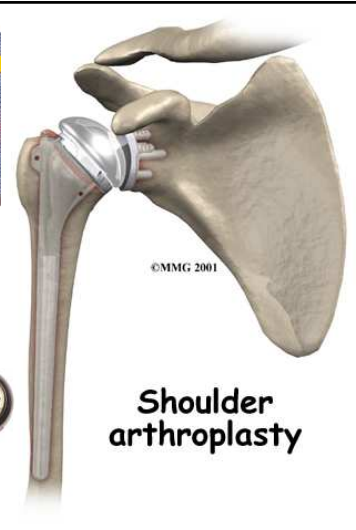
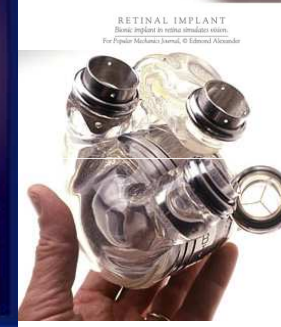
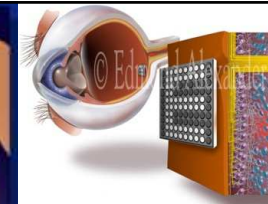
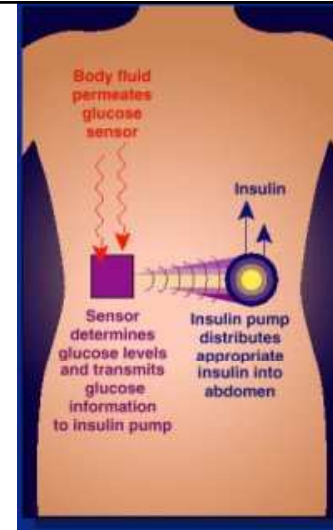


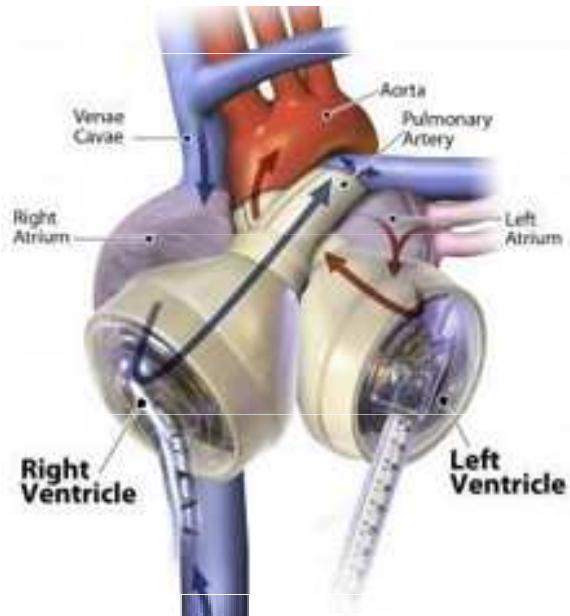
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Lectures on Medical Biophysics

Devices for substitution and assist of body organs

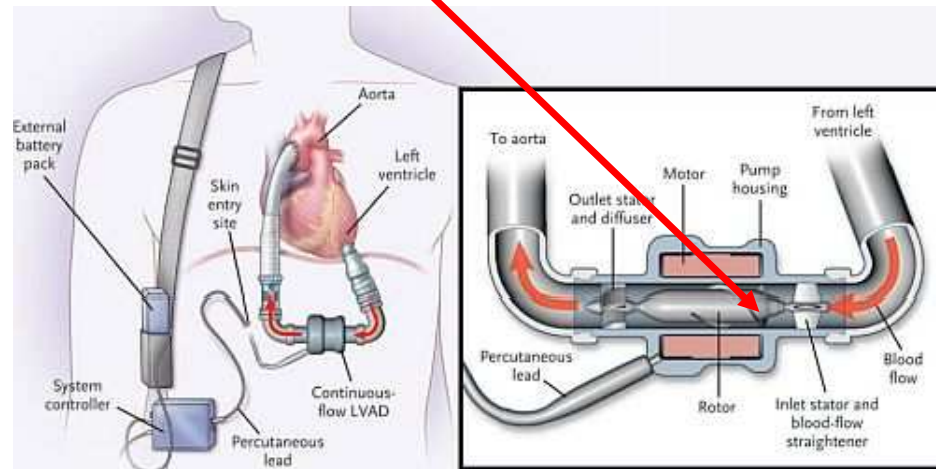
Support and replacement of heart



Two pumps with an external pneumatic drive



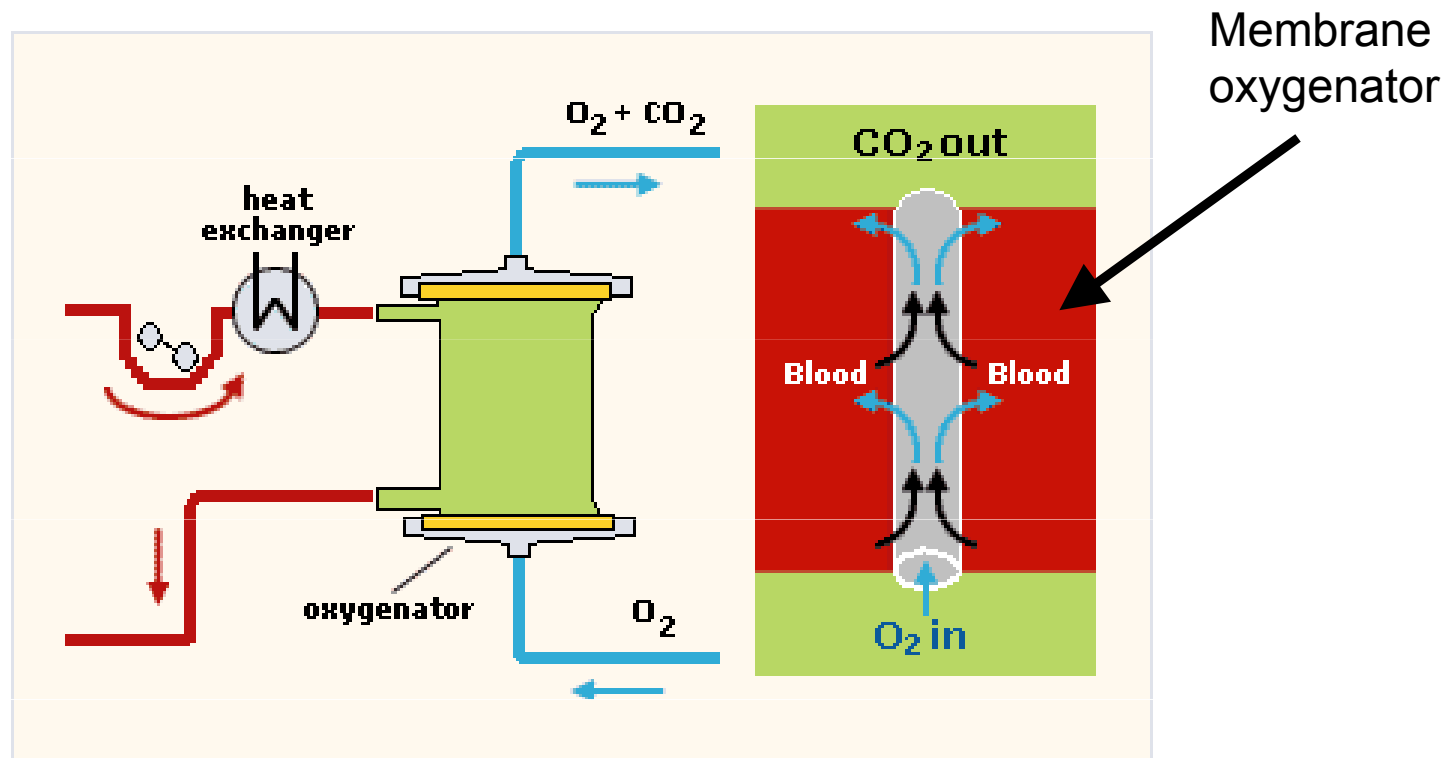
Man who lived half a year with pair of rotation pumps Heartmate 2 without heart and pulse.



Cardiopulmonary bypass

- During major heart or lungs surgery is often necessary to substitute function of these organs by an extracorporeal device. The lungs are substituted by **oxygenator**, which delivers oxygen to the body and removes carbon dioxide from it.
- Two types of oxygenators: with direct contact of the gas with blood or based on diffusion of gases through a membrane between blood and gas.
- In the **bubble oxygenators**, the oxygen bubbles ascend in a cylindrical vessel filled by blood. Blood uptakes oxygen and carbon dioxide is removed. Arising foam must be settled, then the blood passes through a filter and the „**bubble trap**“.
- **Membrane oxygenators** are equipped by semipermeable membranes. Problem: certain denaturation of blood proteins and damage to the blood cells on the membranes limit their use to several hours. The membranes are layered or form capillaries. These oxygenators represent good approximation of lungs but it is necessary to disturb the blood layer on membranes by turbulences.

Cardiopulmonary bypass



Main parts of cardiopulmonary bypass: peristaltic pump, oxygenator, heat exchanger for heating or cooling blood and hence the patient's body.

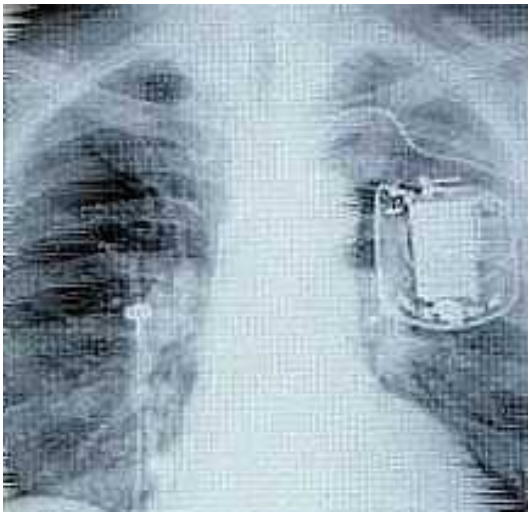
Cardiopulmonary bypass

Bubble oxygenator with heat exchanger.

The common problem of all cardiopulmonary bypasses is the need of certain increase of circulating blood volume – it can be done by dilution.



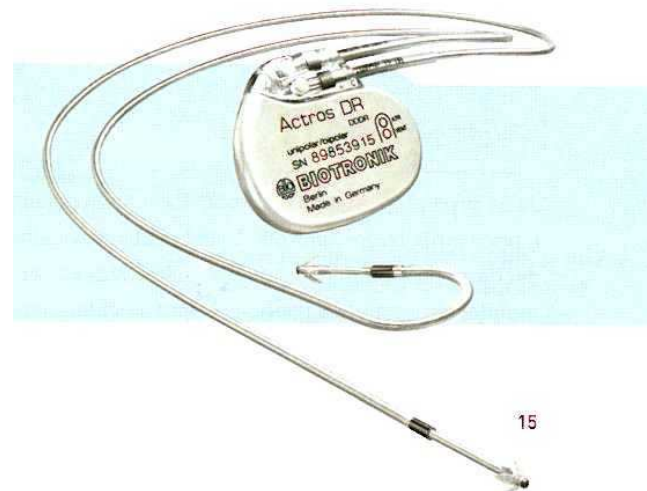
Pacemaker



Pacemakers are used in patients with severe arrhythmias and some other heart diseases. This active implantable device consists of electrodes and a central unit driven by durable batteries. They can be programmed from outside the body according to the patient's conditions. They replace the natural pacemaker – the sinoatrial node.



programmer



Defibrillators

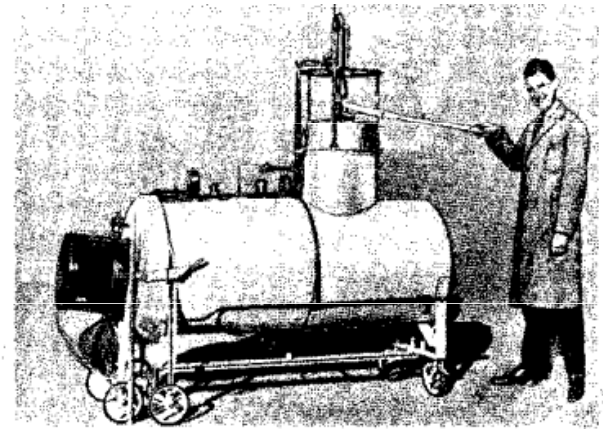
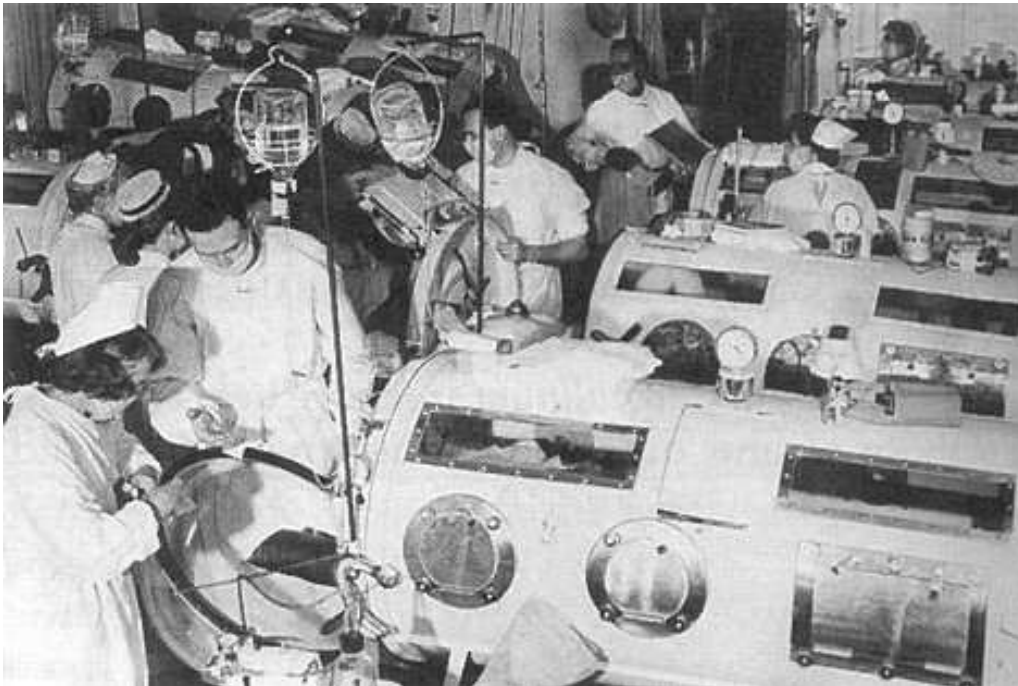


Defibrillators are used in emergency medicine to renew spontaneous heart activity (in case of chamber fibrillation).



Implantable
defibrillator/cardioverter

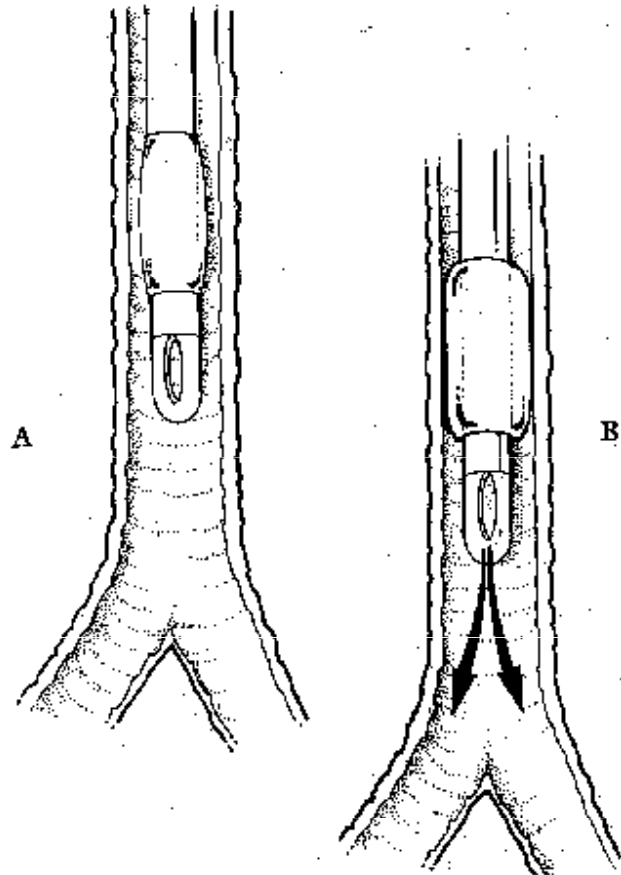
„Iron lungs“ (in the past)



Poliomyelitis (polio)
treatment in 50'.
Later was the
problem solved by
the Salk vaccine.

Mechanical ventilation of lungs

- Ventilation is performed with air pressure or volume limit

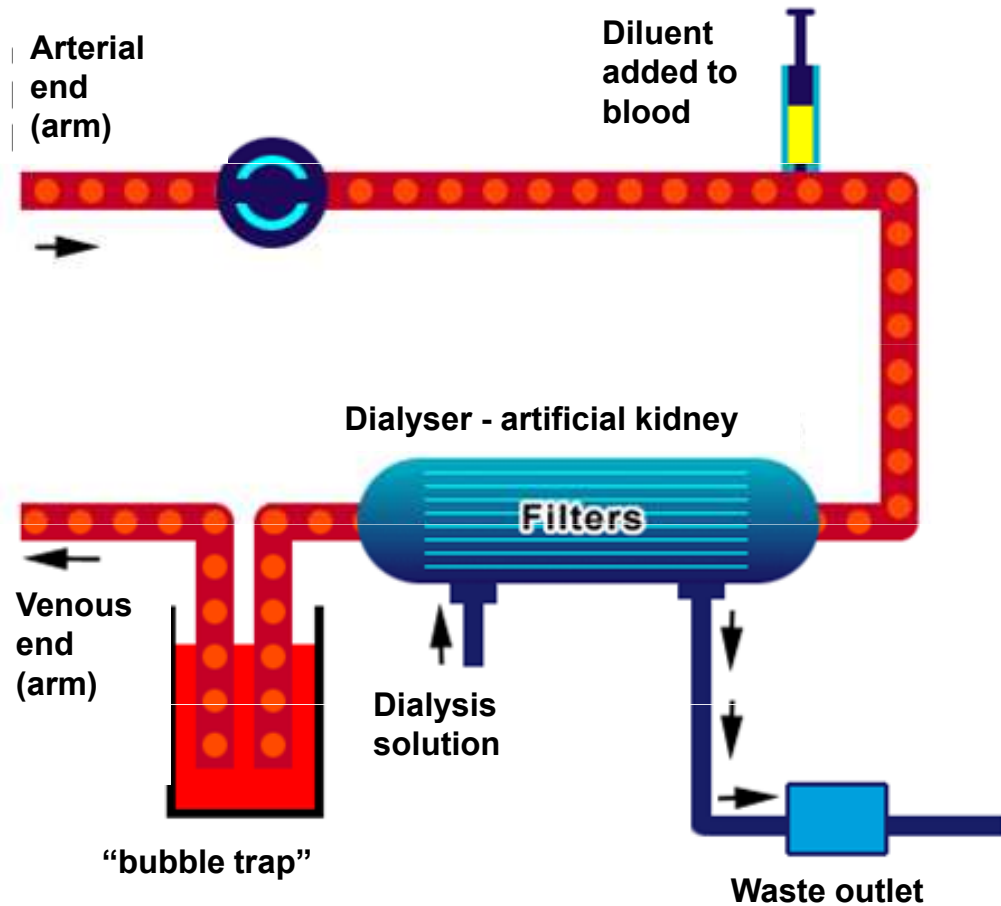


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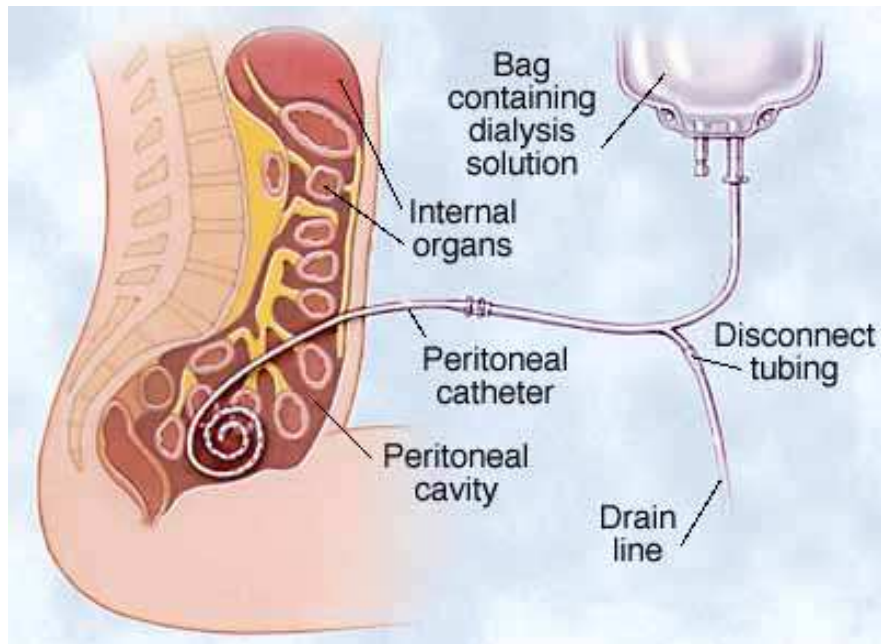
Artificial kidney - haemodialysis



Superfluous volume of blood can be removed by underpressure in the dialysis solution



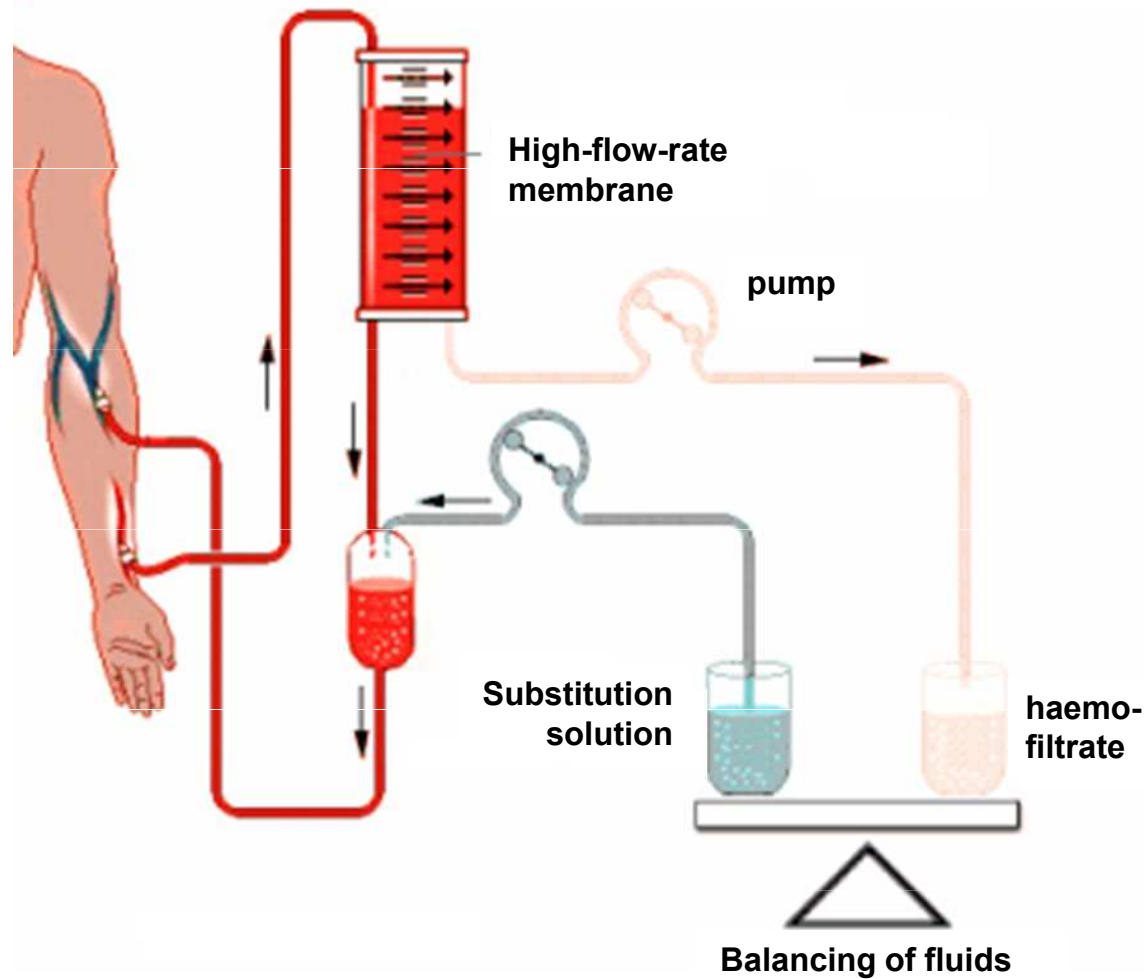
Peritoneal dialysis



Peritoneal dialysis can be done by the patient at home. A catheter is permanently inserted into the peritoneal cavity serves for application as well as removal of dialysis solution. The procedure can be automated and performed during sleep.

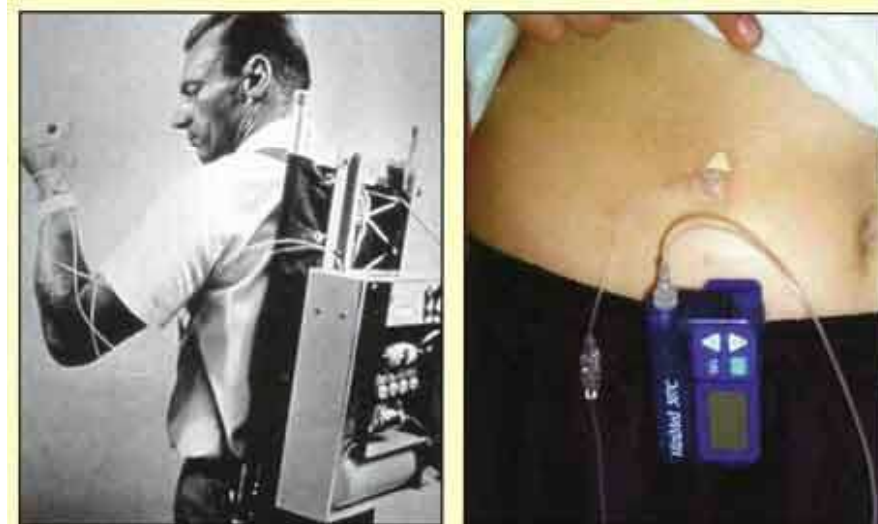
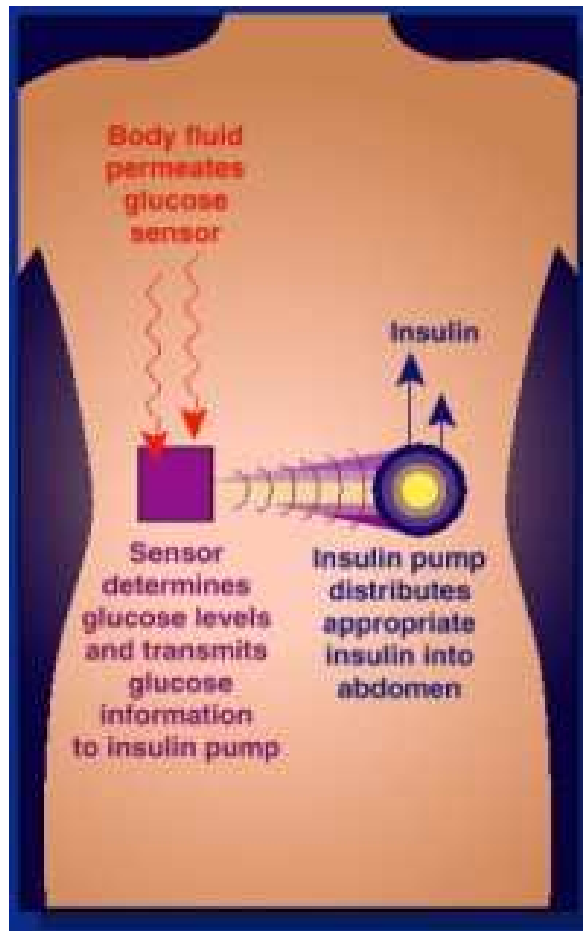
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Haemofiltration



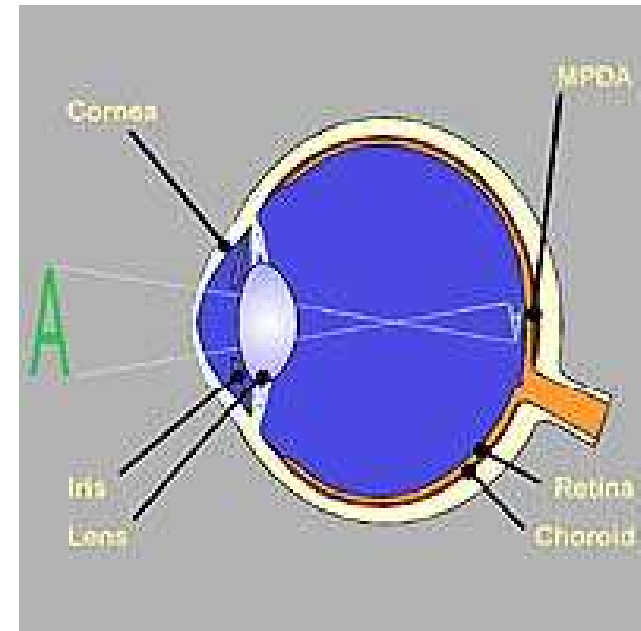
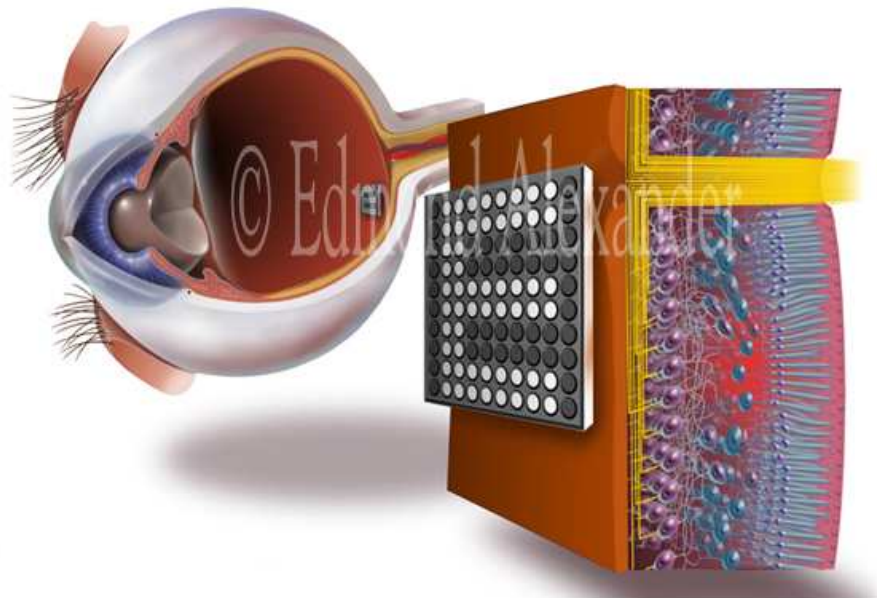
Haemofiltration is an alternative of dialysis. It is very useful in some poisonings. Haemofiltrate with toxic substances is replaced by substitution solution added to blood in necessary amount.

Artificial pancreas – insulin pump



LEFT: The earliest prototype of an insulin pump which also delivered glucagon. Whitehall Laboratory, Indiana, 1963. RIGHT: 14-year-old Canberra pump-wearer, 2002. The device weighs 100g.

Retinal implant



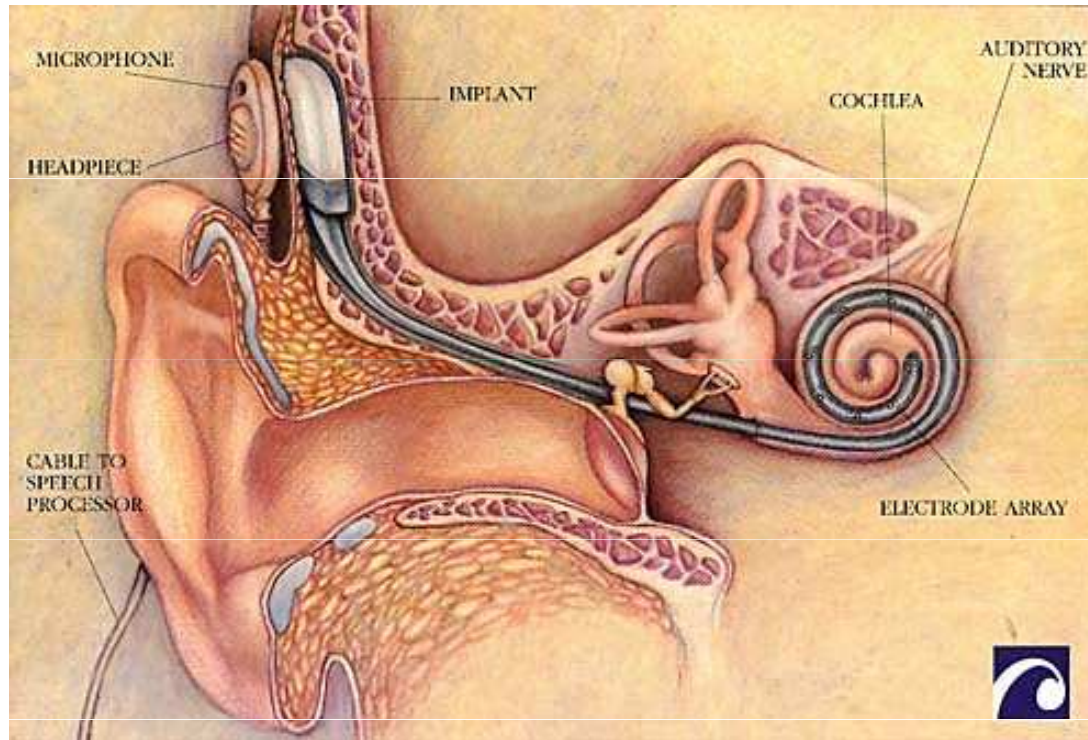
RETINAL IMPLANT
Bionic implant in retina simulates vision.
For Popular Mechanics Journal, © Edmond Alexander

MPDA – micro-photo-diode-array

Such devices are in clinical testing. They should enable basic spatial orientation.

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Cochlear implant

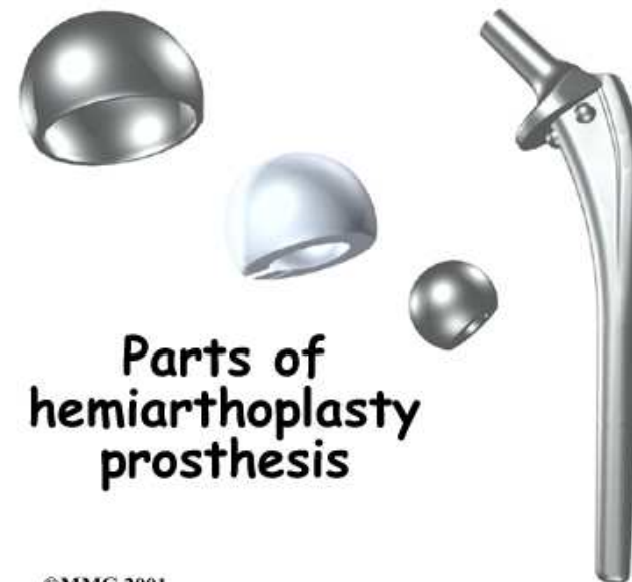
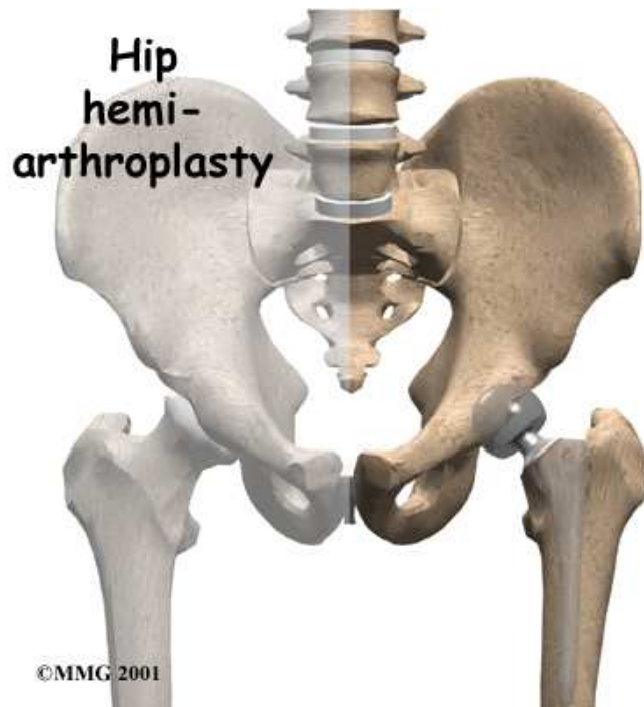


The electronic cochlear implants can partly replace the Corti's organ, mainly in children which have intact auditory nerve. It is an electrode system implanted into cochlea, which can stimulate the nerve by impulses generated in the so-called speech-processor.

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Hip joint substitution

Hip or other joint substitutions are made of combinations of plastics and ceramics or titanium and its alloys. Titanium surface is porous, which enables the bone to grow inside the implant surface - lowering need of bone cement.



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Acetabular cup (hip joint socket) placement



Robots in orthopaedic surgery. The endoprosthesis must be positioned (oriented) with great angular precision.

Knee joint substitution

Before



After



ADAM.

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Ankle joint

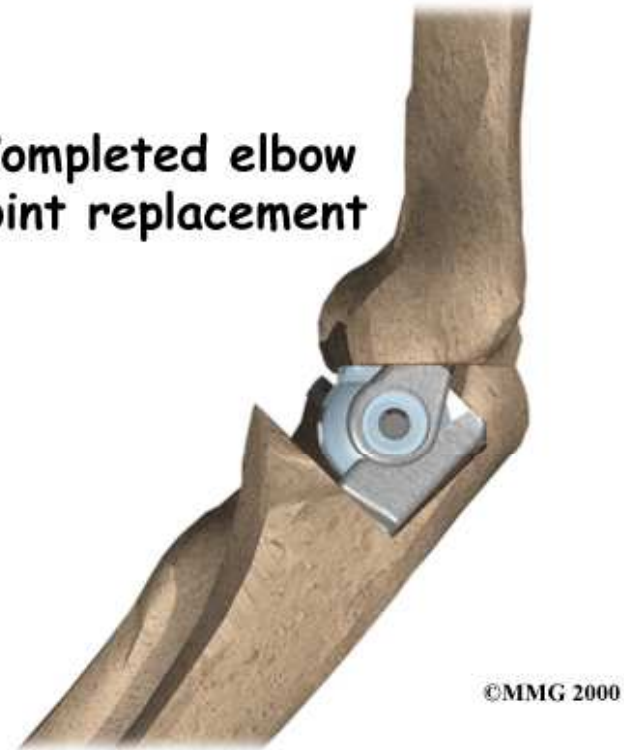


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Elbow and shoulder joint substitution



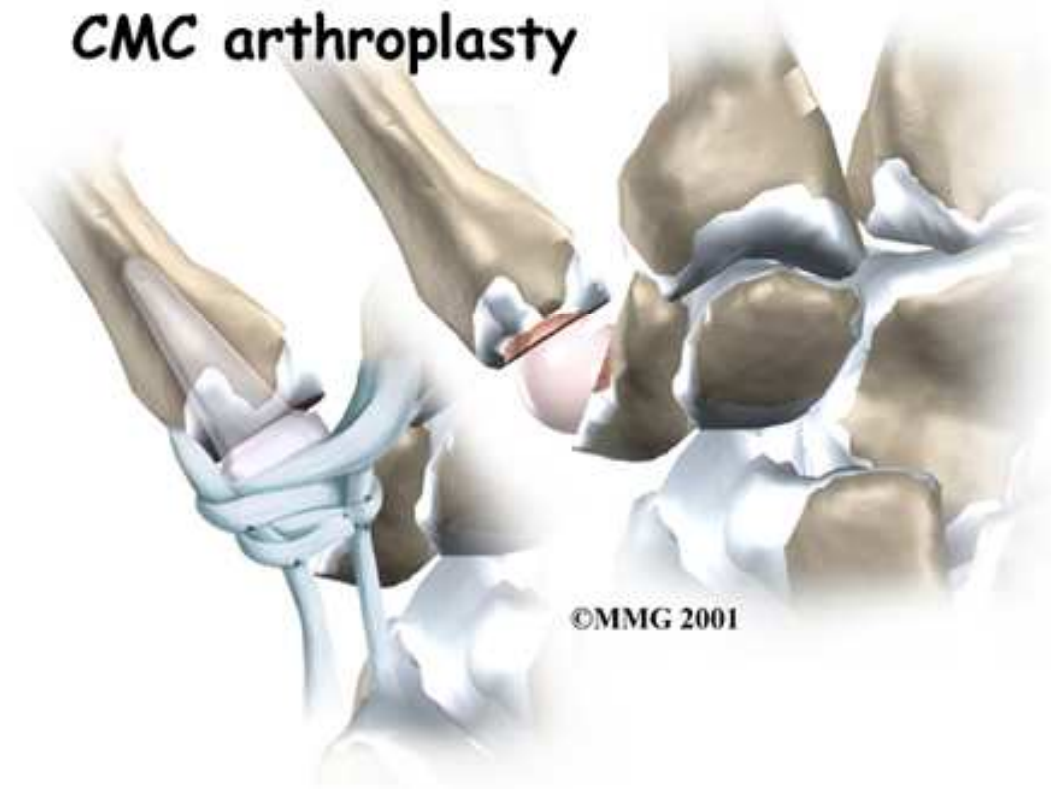
Completed elbow joint replacement



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Joints of thumb and fingers

CMC arthroplasty

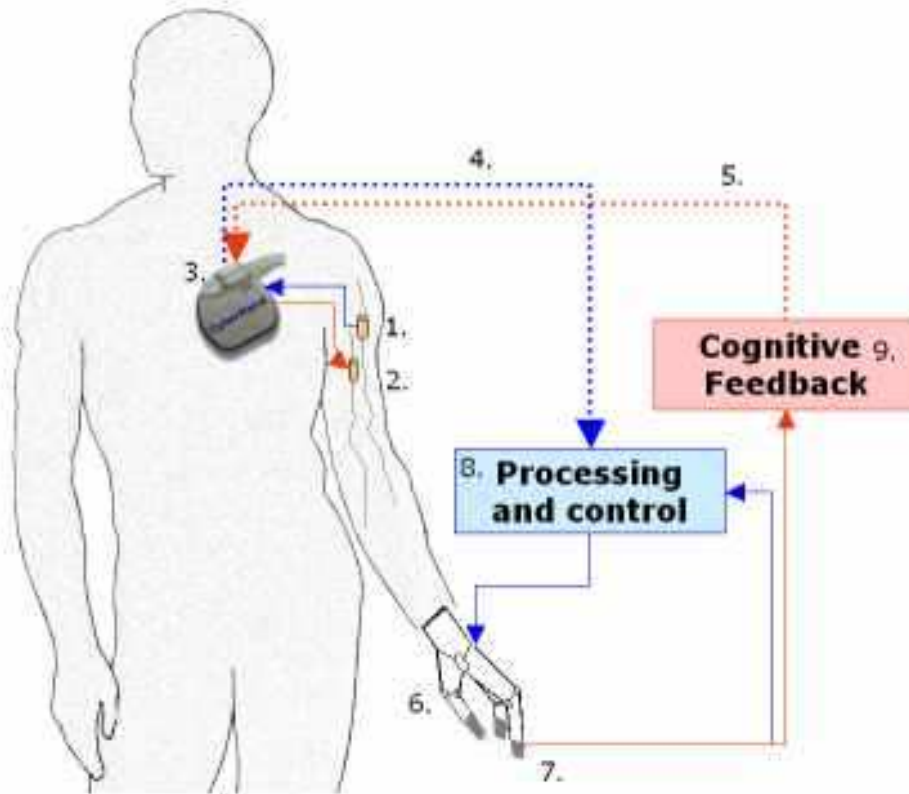


Finger arthroplasty



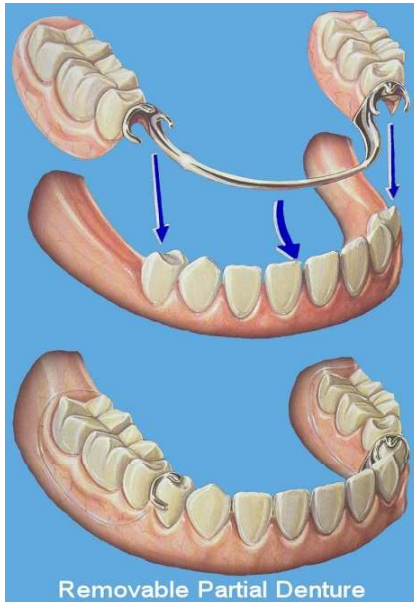
CMC = carpometacarpal

Bioprosthesis of hand – emerging reality



1. Electrode on efferent nerve;
2. Electrode on afferent nerve;
3. Implanted part for recording of nervous activity and nerve stimulation;
4. Efferent telemetric connection;
5. Afferent telemetric connection;
6. Bionic hand;
7. sensors;
8. Decoder of patient's intentions and control of prosthesis;
9. Unit mediating the signals of sensors to the brain.
10. Subsystems 8-9 will be outside body but easy to carry.

Dental prostheses



Partial prosthesis

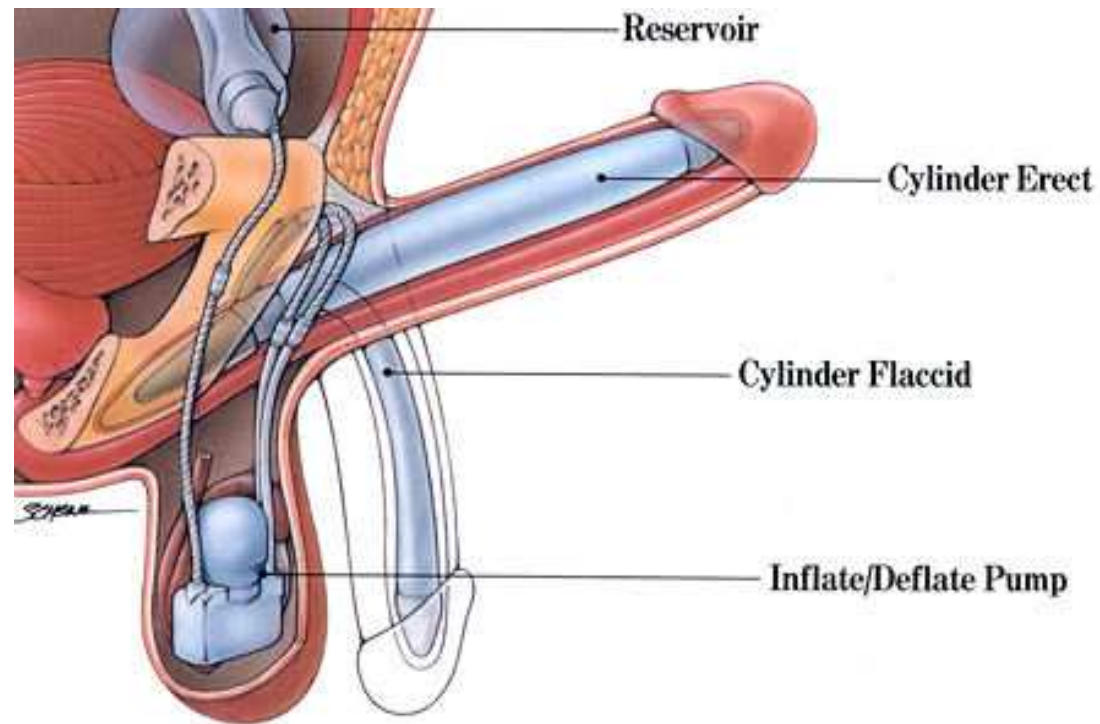


Removable upper prosthesis



Preparation of the bed for total fixed dentition substitution

Penile endoprosthesis



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December 2020

Author: Vojtěch Mornstein



"All I did was to connect an artificial heart to
artificial legs, to an artificial kidney, to ..."

Content collaboration and language revision: **Carmel J. Caruana**