Implantable Devices

Building a Bionic Being

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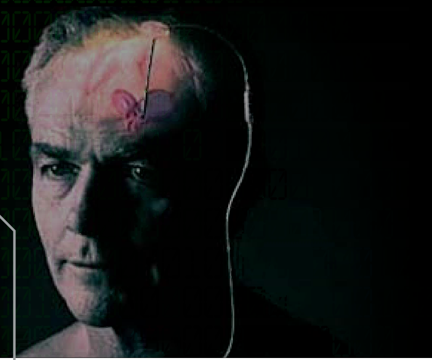


In science fiction, humans have conjured up numerous possibilities of semi-robotic, semi-humanoid beings: cyborgs, which are fictional beings that are part human, part robot; androids, or robots that look like and behave like human beings; automatons, which are humans who behave like machines; and bionic beings, or humans with organs or functions replaced or enhanced by electronically powered parts.

Bionic beings are now very much a reality, perhaps not to the extent of our imagination, yet greater than the extent of our expectations. Approximately 20 million Americans today are embedded with some type of man-made "body part." The population of the US is over 300 million (CIA Factbook 2007). That means 1 out of every 15 Americans depends on some kind of implanted gadget to live or to live comfortably. There are about 80,000 types of gadgets in use, and 4,000 enter the market each year. What are these devices? What are their limitations? And what are their drawbacks? For the purpose of answering these questions, we will rebuild Jill, the victim of a tragic accident, using three major synthetic body parts.

The Prosthetic Arm

Jill is in need of an arm. With advances constantly being made with the mechanical arm, Jill will have one high-tech appendage. Depending on the functionality of the mechanical arm, the cost can range from $15,000 – $100,000. But let's assume that money is no issue for Jill.

There are several different ways of controlling the prosthesis. One major method is targeted muscle reinnervation (Miller et. al. 2008). Motor nerves from the damaged arm are rewired to a large muscle in some other part of the body so that when Jill thinks about moving her arm, the muscle will contract. Sensors attached to the muscle will be triggered, setting the prosthetic limb in motion. Targeted sensory reinnervation works the other way. Sensory nerves are rewired to the skin to allow Jill to feel the heat and pressure applied on her new hand.

There has also been significant research conducted on methods of attaching the prosthetic arm directly to bone to allow for greater control. The downside is discomfort, pain, and infection, since this method is more invasive. UK scientists Gordon Blunn and Catherine Pendegrass saw a resemblance between deer antlers and direct bone attachment prosthesis, and so they developed an attachment based on this natural model. A titanium rod is attached to bone, and muscles grow and anchor to the rod. The prosthetic arm is then attached to the rod (Pendegrass et. all. 2006).

Movement in the human arm is very complicated, with 27 degrees of freedom. On July 18, 2007, the i-LIMB, invented by David Gow in Edinburgh and manufactured by Touch Bionics, went on sale for $17,454. Its fingers are individually powered, and its thumb can be manually rotated. Retired US Army Sergeant Juan Arredondo, a user of the i-LIMB, says, "I can pick up a Styrofoam cup without crushing it. With my other myoelectric hand, I would really have to concentrate on how much pressure I was putting on the cup…I can just grab the cup like a regular person" (Touch Bionics).

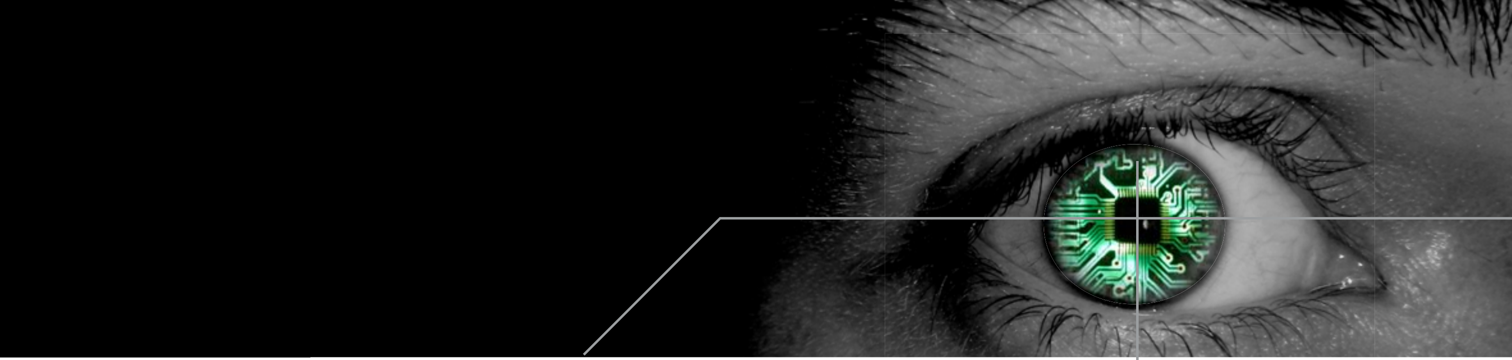
> ***"I can pick up a Styrofoam cup without crushing it."***

Furthermore, the Defense Advanced Research Projects Agency, the Pentagon's research division, is in the process of developing an arm with over 25 degrees of freedom. It will look and behave just like a human arm (Applied Physics Laboratory 2007). With one of the first versions of the prosthetic arm being a hook, we've definitely come a long way.

Artificial Heart

The artificial heart was modeled from Tinkertoys by Bill Sewell in 1949. Jill's heart will be much more advanced than Tinkertoys. In fact, out of compassion for Jill, who already has to relearn how to use one of her arms, we will allow her the same miracle as that of the 15 year-old 2006 Berlin Heart patient.

The first artificial hearts were used only for



temporary purposes, as a substitute until a donated heart could be found. This was the methodology for the recipient of the Berlin Heart, a temporary artificial heart. However, with the aid of the Berlin Heart, the girl's original heart was able to heal naturally, and no transplant was needed; the artificial heart was removed (CBC News 2007).

There are several different types of artificial hearts. The permanent total artificial heart is designed for leaving in, and the record time that someone has lived with it is 620 days. The heart has an internal component and an external component. The permanent fully implantable total artificial heart is completely internal, which means that there is less risk of infection. However, it does come with an external battery pack.

Artificial heart designs vary with model. For example, the intrathoracic pump involves a pump placed inside the thoracic cavity, while the paracorporeal pump is implanted at the patient's side.

More than just Tinkertoys: AbioCor Implantable Replacement Heart is the first self-contained total artificial heart.
http://www.medgear.org/images/abiocor.jpg

For less drastic cases, ventricular assist devices (VAD) may be used. These do not replace the heart but help it by taking over much of the heart's function (FDA 2004). Most VADs share a similar set-up: a pump is placed in the needy ventricle and pushes blood into the appropriate artery. The pump is connected to a controller and a power supply through a lead. The advantage of the VAD is that the heart-rate of total artificial hearts are fixed, but since VAD recipients keep their natural hearts, their heart rate can adjust according to the needs of their physical condition.

One major distinction among the different types of VADs is the type of pumps that they carry. Pusatile pumps attempt to reproduce the normal heart beat, while continuous flow pumps simply generate a continuous flow. Some pusatile pumps are able to adapt their beating and pump volume to that of the natural heart. Those contained within the body require an external vent. Continuous flow VADs usually employ either centrifugal pumps and axial flow pumps, which differ in the manner and direction in which they accelerate the blood.

And for those who have functioning hearts which they are concerned could give out, there are implantable defibrillators. These devices are placed above heart, and should the heart stop, sensors would alert the device, which would automatically send a shock through the patient.

Artificial Skin

Jill has suffered a severe burn, which hasdemolished a large area of skin. With the wound exposed, Jill is at risk of dehydration and life-threatening bacterial infections. Normally, skin grafting, or transplanting of skin that can be spared from another area of the body, would be used, but Jill's wound is so large that she just does not have enough skin. Enter artificial skin.

Artificial skin is made of collagen, a fibrous structural protein that is responsible for the strength and elasticity of skin. Sheets of artificial skin are placed over the open wound, and the dermis, a layer of the skin which usually does not regenerate, begins to grow. Pieces of epidermis can then be transplanted which will grow over the new dermis.

Recently, scientists have been prodding at new methods. In one possible method, skin cells are dispersed throughout a collagen scaffolding. The cells grow and encourage growth of new skin cells. The epidermis would not need to be transplanted; instead it would grow in the artificial skin. The problem with this method is that it takes about a week for blood vessels to connect with the new dermis, and without the antibodies in blood, the skin cells in the collagen and the new dermis tissue are highly susceptible to infection.

The solution: antibacterial bandages. But that is not enough for Dorothy Supp, who has currently been developing genetically engineered skin cells that produce high levels of antibacterial protein (McFarland 2008). Supp envisions one day creating skin cells with the ability to grow structures for sweat, pigment, and hair.

Tools have been an integral part of our lives ever since our *Homo habilis* ancestors. So when we need new body parts, it seems only natural that we would try to make them. Had Jill lost her sight or vision, she could have looked into visual or ocular implants. Had Jill broken a hip or spinal disk, she could have talked to her doctor about artificial hips and spinal disks. Had Jill's temperament been severely affected by her accident, she could potentially have gotten an implantable nerve stimulator. Located above the lungs, it is connected to the spinal chord and periodically sends pulses to lighten the wearer's mood.

It is important to remember, however, that no matter how miraculous a device may seem, every implant comes with a risk. For example, a wound could get infected, and the device may be identified as foreign and be rejected by the body. When considering an implant, take care to consider its risks and how much benefit can realistically be derived from the device. While it is a good idea to check up on the statistics, keep in mind that the statistics are tested and published by the drug companies, and so may contain inflating factors. And be sure to read up on any controversies surrounding the device.

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