Problems technical, not ethical

When a scarce item is needed for an important task, the natural thing is to look for an easily available substitute.

Replacements for the human heart and other organs have been under development for some years now, and hardware has replaced worn human parts and corrected failing functions.

Artificial organs have the advantage over living transplants in that they don't elicit the immunologic response that causes the recipient to destroy foreign tissue.

But before a major organ like the heart is replaced by a machine, the immense problem of materials and power supply will have to be licked. Until that time, lesser projects that replace parts of the heart, or give temporary help while recovery of the organ is taking place, are giving experience useful in the more ambitious projects. In the heart area, they include valves, pacemakers and heart assist pumps.

The materials problem has two basic aspects: The artificial material must have no deleterious effects on the blood it handles, and it must be strong enough to take the strain for many years. The two requirements aren't easily compatible, and an ideal material that can take constant flexing and still not cause clotting and other blood damage has not yet been found.

Progress in material development has made it possible to build more effective valves, however, and the same materials are being used in prototype pumps. The early valves used a moving disk or ball in a cage to regulate flow; these bulky, slow-acting devices may be replaced by a flexible leaflet-type valve very similar to the living configuration. The new valve material is soft silicone rubber built around a thin mesh of tough polypropylene. The material is also impregnated with heparin, a drug which cuts down clotting.

Pacemakers also have materials problems. These electric signal generators, which supply the timed impulse that stimulates the heart to beat when the normal nervous impulse falters, need wire electrodes to carry their signals to the heart muscle. The constant flexing of the wires due to the heart's motion has caused electrodes made of stainless steel or platinum to become fatigued and break. A special alloy developed for watch mainsprings, now being used, gives better service.

Power supplies for pacemakers can be very small; currently in use are small batteries that last a few years and can be replaced by simple surgery. To eliminate that necessity, permanent power supplies are being studied. One type, tested successfully in animals, uses a piezoelectric crystal that puts out electric current when squeezed. Placed in the heart ventricle, the crystal charges a condenser, which then discharges at a timed rate by the pacemaker. Another type, being developed by the Atomic Energy Commission, uses a radioactive power source.

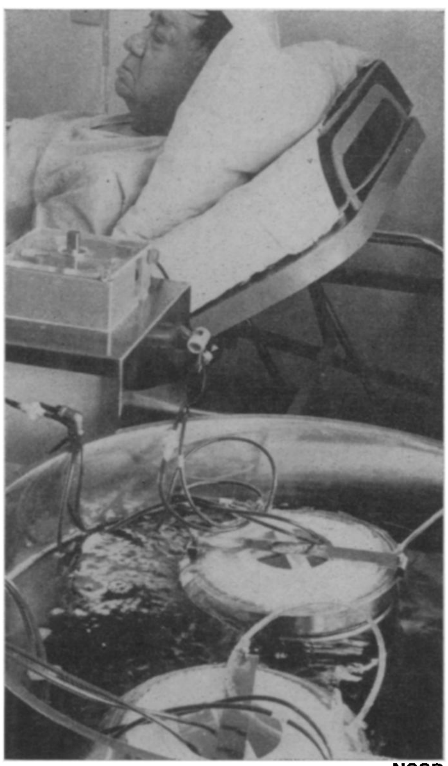
The power supply problem becomes more important in artificial hearts, since power is needed to pump the blood, rather than just stimulate the heart muscle. Up to seven watts of electric power are called for. At present, all prototype designs have their power supplies outside the body, and the pump is powered by wires or tubes passing through the chest wall, making infection a real danger.

Implantable power supplies being considered include piezoelectric systems run from the lung motion, and isotope power supplies.

One of the most intriguing possibilities is the development of a fuel cell that runs on glucose from the blood. Metabolizing the glucose in a particular way would produce a flow of electrons for electric current to power the artificial heart. The glucose fuel cell would have the advantage that its wastes are normal metabolites that the body is accustomed to handling.

All power supplies produce heat; implantable power would saddle the body with some 10-25 extra watts continuously. Experiments with dogs shows that heating the blood with electric heaters of up to 24 watts for long periods raised the body temperature only one degree C., so the problem may not be too serious.

Power requirements may be lowered by the use of fluid logic circuits to control the pumping action of the heart. In one prototype model, the pump is a flexible sac within a rigid plastic body. Air pressure in the body collapses the sac containing blood, until a small port is uncovered. Air in this port causes the power pressure to be diverted from the pump, and the flexible sac begins to fill again. The cycle repeats



NCCD

Artificial kidney: too big to carry.

Northern Electric Co.

Hydraulic power for artificial limbs.

when the port is once again covered, directing the power pressure into the pump again.

Work toward an implantable artificial kidney is still in its infancy. Although workable machines have now been developed to cleanse the blood of the poison products removed by healthy kidneys, practical implantable artificial kidneys are a long way off. Since live kidneys are more readily available than transplant hearts, the solution to lost kidney function is most likely to lie in transplantation rather than artificial replacements.

The same holds true for the more complex liver, whose whole operation is not yet understood. Although some speculation on replacement of the pancreas by an artificial producer of insulin has taken place, development of this device also seems a long way off.

Artificial replacement of limbs lost or missing has a long history. But only recently has the possibility of simulating more than a few primitive functions looked promising.

Important problems in functioning artificial arms are the power supply and the means of control.

Most common power sources are electric motors, which have limitations in weight and the amount of work they can do, and pressurized gas, which results in jerky movement and has durability problems.

A newly-developed system uses hydraulic power, with the fluid pressurized by an electric motor. The new arms are lightweight, since the power supply is not in the limb itself, and the hydraulic system is smooth and reliable.

Control of the new system, developed by the Northern Electric Co. of Canada primarily for thalidomide victims, is accomplished by buttons. Individual arrangement of the controls is designed to fit the needs of each patient, many of whom have small stumps which can be used to push buttons or levers.

Another control system measures the tiny electric currents when a muscle contracts, amplifies it, and uses it to actuate artificial arm movement. Such a myo-electric control system is being developed for the Northern Electric arm, for use where button controls aren't practical.

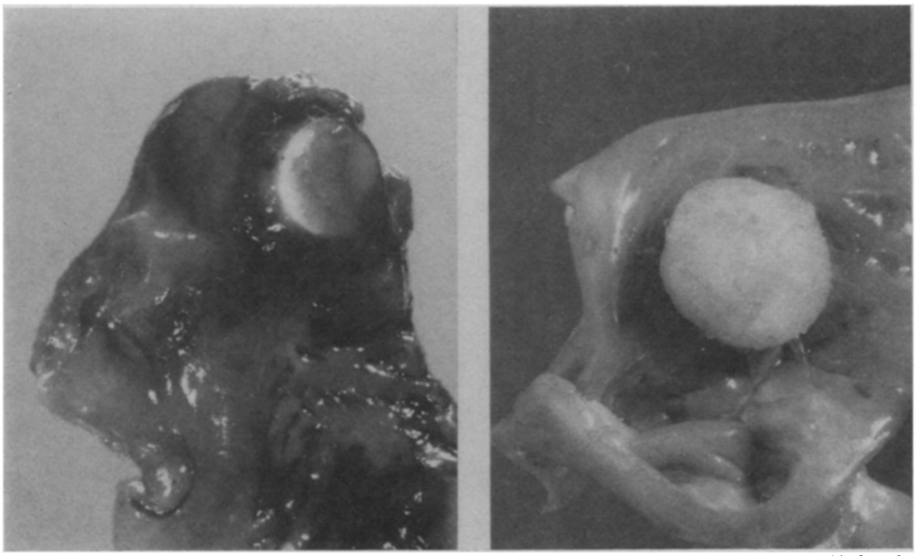
These control systems simulate the nervous control of muscles, but they don't give any feedback to the nervous system to tell what the arm is doing. That has to be learned by the patient, by watching what the arm does and relating it to how he operated the control system.

Hooking into the central nervous system in any natural way seems a long way off. Some attempts have been made to devise a system of vibrators or electric probes that would stimulate the skin at various points according to a code that reflects the operation of the artificial arm. These systems have promise but are still in the future.

Feedback within the appendage itself has been developed, so that fairly sophisticated operations can be carried out. In one system, piezoelectric pressure sensors in the artificial fingers give enough control to allow the user to pick up a delicate object without crushing it, or increase the pressure to crush, if necessary.

With electronic logic circuits becoming ever more compact, the prospect is bright for programming in complex movements such as lifting a spoon or reaching for an object. One intriguing possibility in this direction would be an artificial leg that had normal walking operation automatically programmed.

Carl Behrens



Hufnagle

Heparin prevents clotting; untreated material (left) after two hours.