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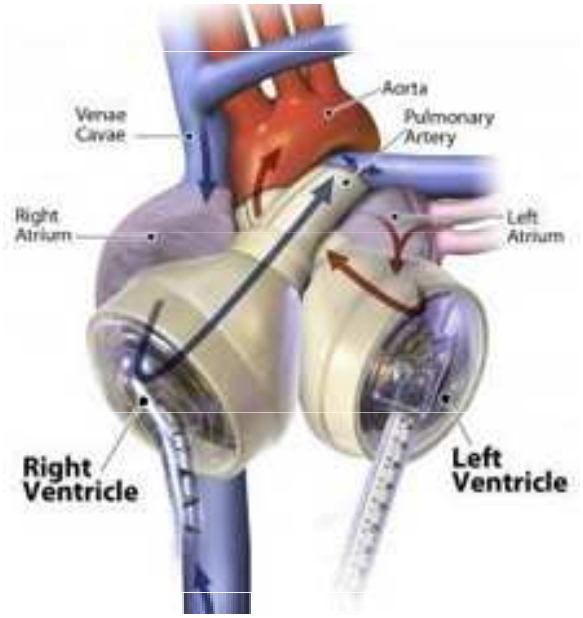
Lectures on Medical Biophysics

Devices for substitution and assist of body organs

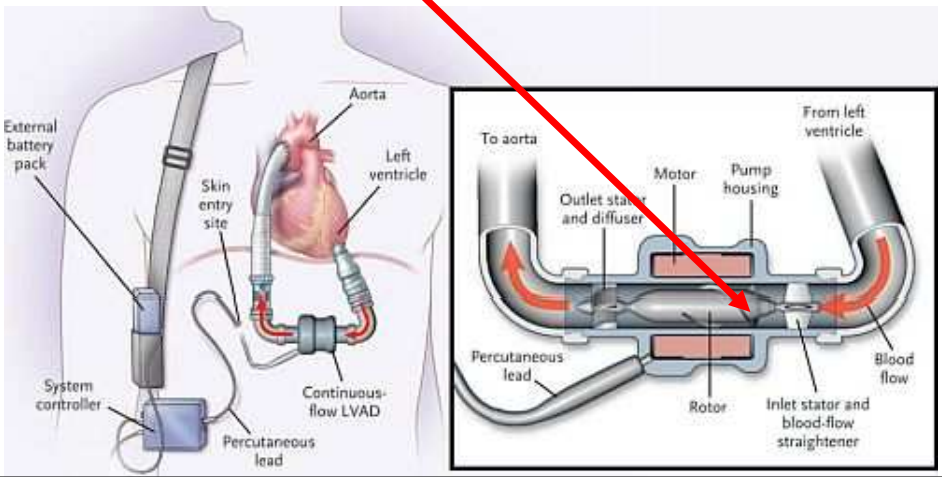
Department of Biophysics, Medical Faculty, Masaryk University in Brno

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.



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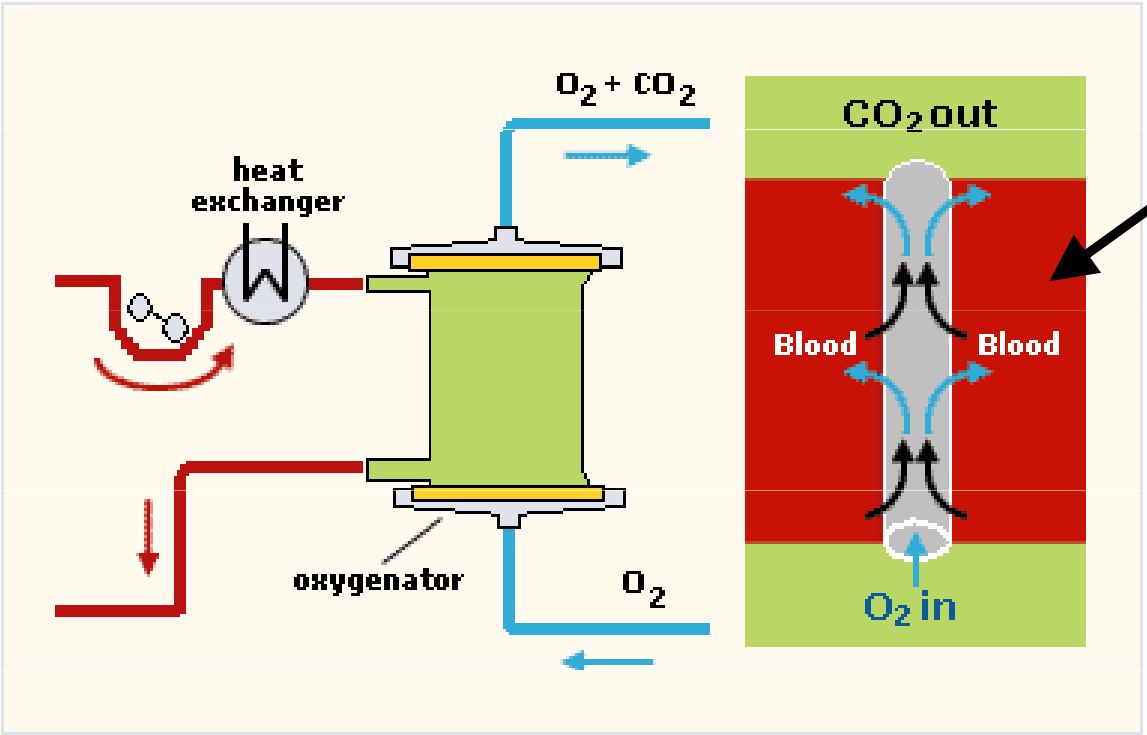
Cardiopulmonary bypass

- 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

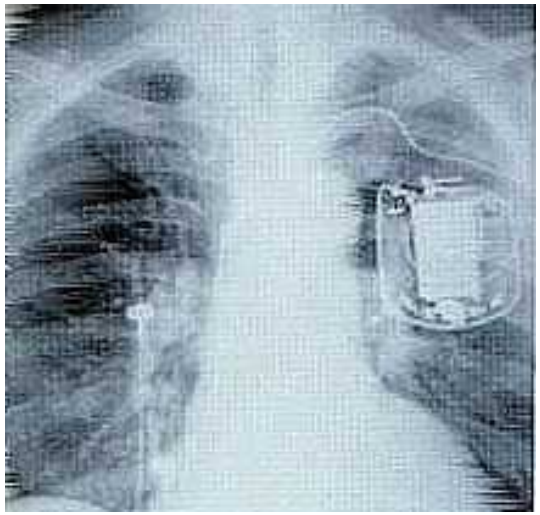


Membrane oxygenator

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

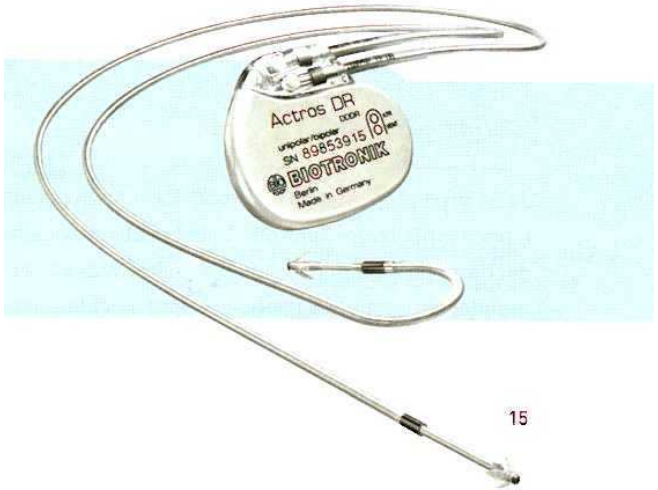
Main parts of cardiopulmonary bypass: peristaltic pump, oxygenator, heat exchanger for heating or cooling blood and hence the patient's body.

Pacemaker



programmer

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 the patient's conditions. They replace the natural pacemaker – the sinoatrial node.

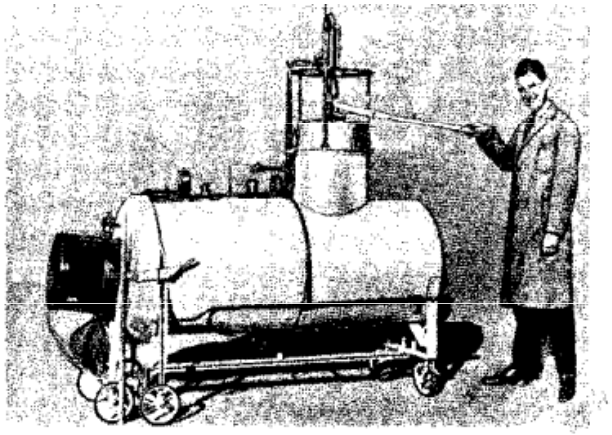


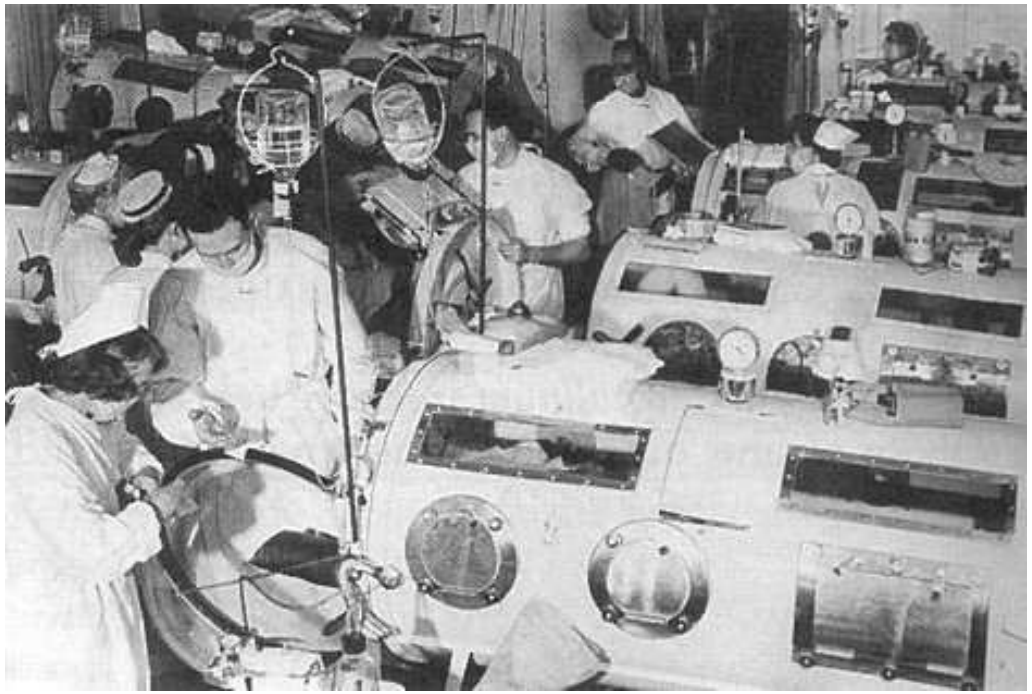
Defibrillators

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

Implantable defibrillator/cardioverter

„Iron lungs“ (in the past)

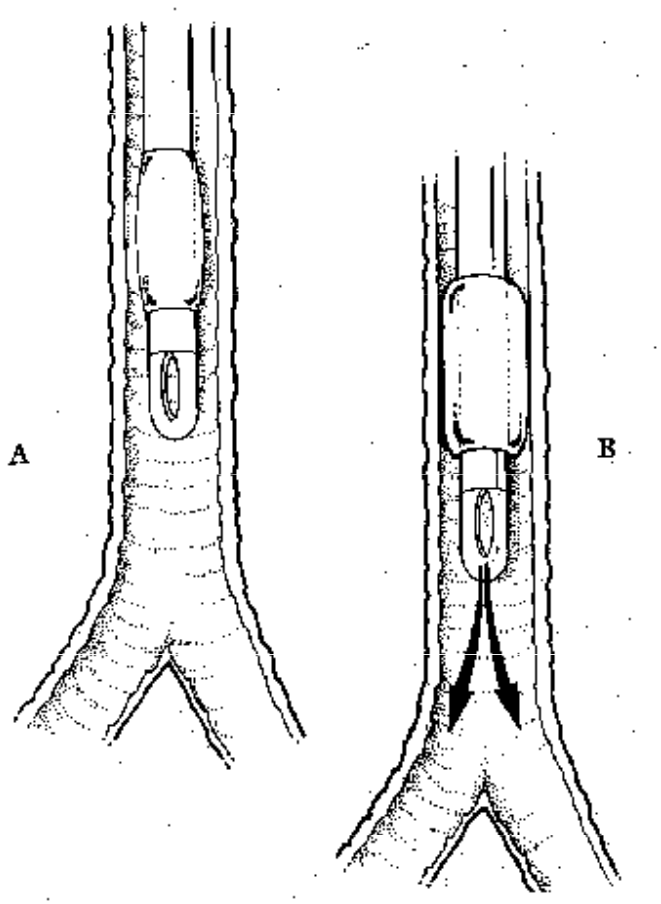




Poliomyelitis (polio) treatment in 50´. Later was the problem solved by the Salk vaccine.

www.blinn.edu/natscience/phillips/ironlung.html

Mechanical ventilation of lungs



– Ventilation is performed with air pressure or volume limit

Homework:
Look for
ECMO!!!

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http://www.mtsinai.org/pulmonary/books/physiology/chap10a.htm

Artificial kidney - haemodialysis

Arterial end (arm)

Diluent added to blood

Dialyser - artificial kidney

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

Venous end (arm)

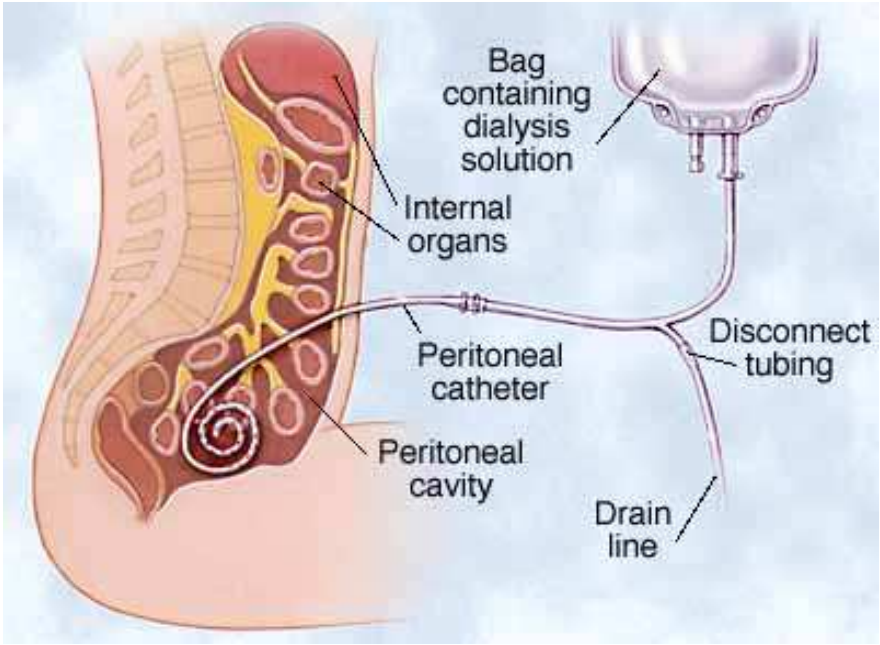
Dialysis solution

“bubble trap”

Waste outlet

According to: www.renalpatients.co.uk/ haemodialysis.htm. www.rheomed.de/Bilder/ produkte/dialyser.jpg

Peritoneal dialysis



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

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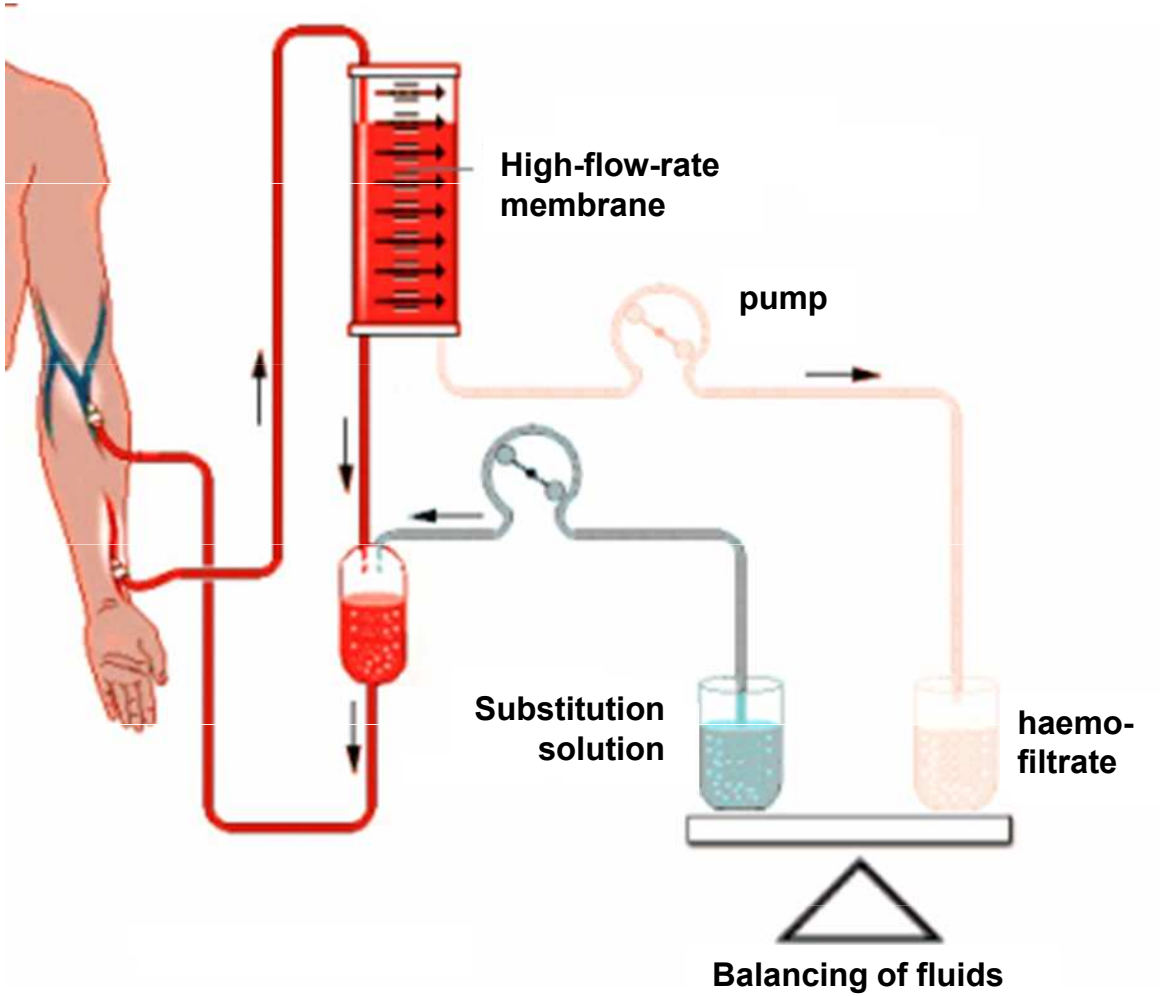
www.devicelink.com/ expo/awards02/98winQ.html. www.healthyeatingliving.com/ Kidney_failure.htm.

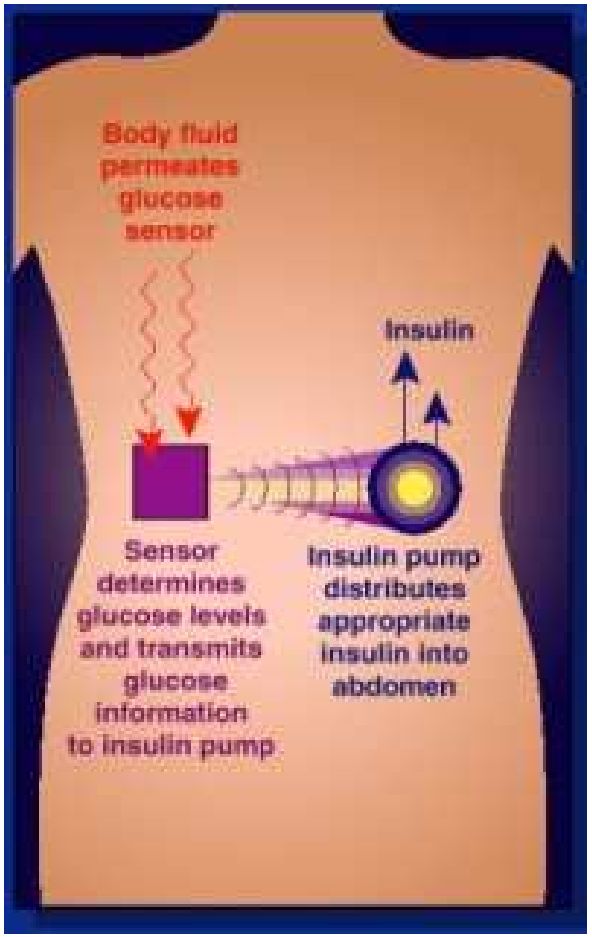
Haemofiltration

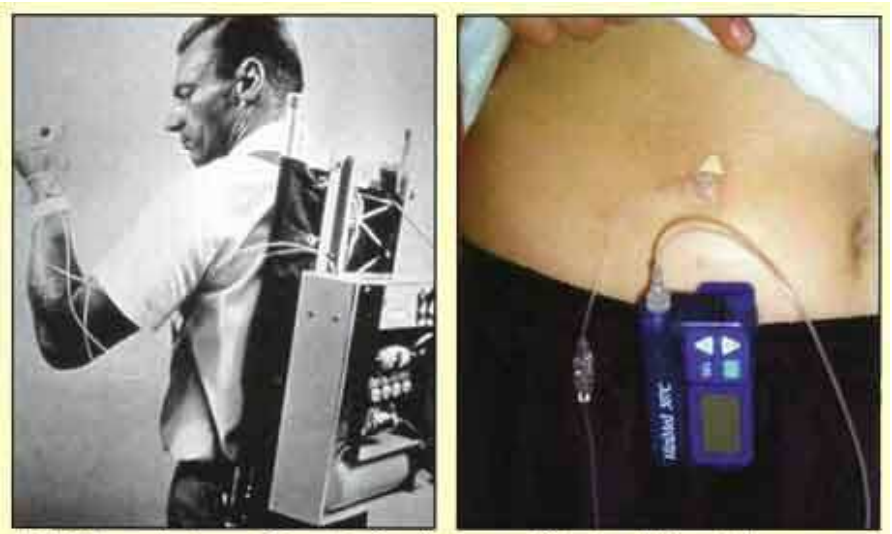


Hemofiltration is an alternative of dialysis. It is very useful in some poisonings. Hemofiltrate with toxic substances is replaced by substitution solution added to blood in necessary amount.

According to: info-dialyse.de/.../ haemo_haemofiltration.php.

Artificial pancreas – insulin pump

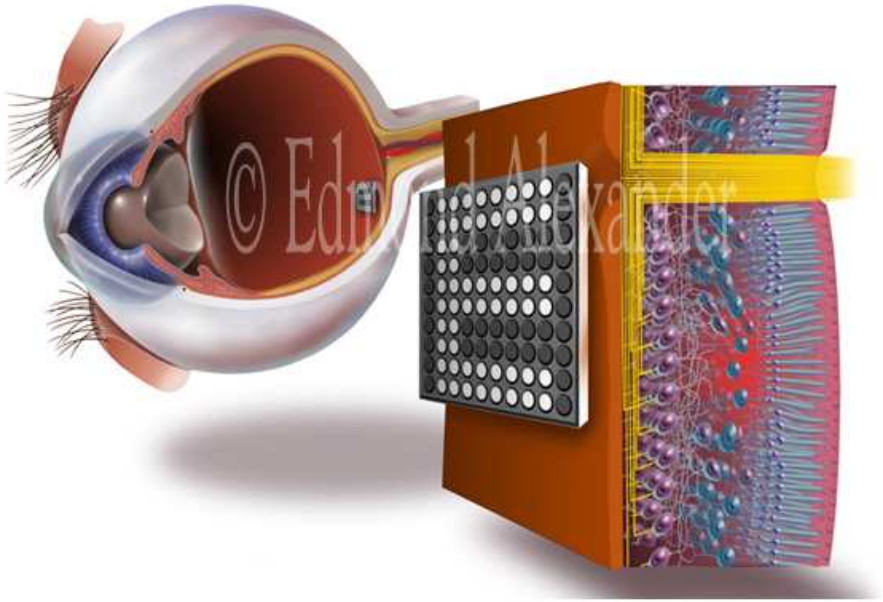




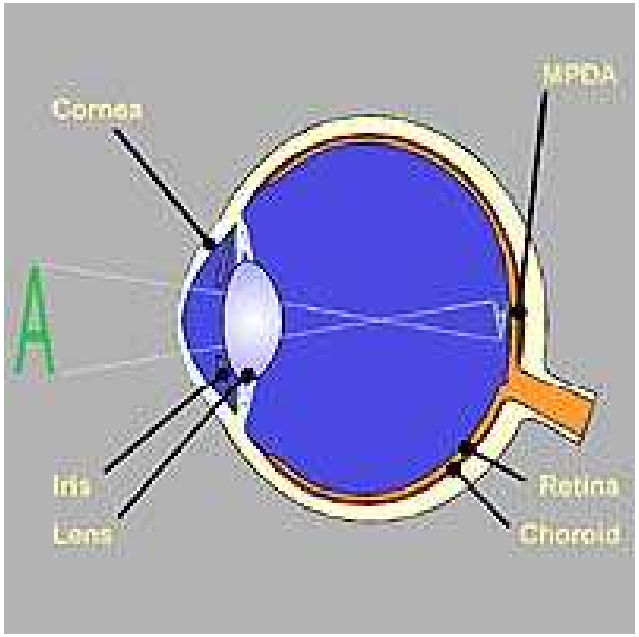
LEFT: The earliest protoType of an insulin pump which also delivered glucagon. Whitehall Laboratory, Indiana, 1963. RIGHT: 14-year-old Canberra pump-wearer, 2002. The device weighs 100g.

http://www.diabetesaustralia.com.au/conquest/0204-insulin-pump-therapy.htm www.pnl.gov/ energyscience/06-01/ws.htm.

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.

www.nmi.de/deutsch/ showprj.php3?id=3&typ=1

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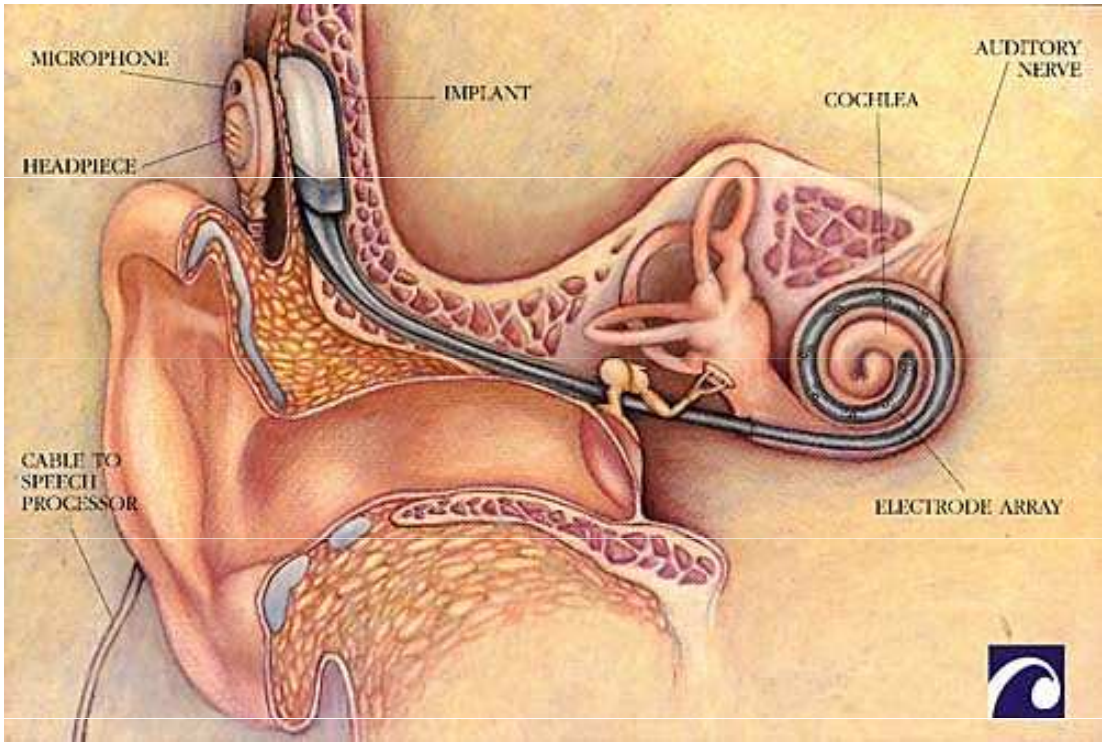
Cochlear implant



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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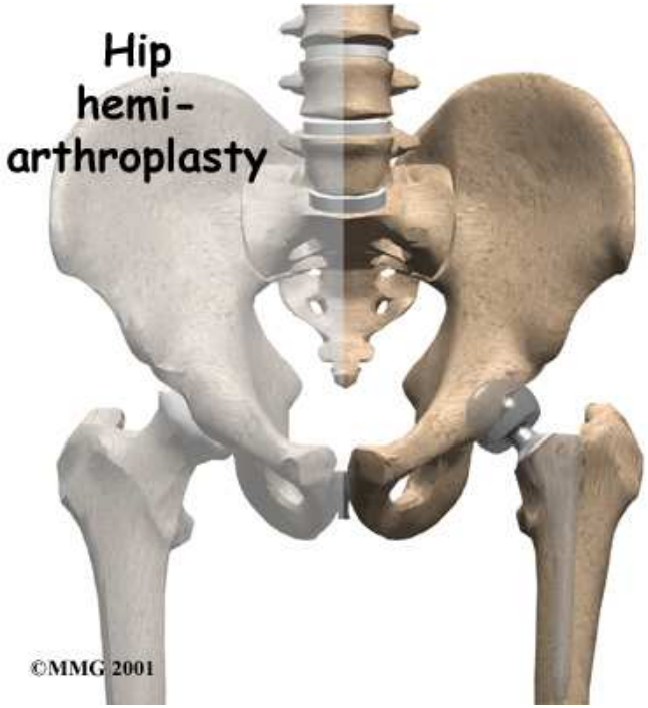
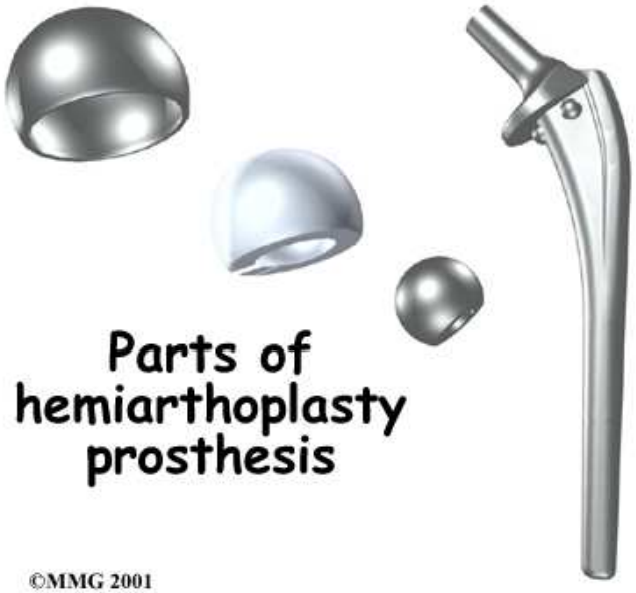
http://www.accessexcellence.org/AB/BA/biochip3.html

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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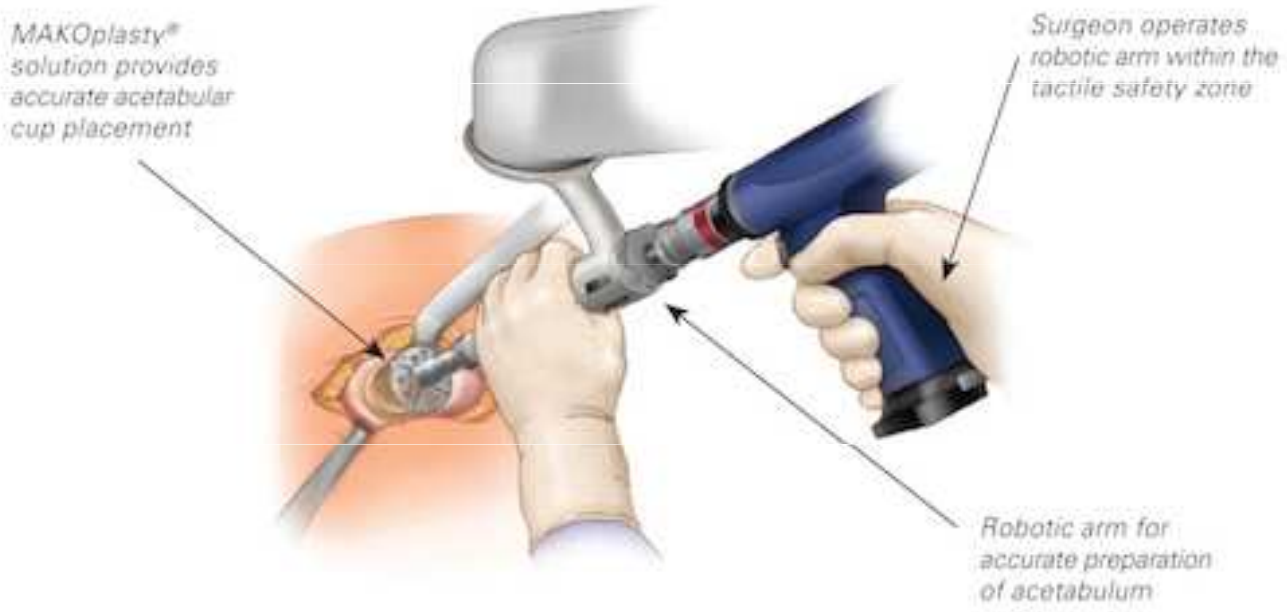
http://www.orthogastonia.com/patient_ed/html_pages/hip/hip_hemiarthrooplasty.html

Acetabular cup (hip joint socket) placement



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

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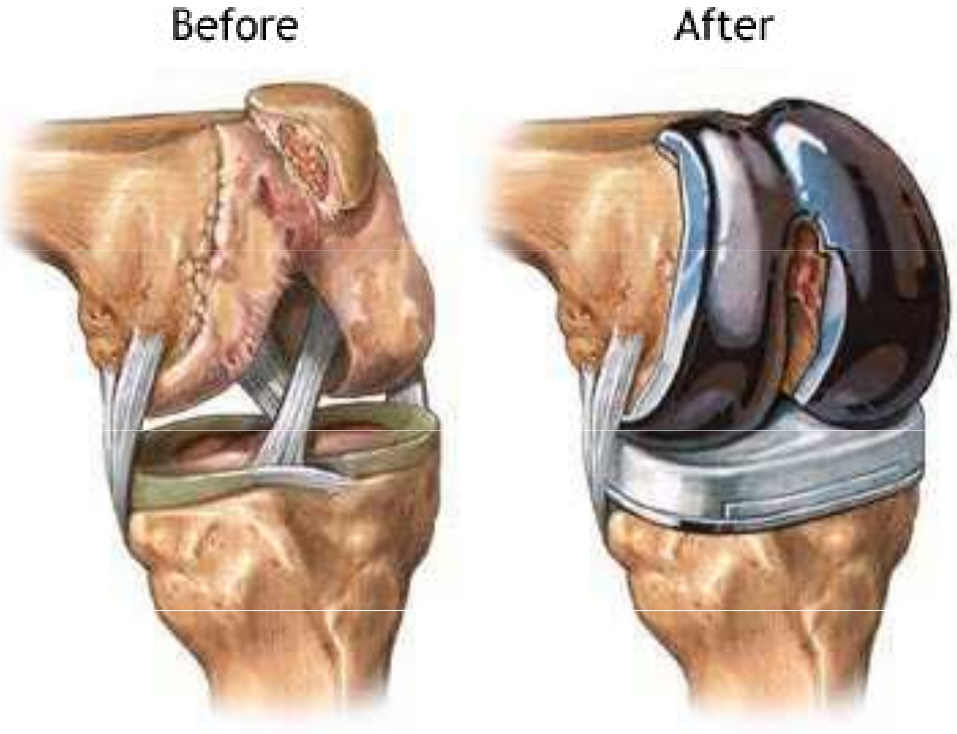
Knee joint substitution



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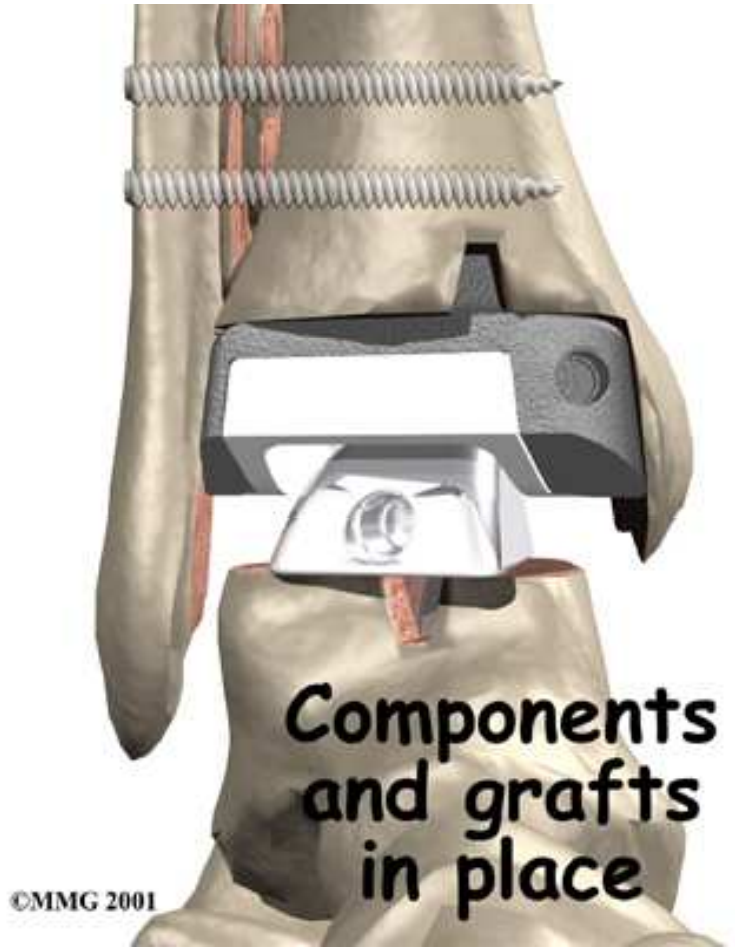
Ankle joint



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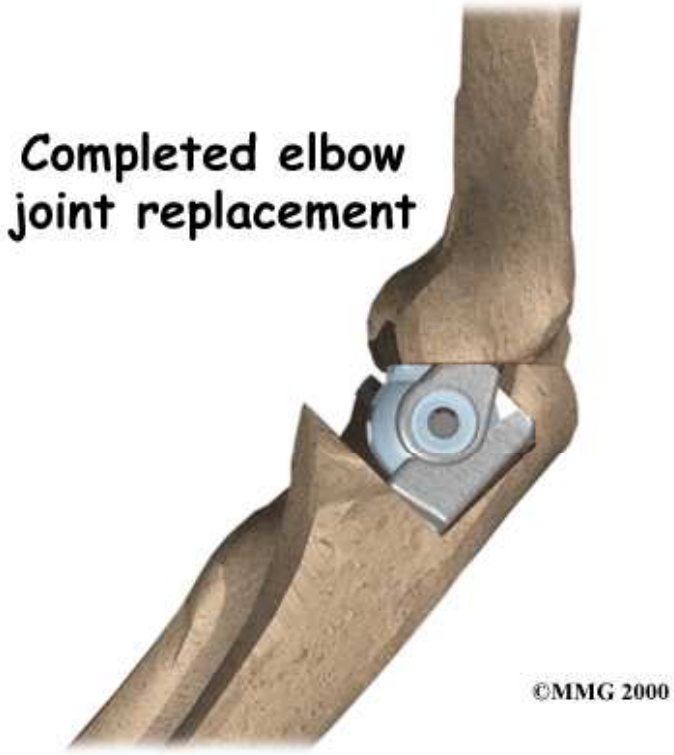
http://www.orthogastonia.com/patient_ed/html_pages/ankle/ankle_arthroplasty.html

Elbow and shoulder joint substitution



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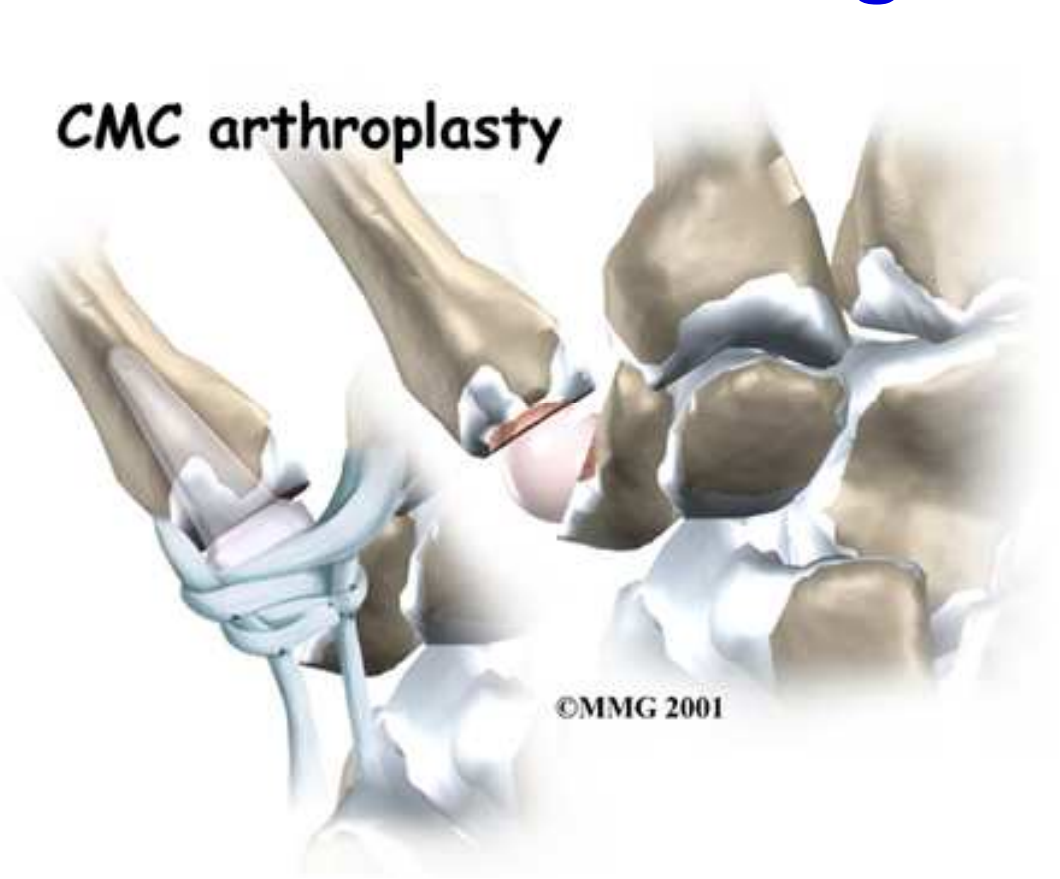
http://www.orthogastonia.com/patient-ed.html

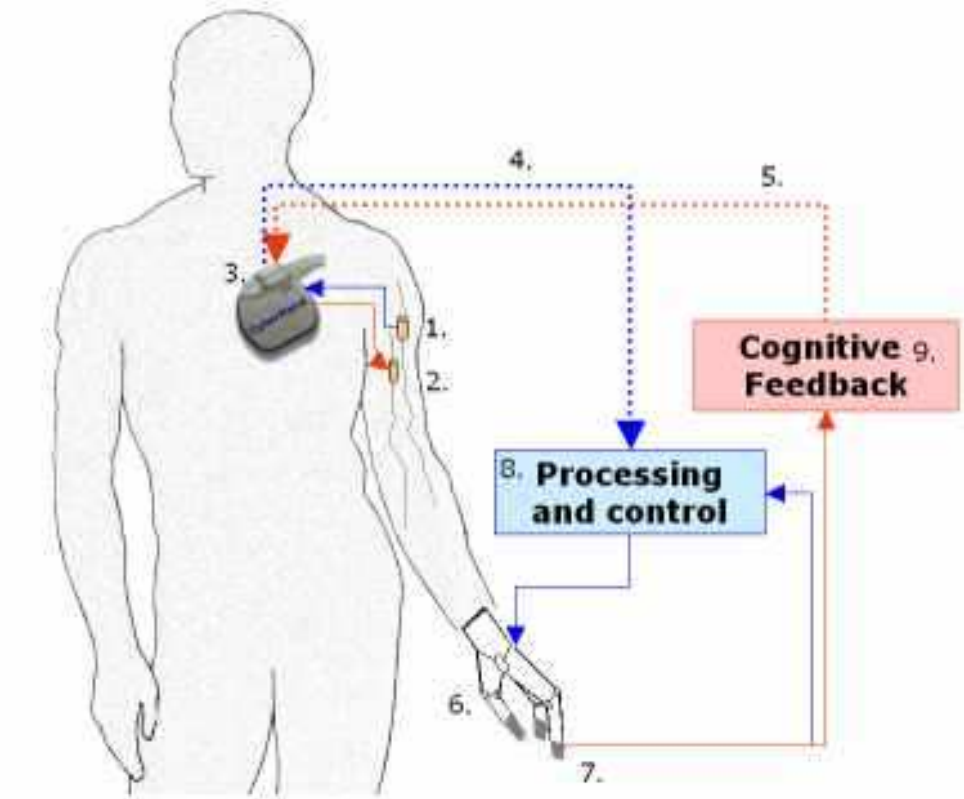
Joints of thumb and fingers



CMC = carpometacarpal

http://www.orthogastonia.com/patient_ed.html

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.

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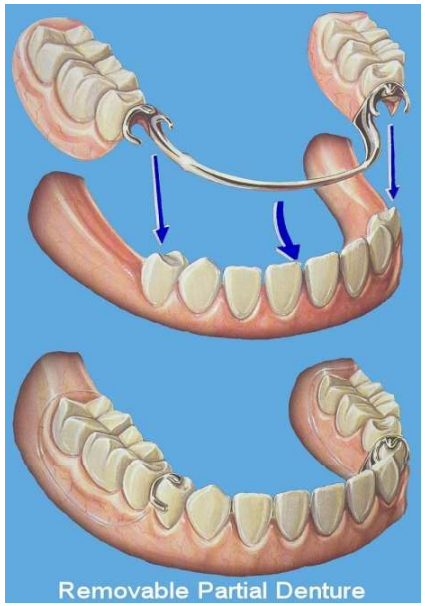
http://www-arts.sssup.it/research/projects/CyberHand/default.htm

Dental prostheses

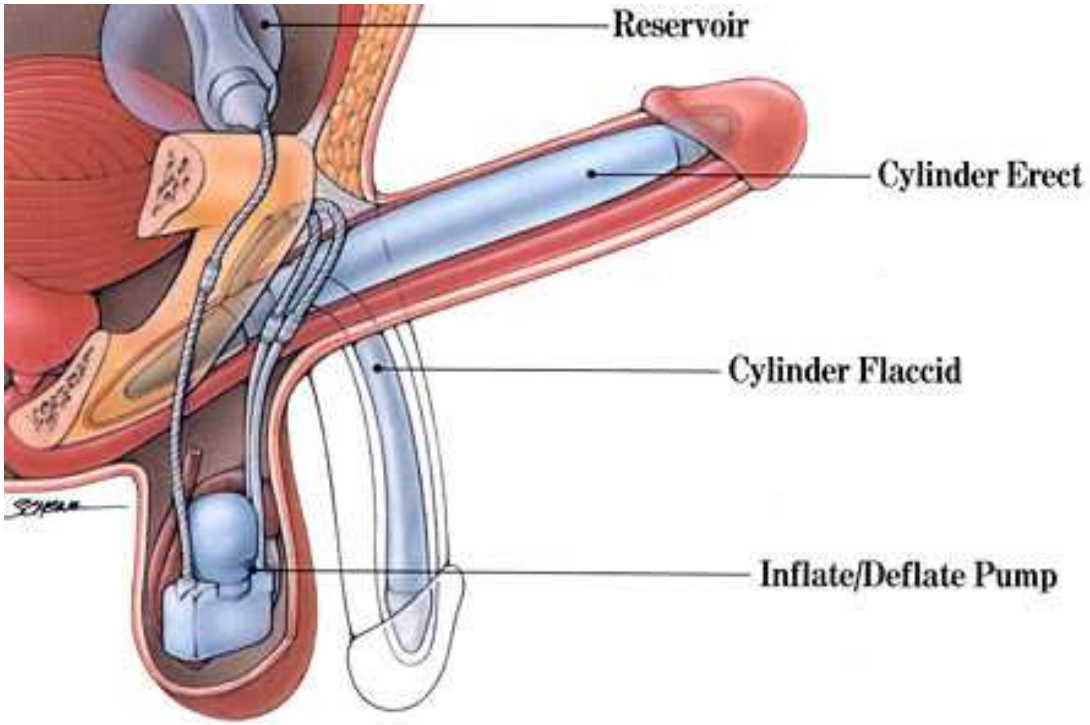


Partial prosthesis

Removable upper prosthesis

Preparation of the bed for total fixed dentition substitution

Penile endoprosthesis



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Author: **Vojtěch Mornstein**

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