," possibly combined with genetically engineered hepatic cell lines.

Restoring lost senses. Pop music icon Stevie Wonder made headlines in 1999 when he declared that, thanks to research being done at Johns Hopkins University on artificial retinas, he might one day be able to see. He was referring to the type of work engaged in by ophthalmologist Mark Humayun, developer of an artificial retina—essentially a silicon chip laced with photovoltaic light sensors. "It's basically just hype," says Alan Chow, at the Chicago-based

Optobionics Corporation, who has the only clinical trial of an implanted retinal device under way. Wonder, who became blind shortly after birth, likely has substantial damage to his retinas and would not be a good candidate for the experimental devices. People who are losing vision because of hereditary degenerative diseases or because of macular degeneration, a common age-related disease, are better candidates. Researchers are exploring several promising devices, including one that converts light into electrical signals. But they still must clear the substantial hurdle of having the brain interpret those electrical impulses into an image. When will that breakthrough come? Says one researcher, "That's like someone asking us when will we arrive at the moon when we've just begun to build a rocket."

Similar struggles beset attempts to counteract profound deafness. While listening aids allow many hearing-impaired people to function in daily life, many others cannot be helped. One option, at least for those with an intact auditory nerve, is the cochlear implant, an array of microelectrodes that directly stimulate the auditory nerve. Some 40,000 people worldwide can converse on the telephone with the aid of such devices, and younger recipients can participate in mainstream education. For those without an intact auditory nerve, the situation is much more complex. Researchers are trying to develop electronic brain-stem implants that will allow sound impulses to bypass the nonworking sections of the ear. This is much like replacing a retina: The challenge is finding a way to create signals the brain can interpret. The implants have already been used on animal subjects, with the first human trials set for later this year. They may significantly improve speech recognition, but even if the trials fail they may still yield valuable clues as to how profoundly deaf persons might retrain their brains to utilize these new devices.

Restoring mobility. Linking man and machine is a staple of science fiction, from *Robocop* to *Star Trek*'s Borg, but "limb replacement as depicted by Hollywood will likely remain a fantasy," says William Craelius, a biomedical engineer at Rutgers University. The National Aeronautics and Space Administration has developed a robotic hand capable of moving 22 joints independently, but building a mechanical hand that can be attached and controlled by humans has been an elusive challenge. That may be changing. The Dextra prosthetic hand, for instance, uses a small computer (that fits in the user's pocket) to register neural signals passing from the muscles into a special sleeve. Responding to these impulses, the hand can flex and extend all five digits. Miniaturization of such devices could allow much of this technology to be permanently attached, with computer components implanted beneath the skin. One hurdle: protecting the implanted components from corrosion by the body's fluids and ensuring long-term functionality. Kevin Warwick, a cybernetics professor at Britain's University of Reading, recently turned himself into an experimental cyborg, connecting nerves in his arm to wires leading to a small microprocessor. The nerve impulses generated by his movements will be transmitted to a remote computer. Warwick's wife will soon be fitted with a similar device to test whether he can learn to remotely control *her* hand with *his* arm motions.

Other researchers look to biological rather than mechanical fixes. Thomas Koob, a biochemist at Shriners Hospital for Children in Tampa, Florida, believes that the collagen-like material of skate egg cases (small black pouches, popularly known as mermaid's purses, that often wash up on Atlantic beaches) may be the key to successful human tendon repairs. Other scientists plumb the latest discoveries in cell regeneration and gene therapy in hopes of repairing spinal cord injuries.

As scientists learn more about ways to prolong life, will we reach the point at which the body simply ages beyond hope of rejuvenation? What are the ultimate limits of the human life span?

S. Jay Olshansky, a biodemographer at the University of Illinois, thinks "anything past 130 is ridiculous." But William Haseltine, the chair and CEO of the Maryland-based Human Genome Sciences Corporation, thinks that stem cells may eventually offer a route to virtual immortality. He predicts that it will one day be possible to "reseed the body with our own cells that are made more potent and younger."

The question can't be resolved today, *Science* writer Constance Holden points out, because there is no reliable "biomarker" in the body—some change that occurs in all humans regardless of environment—that would allow researchers to compare aging rates in different individuals, and thus reliably predict how long people might plausibly live. "At this point," says Holden, "the most reliable biomarker for aging is death."

The Last Guru?

"The Cult of Castells" by James Crabtree, in *Prospect* (Feb. 2002), 4 Bedford Sq., London WC1B 3RD, England.

The first years of the new century haven't been kind to the late 20th century's bumper crop of cybergurus. One of the few still standing is also one of the most unlikely: the 57-year-old Spanish-born, French-educated, ex-Marxist professor of sociology and planning at the University of California, Berkeley, Manuel Castells.

A pile of thick, jargon-clotted books attests to Castells's great industry. His 1,200-page information age trilogy (1996–98) is regarded in some academic circles as a masterwork on a par with those of Karl Marx and Max Weber. Castells has been called the "Voltaire of the Information Age." In a new book, *The Internet Galaxy*, he is reaching for a wider audience.

Crabtree, a researcher at Britain's Industrial Society, is respectfully skeptical. He explains that just as Marx put the state at the heart of the social order and Weber put bureaucracy, Castells puts networks, such as the Internet. They are the "prime organizational form" of the information age. Electronic communications networks, along with the social and cultural revolutions that began in the 1960s and the global economic restructuring that started in the 1980s, are the driving forces in modern society. The decline of stable organizations and fixed values creates far-reaching change. As Crabtree puts it: "The network citizens, stripped of certainty and security while cocooned in networks they cannot control or comprehend, become dominated by the search for personal or collective identity. Some adapt well, while others react aggressively."

Crabtree sees a lot of flaws in Castells's thought. His work is full of jargon—"timeless time," "the space of flows"—and it often sacrifices precision and careful definition of ideas for the sweeping assertion. There's not much evidence that Castells's ideas have a great deal of explanatory or predictive value. And very often Castells seems to "shoe-horn" into his grand theory things that don't fit. He tries to incorporate the Qaeda terrorists into his model of "networked dissent," but Crabtree observes that the group in some ways is the antithesis of a network. For example, it "deploys autonomous cells defined by their *not* being in constant contact with the whole group."

For all that, Crabtree concludes that Castells's reputation is largely justified. His network society is "an imperfect roadmap, perhaps no more than a useful metaphor." Yet it is the most useful roadmap we have. If it now seems somewhat commonplace, it is only because Castells's ideas have carried the day.

Glowing with Optimism

"The Changing Climate for Nuclear Power in the United States" by Richard Meserve, in *Bulletin* (Winter 2002), American Academy of Arts & Sciences, 136 Irving St., Cambridge, Mass. 02138.

"The demise of the nuclear power industry was widely expected only a few years ago" writes Meserve, chair of the U.S. Nuclear Regulatory Commission. But things may be changing.

While the number of nuclear plants has dropped from 111 to 103 since 1990, the amount of electricity these plants produce has increased by nearly 40 percent. Although that 750 billion kilowatt-hours (kWh) of