Welcome to FYS 4250!





http://www.cpdevent.com.au/wp-content/uploads/2015/11/disruptive-tech-1600x600-c-default.jpg

FYS 4250

Lecture 1

Welcome to FYS 4250

Today's program

1. A short introduction to the course
2. Case 1



Before we start:





https://chantellglenville.com/happiness/the-problem-of-expectations/

Introduction to FYS 4250

What is the main goal for FYS 4250?

- *To give the students an overview of the basic concepts of biomedical instrumentation*



Seemallorca.com

Introduction to FYS 4250

What should the student be capable of?

- Know the different medical technologies, describe the use, area of application and working principle, limitations, distinctive technological feature, strengths/weaknesses, sources of errors. Both alone and compared to other similar technologies



www.withfriendship.com

Introduction to FYS 4250

How shall we be able to reach our goals?

- 16 Patient cases, each introducing different aspects of medical technology
- 1 Special lecture
- 2 Repetitions of the main technologies
- 1 Field trip to Oslo University Hospital
- 2 Exams (Mid-term exam = 40% of your final grade, and the final exam = 60% of your final grade)



Epicrapbattlesofthistory.wikia.com

What is special with medical instrumentation?

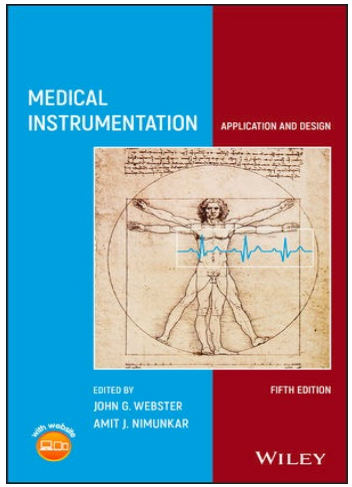
It’s about medical devices:

- Often critical or life critical
- Heavily regulated
- Often connected to a patient, risk of electrical shock
- Must be reliable
- Must endure aggressive cleaning agents
- Must be resistant to moisture
- Advanced signal processing, often measuring small signals in an ocean of noise
- Must be resistant to electrical noise
- Must tolerate one error without putting the patient in danger



http://image.made-in-china.com/2f0j00iCBQTrskJZpa/Medical-Equipment-ICU-Ventilator-Cwh-3010A.jpg

Introduction to FYS 4250

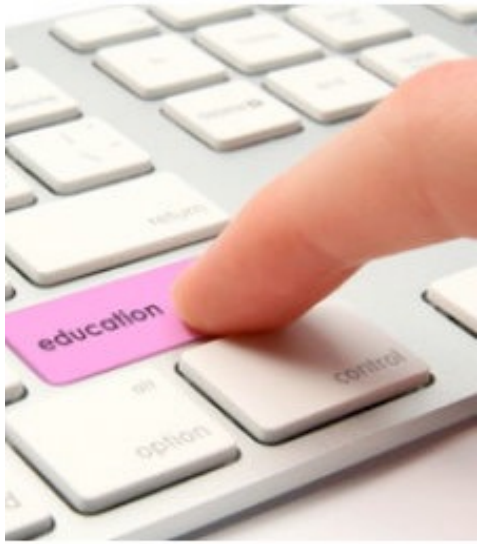


What about the practical issues?

- We will use the “Medical Instrumentation, 5th edition, John Webster” but you can use 3rd or 4th edition if you like
- We will use some offprints from other sources (compendium)
- The time schedule will be published on the homepage, any departure from this will be published in ”messages” at least 24h before the lecture
- Other practical issues (like exam-questions) will be handled by the institute

Introduction to FYS 4250

- Any other questions?
  - *Okay, let's start.*



Generalized medical instrumentation system

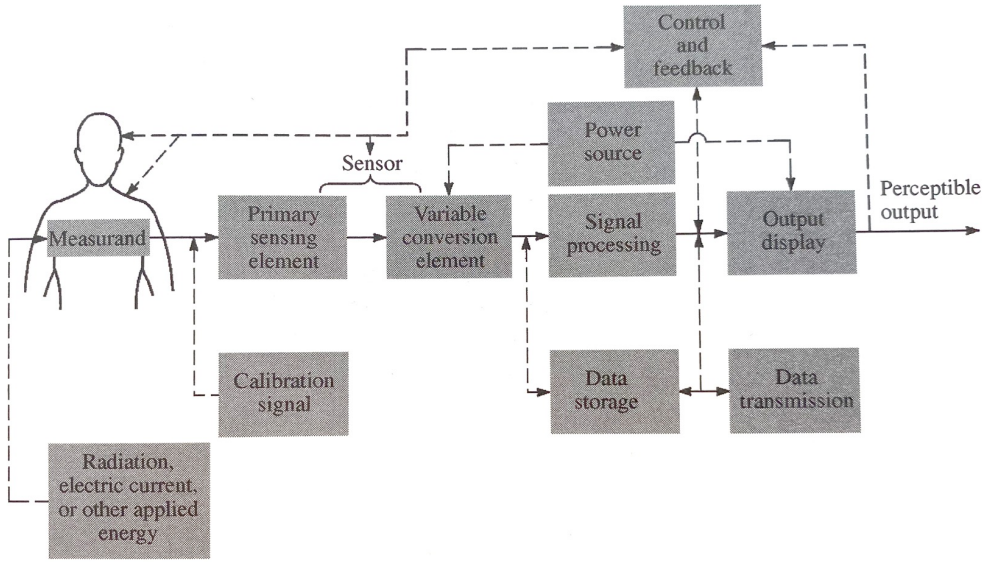


Figure 1.1 Generalized instrumentation system The sensor converts energy or information from the measurand to another form (usually electric). This signal is then processed and displayed so that humans can perceive the information. Elements and connections shown by dashed lines are optional for some applications.

Desired inputs = Measurands that the instrument is designed to isolate
Interfering inputs = Quantities that inadvertently affect the instrument as a consequence of the principles used to aquire and process the desired inputs
Modifying inputs = Undesired quantities that indirectly affect the output by altering the performance of the instrument itself

Case 1



- A twelve year old girl is non-diabetic, non-hypertensive and with no history of heart disease. Due to prematurity complications, she developed almost total deafness because of damage to sensory hair cells in her cochlea's. To counteract this, the patient had a cochlear implant before she was two years old.

- She had no regular medication, and she had no shortness of breath, chest pain, or any palpations associated with near syncopal incidents. She told however about of intermittent lightheadedness and dizziness. Her blood pressure was 135/75 with a pulse rate of 34, her skin was dry and warm, and no jugular venous distention was noted. She was slightly feverish with a temperature of 38.4°C and had a general feeling of fatigue.

Infrared ear thermometer

Q: Why do we need to measure the tympanic membrane?

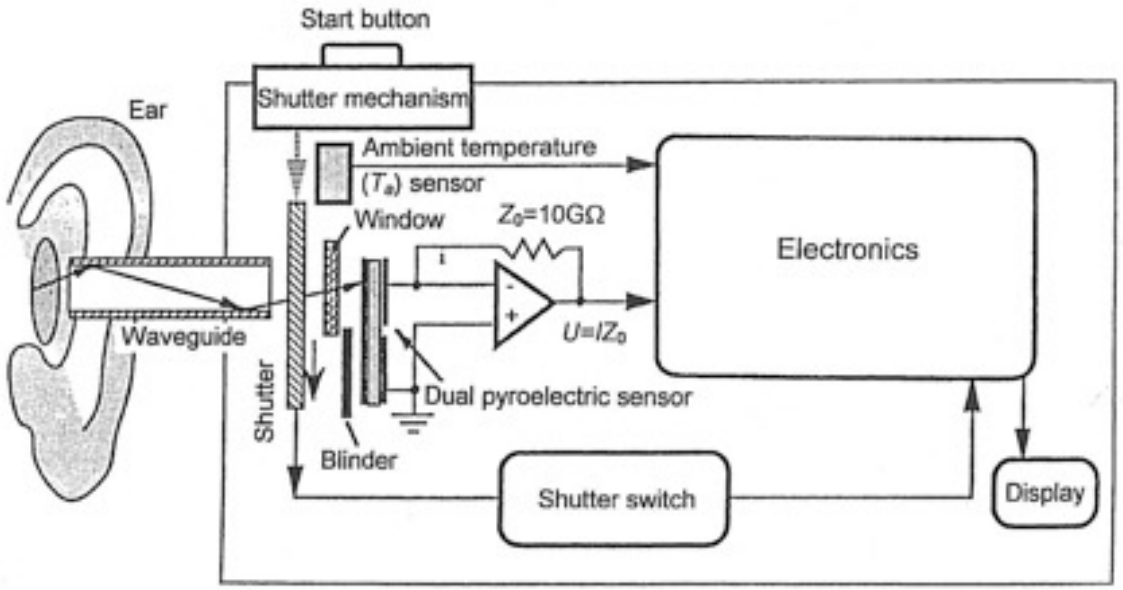


Image: Harsanyi, 2000, p 102

Application of radiation thermometry, determines core body temperature by measuring the magnitude of infrared radiation emitted from tympanic membrane and surrounding ear canal. (Tympanic membrane and hypothalamus are perfused by the same vasculature -> Hypothalamus is the body thermostat

Radiation thermometer

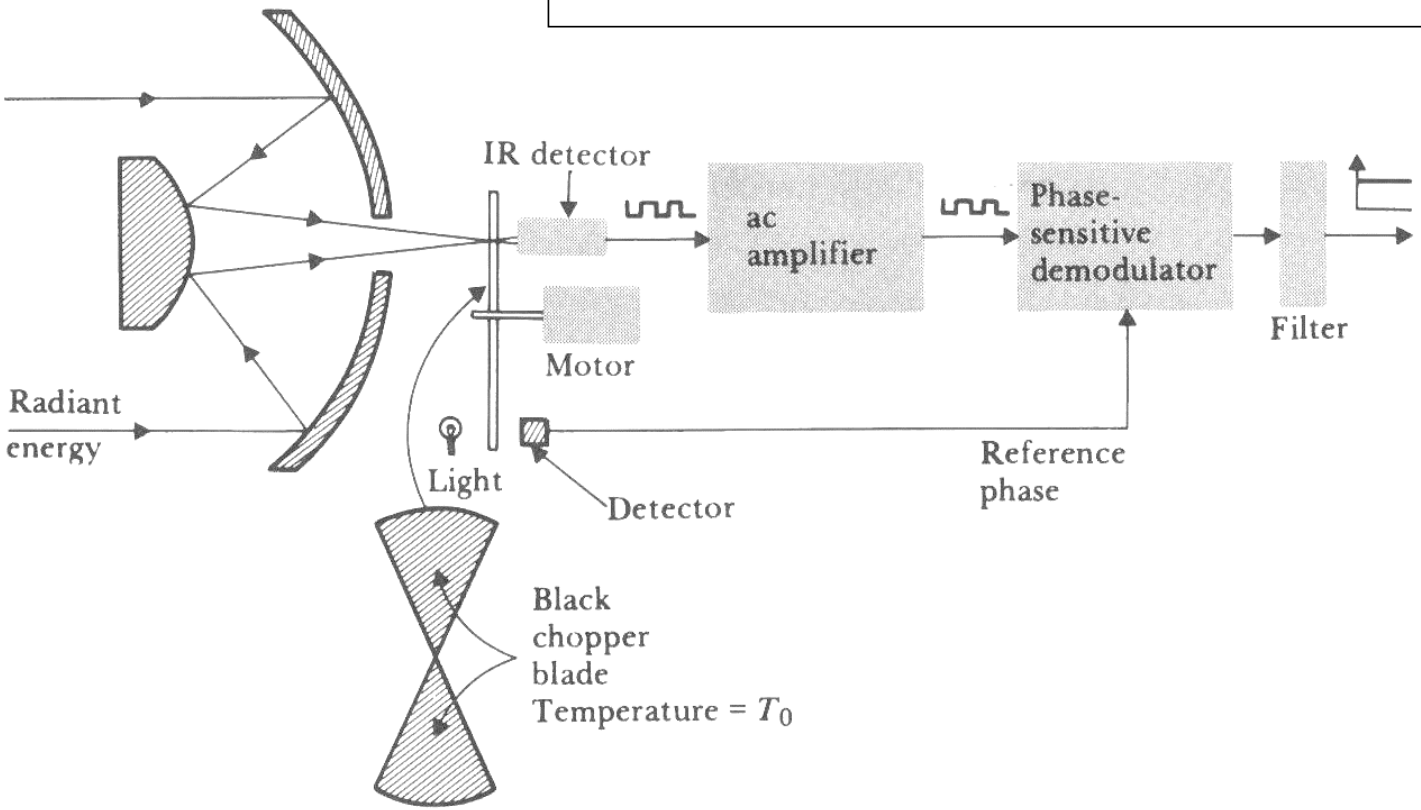


Figure 2.19 Stationary chopped-beam radiation thermometer (From *Transducers for Biomedical Measurements: Principles and Applications*, by R. S. C. Cobbold. Copyright © 1974, John Wiley and Sons, Inc. Reprinted by permission of John Wiley and Sons, Inc.)

Case 1



- Her doctors believe her symptoms may have roots in her early childhood and start to investigate her medical history. They find several astounding registrations, like lithotripsy at an age of twelve, a long period in an infant incubator after premature birth in week 25 resulting in a stroke and a cochlea implant at the age of 1,5 year.

Kidney stone crusher (Lithotripter)

Source: www.dornier.com

Exercise

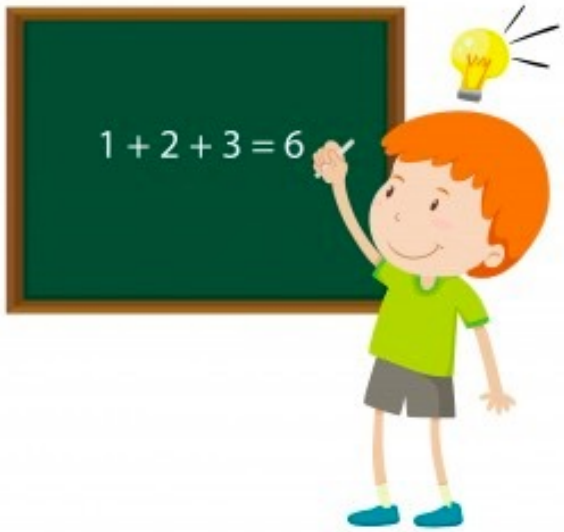
Form groups of 2 or 3 students, and discuss:

- Why is the energy from the sound waves or the electric discharge destroying kidney stones only, without harming the surrounding tissue?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answer



1. *The energy beam is focused with an ellipsoidic shaped reflector, the other focus point is the kidney stone*

Kidney stone crusher

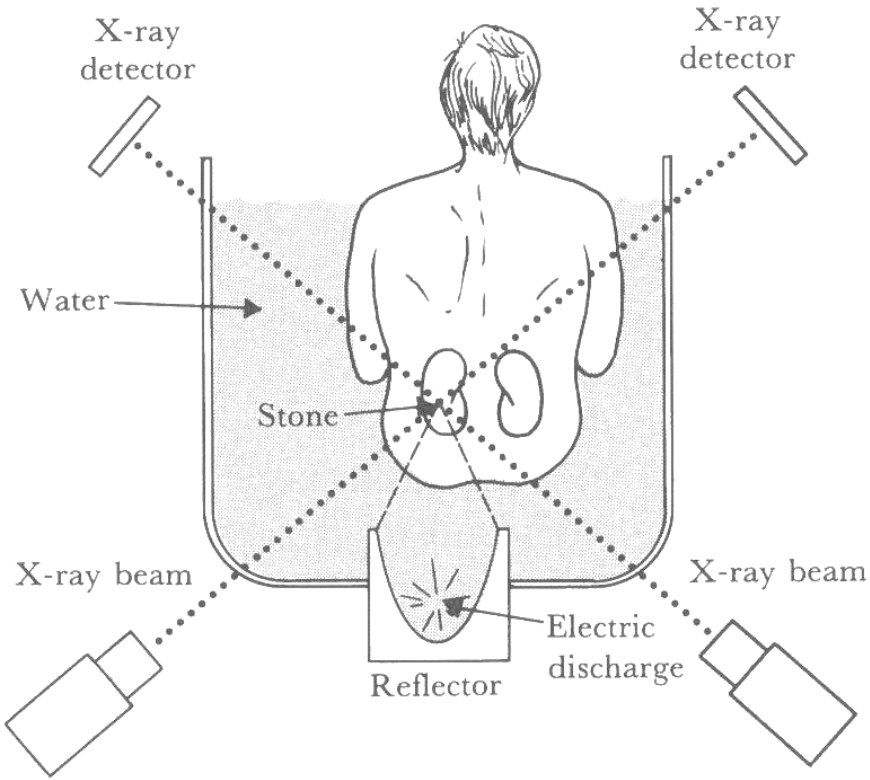
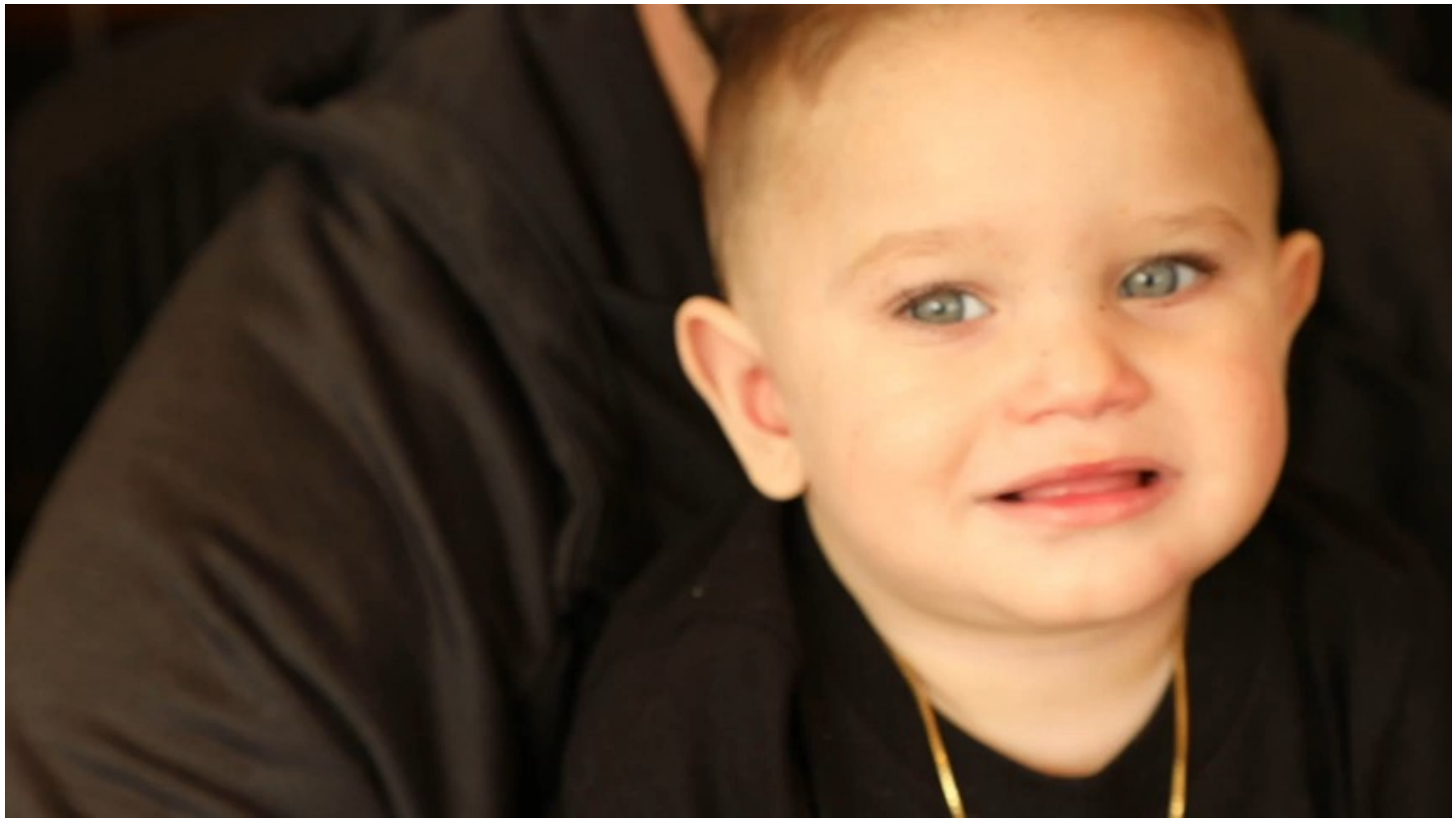


Figure 13.18 In extracorporeal shock-wave lithotripsy, a biplane x-ray apparatus is used to make sure the stone is at the focal point of spark-generated shock waves from the ellipsoidal reflector.


Cochlea
Implants
Medicaldevice-network.com

Cochlea implant



https://www.youtube.com/watch?v=7FXULNhUs1s

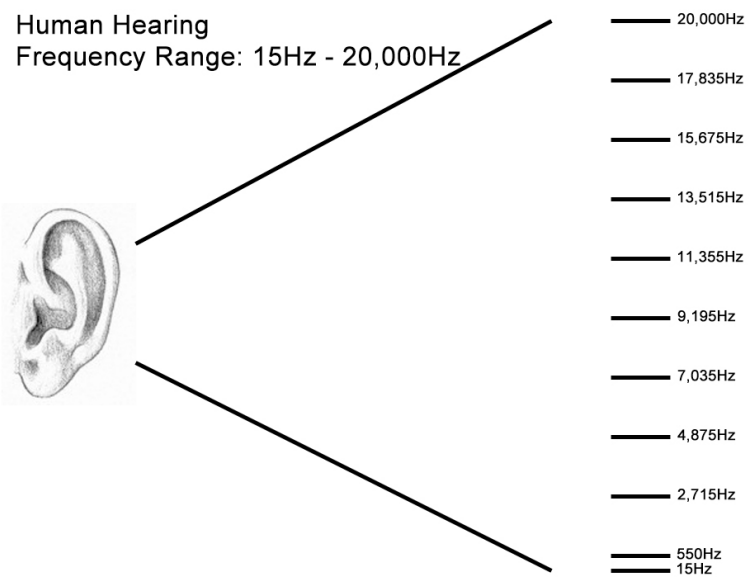
Hearing



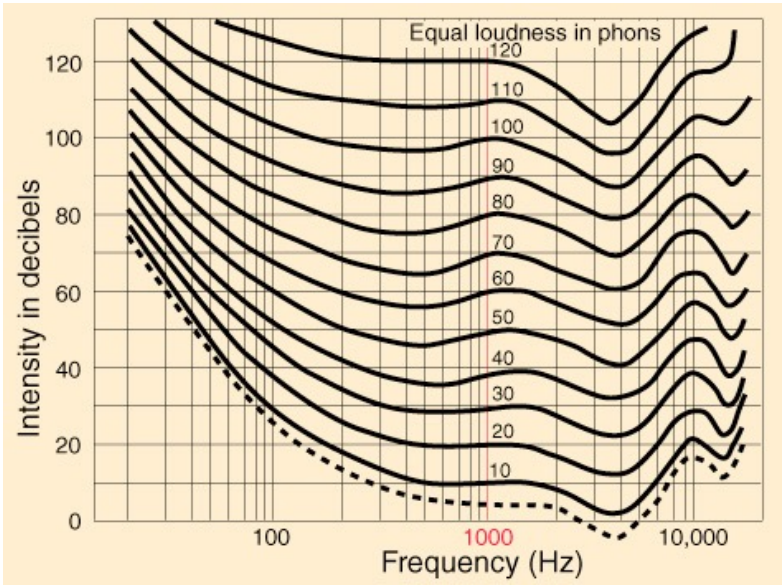
Source: Med-EL (https://www.youtube.com/watch?v=flIAxGsV1q0)

Hearing frequency range

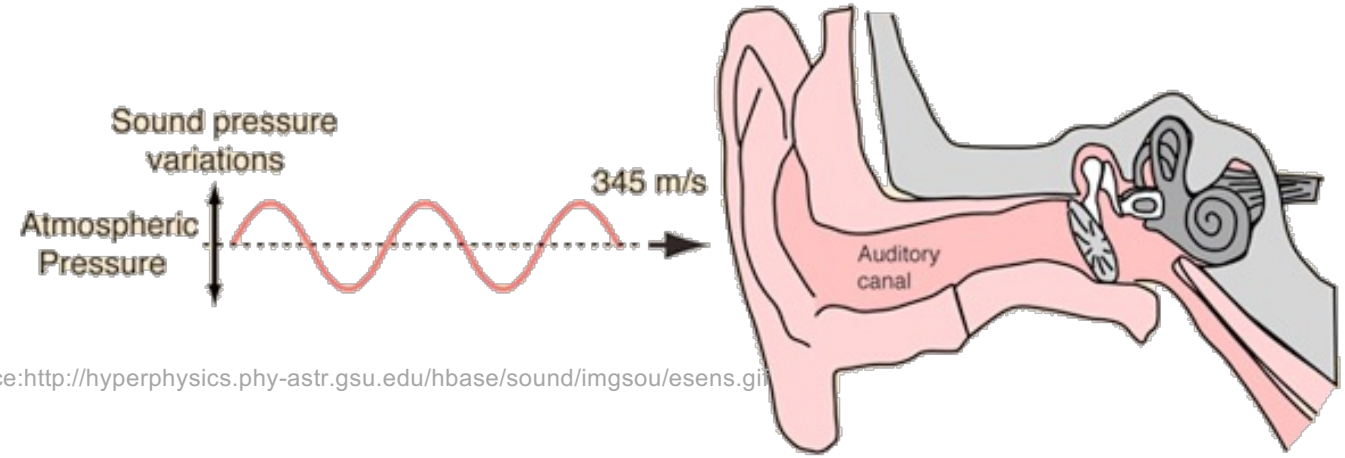
Sound intensity I(dB) = 10log (I/I (0)) = sound power per unit area (watts/m*m)
Sound Loudness is a subjective term describing the strength of the ears perception of a sound. Closely related but not identical to sound intensity. The sound intensity must be factored by he ear's sensitivity to the particular frequencies contained in the sound.



http://www.iigwest.com/investigations/meier/images/Meier_Audio_Hearing.jpg



http://www.nu9n.com/images/fletcher.jpg



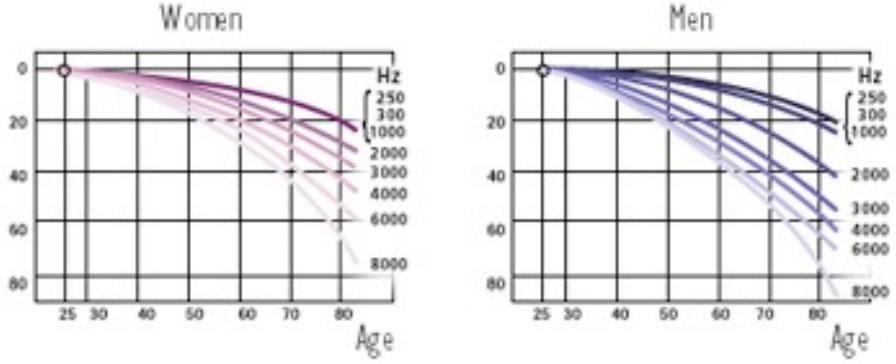
Source:http://hyperphysics.phy-astr.gsu.edu/hbase/sound/imgsou/esens.gif

The ear is incredibly sensitive:

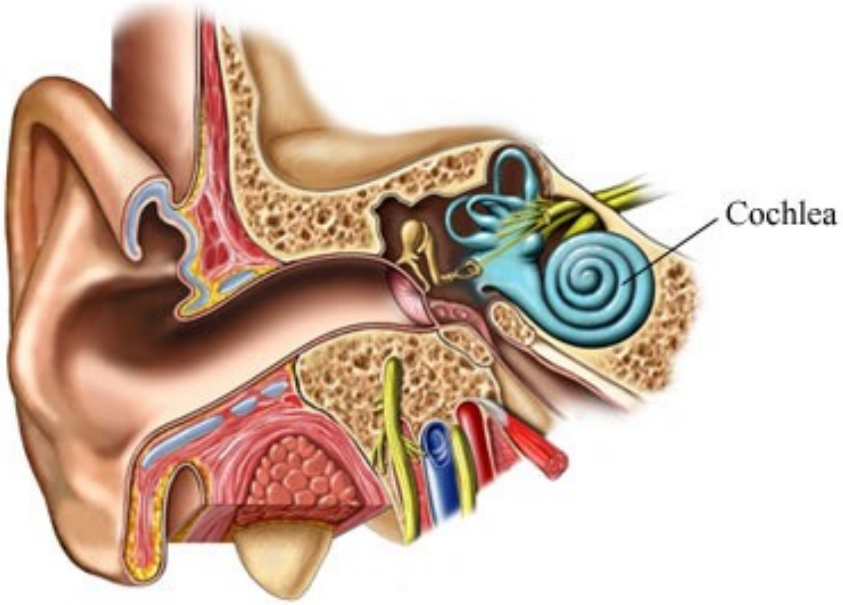
- The threshold of hearing is less than one billionth of atmospheric pressure

And has an incredible range of operation:

- Threshold of pain is 10^{13} of the threshold of hearing



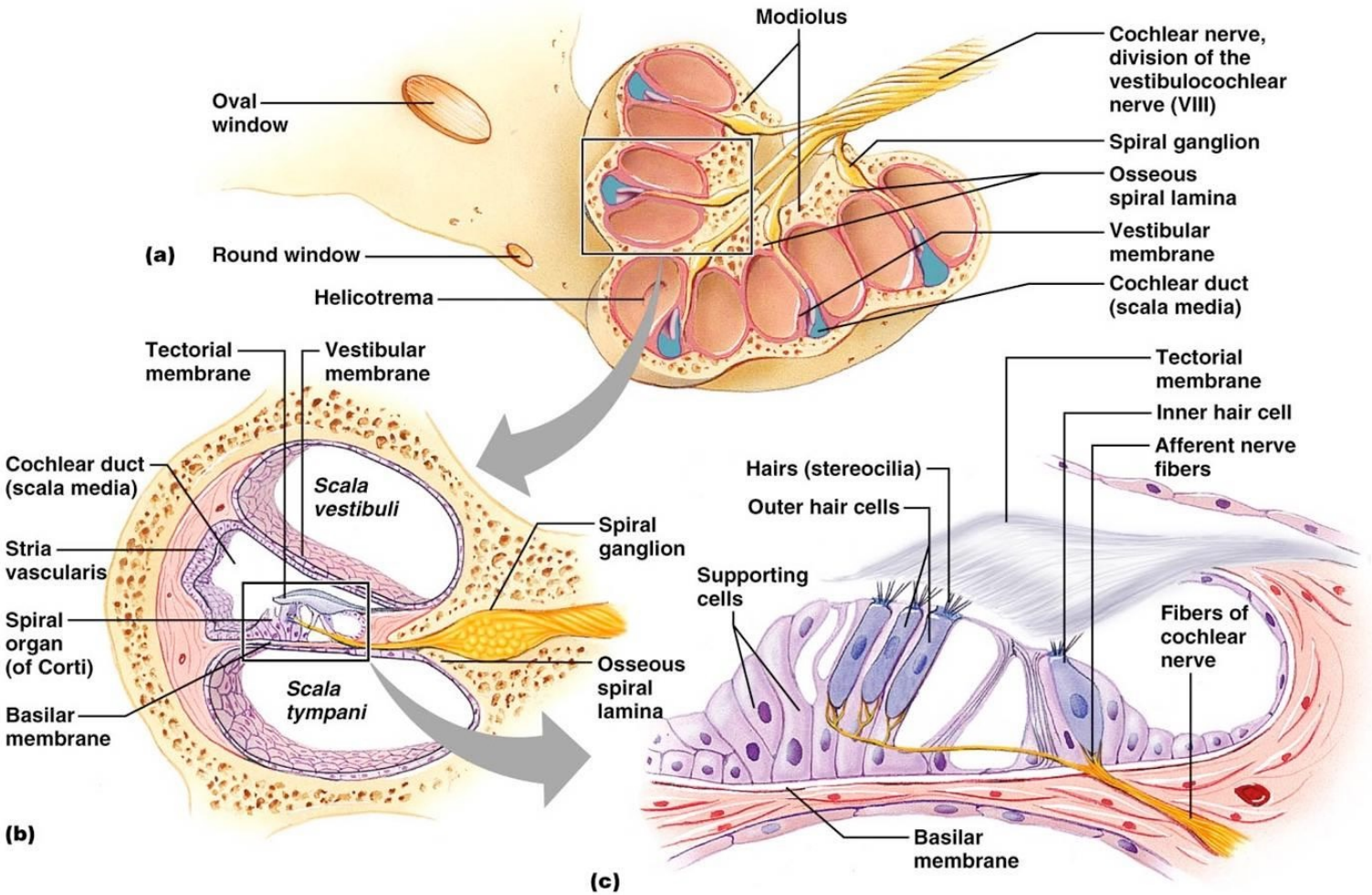
The Cochlea



http://www.odec.ca/projects/2007/park7r2/AQ00008_cochlea.jpg

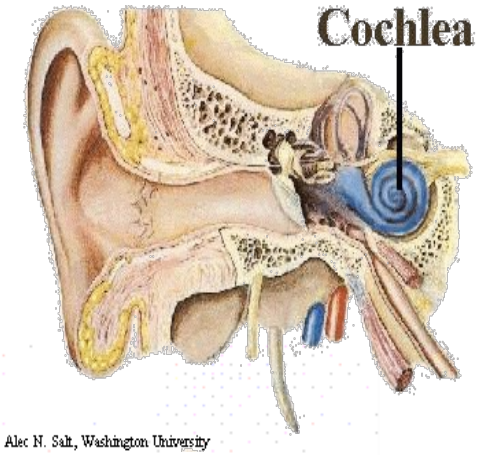
The cochlea is divided into an upper duct called the scala vestibuli and a lower duct, called the scala tympani, by a thin bony shelf called the osseous **spiral lamina**. It is a narrow shelf of bone arising from the modiolar side of the cochlea.

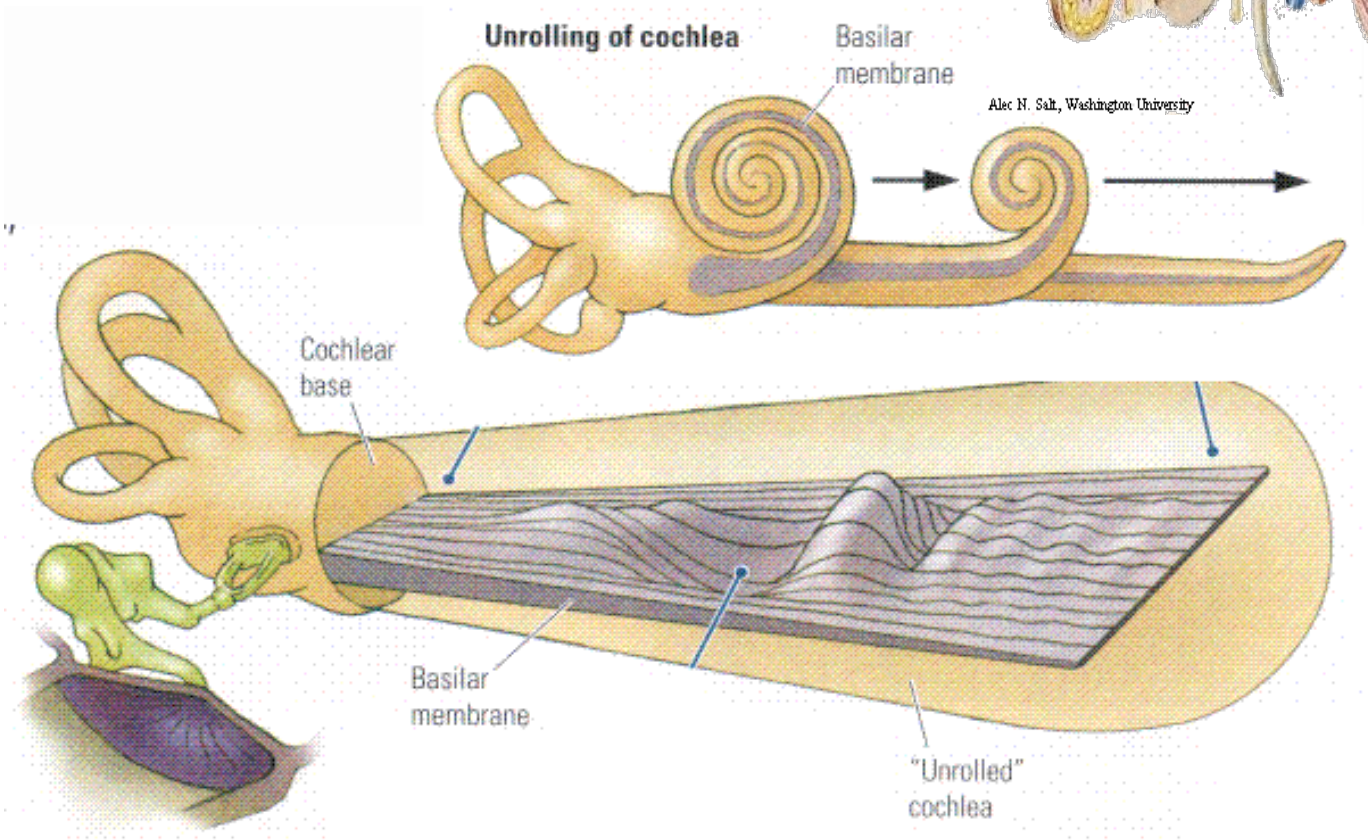
This division is completed by the membranous cochlear duct or scala media. Its floor is formed by the basilar membrane. The vestibular membrane, or Reissner's membrane, forms the roof of the scala media.



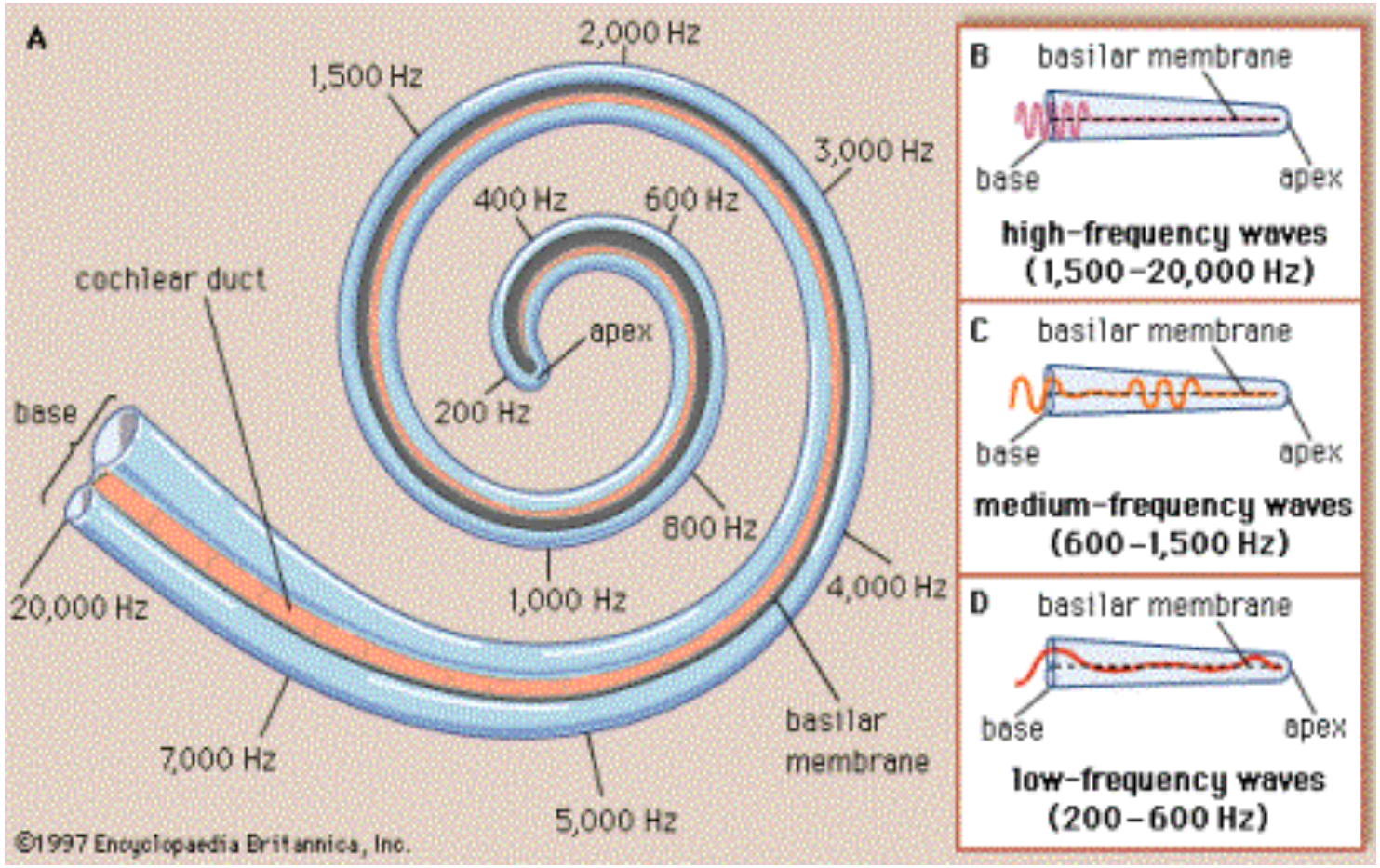
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The Cochlea

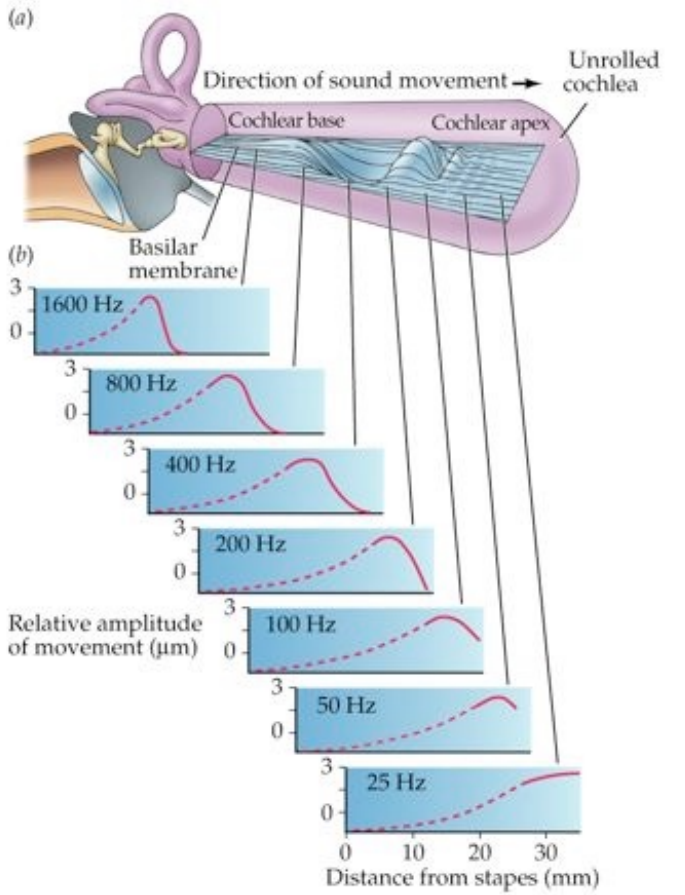




http://www.cs.indiana.edu/~port/teach/641/inner_ear.gif


A
2,000 Hz
1,500 Hz
3,000 Hz
400 Hz
600 Hz
cochlear duct
apex
200 Hz
base
800 Hz
20,000 Hz
1,000 Hz
4,000 Hz
basilar membrane
7,000 Hz
5,000 Hz
©1997 Encyclopaedia Britannica, Inc.
B
basilar membrane
base
apex
high-frequency waves (1,500–20,000 Hz)
C
basilar membrane
base
apex
medium-frequency waves (600–1,500 Hz)
D
basilar membrane
base
apex
low-frequency waves (200–600 Hz)

Frequency tuning



© 2001 Sinauer Associates, Inc.

Cochlear implant

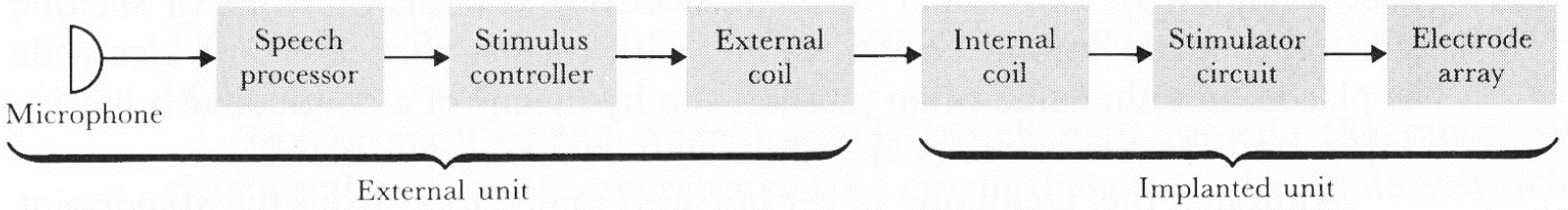
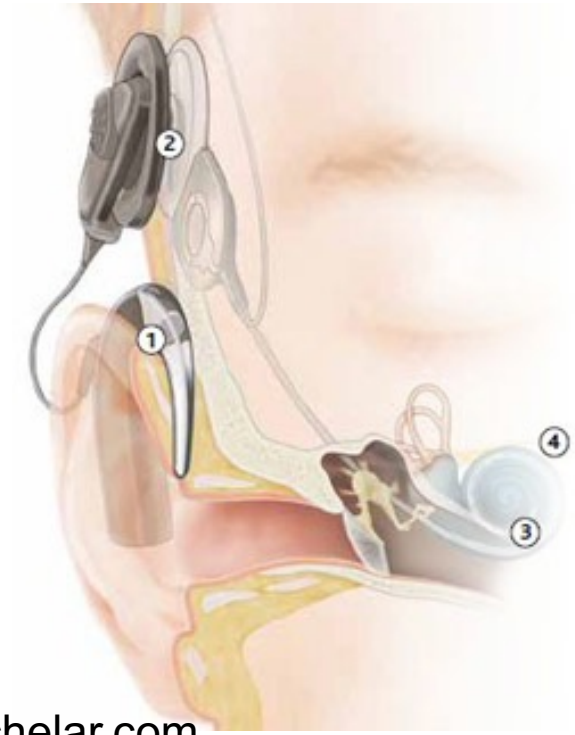


Figure 13.9 Block diagram of a cochlear prosthesis

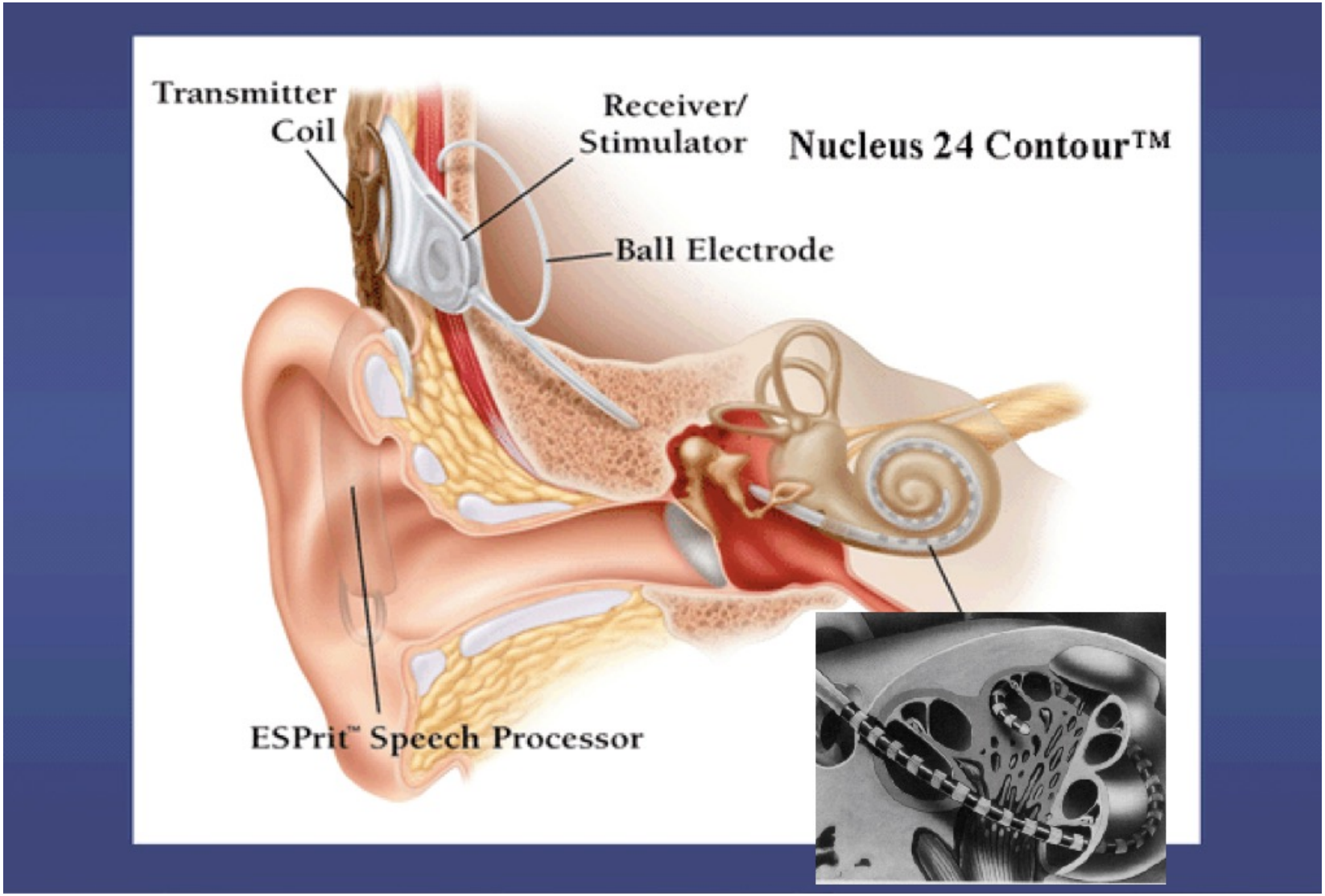
For deaf patients whose hearing impairment results from dysfunction of the sound-transducing elements of the middle and inner ear.
Speech processor = determines what specific characteristics will be used to control stimulating electrodes (Set of bandpass filters)
Stimulus controller = takes information from SP and uses it to determine when a stimulus pulse should be applied to a particular set of electrodes
Electrode array = array placed on a flecible structure that can assume spiral shape of the cochlea in contact with the cochlea-nerves (very small)

The cochlea implant



www.cochelar.com

Source: ESPrit



The CI-amplifier

Understanding speech is the ultimate goal, and at the same time a very complex task. Normal speech consists of a number of different frequencies, small shades and sounds that has to be perceived and combined in the brain in order to understand what is said. Deaf patients will typically have a 70-80 dB hearing loss, reaching a dynamic range of approximately 15-25 dB. At the same time very loud sounds have to be attenuated, a general fixed gain will be unpleasant for the patient. Requirements:

- Low power consumption
- Speed,
- A minimum of 60 dB dynamic range
- Variable gain
- The processor needs powerful algorithms to balance the gain and the electrode output

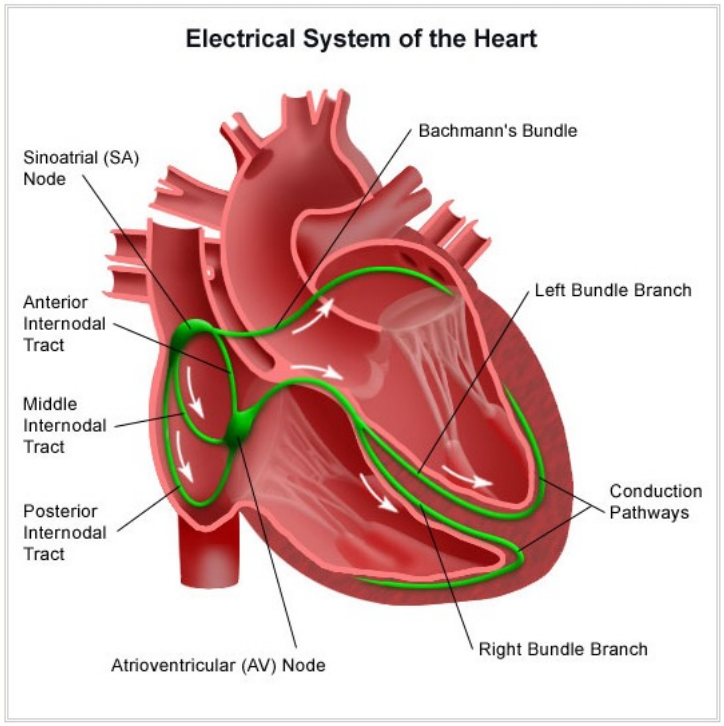
Case 1



- No explanation has been found in her medical history, and ECG monitoring for 24 hours is initiated. The heart rate seems to have been alternating between fast and slow, but there are no ST-elevation or other signs of infarction, neither are any murmurs or other typical cardiac symptoms. Based on exclusion of other explanations, she is diagnosed with a sick sinus syndrome, a disorder of the sinus node of the heart. As the sinus node fails to pace properly, the heart rate will be fluctuating. A sick sinus node can start the beats too slowly, pause too long between heartbeats or not producing paces at all.

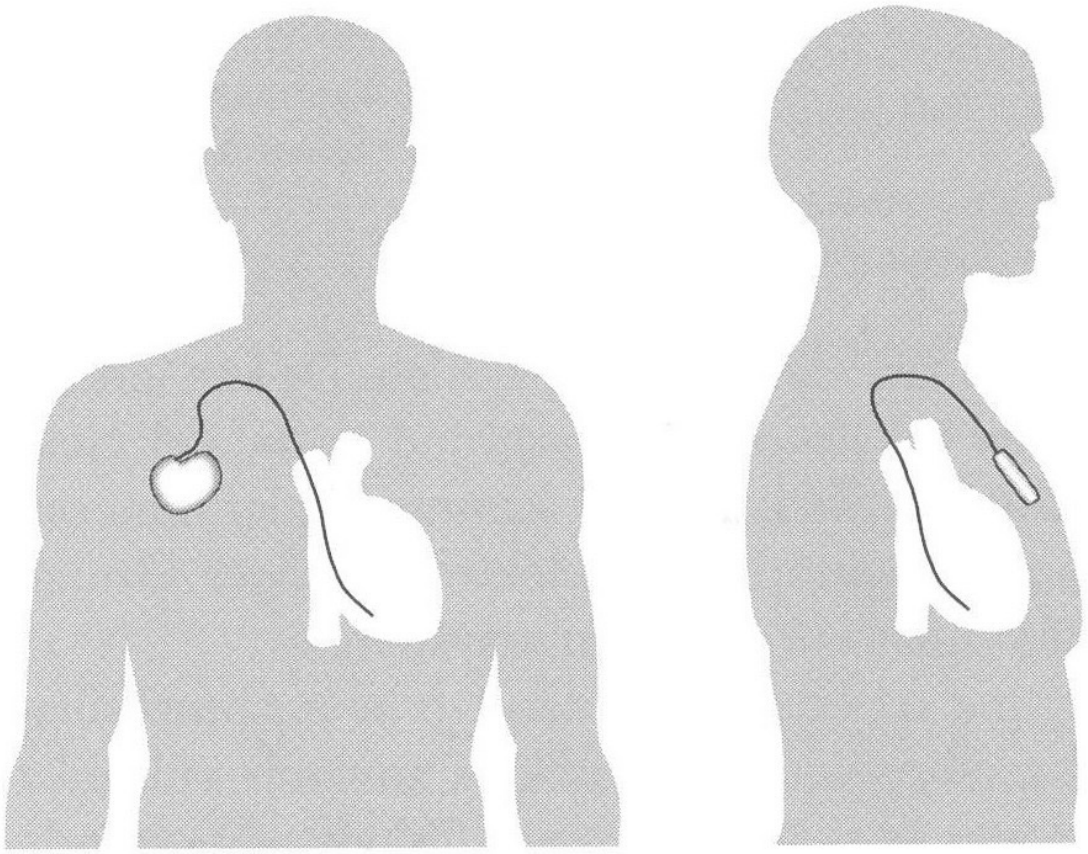
What is your treatment?

Conduction pathway



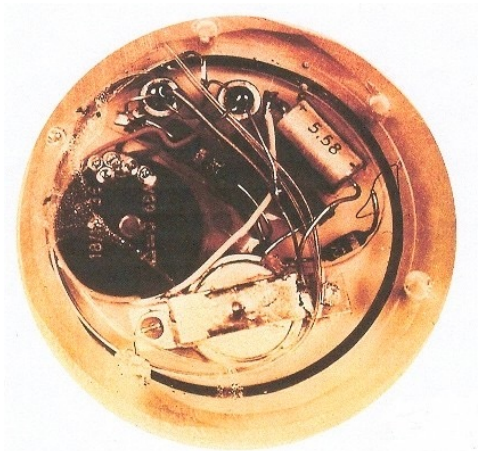
Source: St. Jude Medical

Active implant: pacemaker



Figur 3:51. Subkutant implanterad pacemaker med ledningar.

Pacemaker (Asynchronous)



https://www.understandinganimalresearch.org.uk/news/communications-media/top-ten-medical-inventions-pacemakers/

Q: What is the main problem with this device?

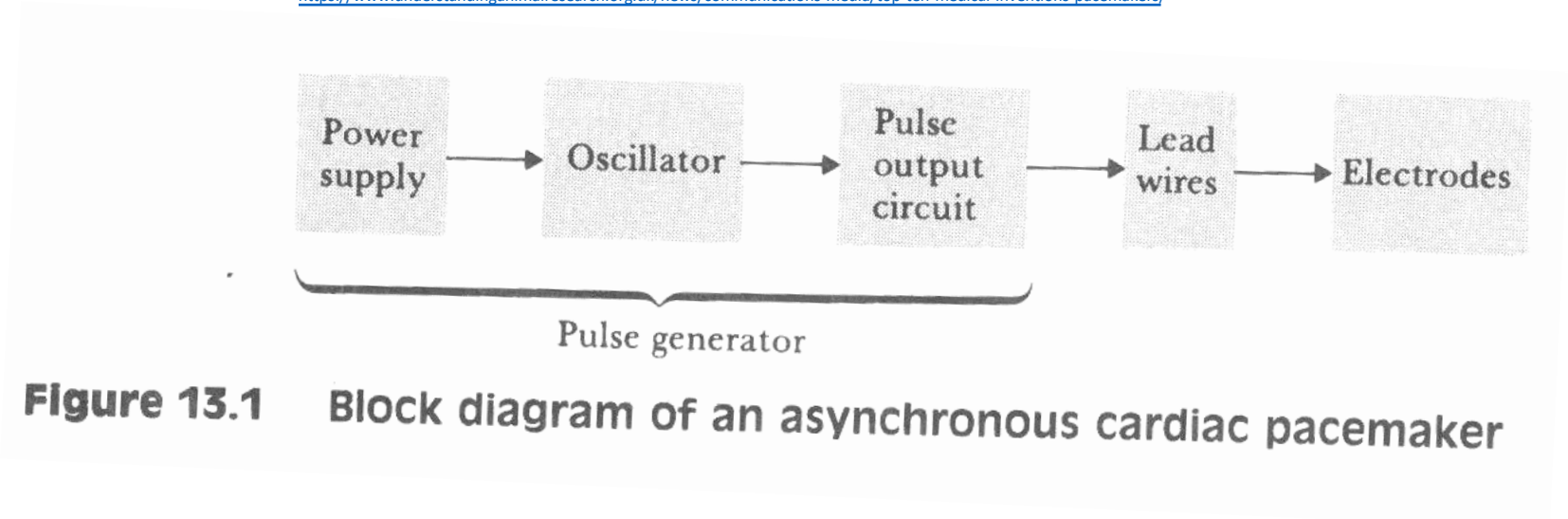


Figure 13.1 Block diagram of an asynchronous cardiac pacemaker

Demand pacemaker (Synchronous)

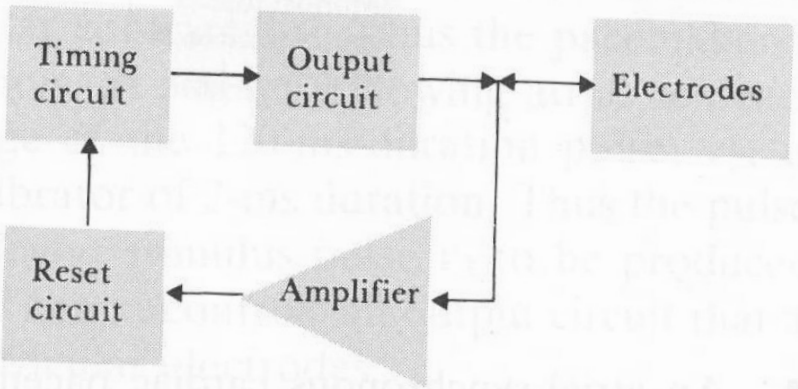


Figure 13.3 A demand-type synchronous pacemaker Electrodes serve as a means of both applying the stimulus pulse and detecting the electric signal from spontaneously occurring ventricular contractions that are used to inhibit the pacemaker's timing circuit.

Patients can establish a normal cardiac rythm between cardiac blocks -> continuous stimulations can result in serious complications. (artificial stimulus falls in repolarization period following a spontaneous ventricular contraction -> ventricular fibrillation).

Must not compete with the hearts' normal pacing action

Two synchronous types:

Atrial-synchronous pacemaker

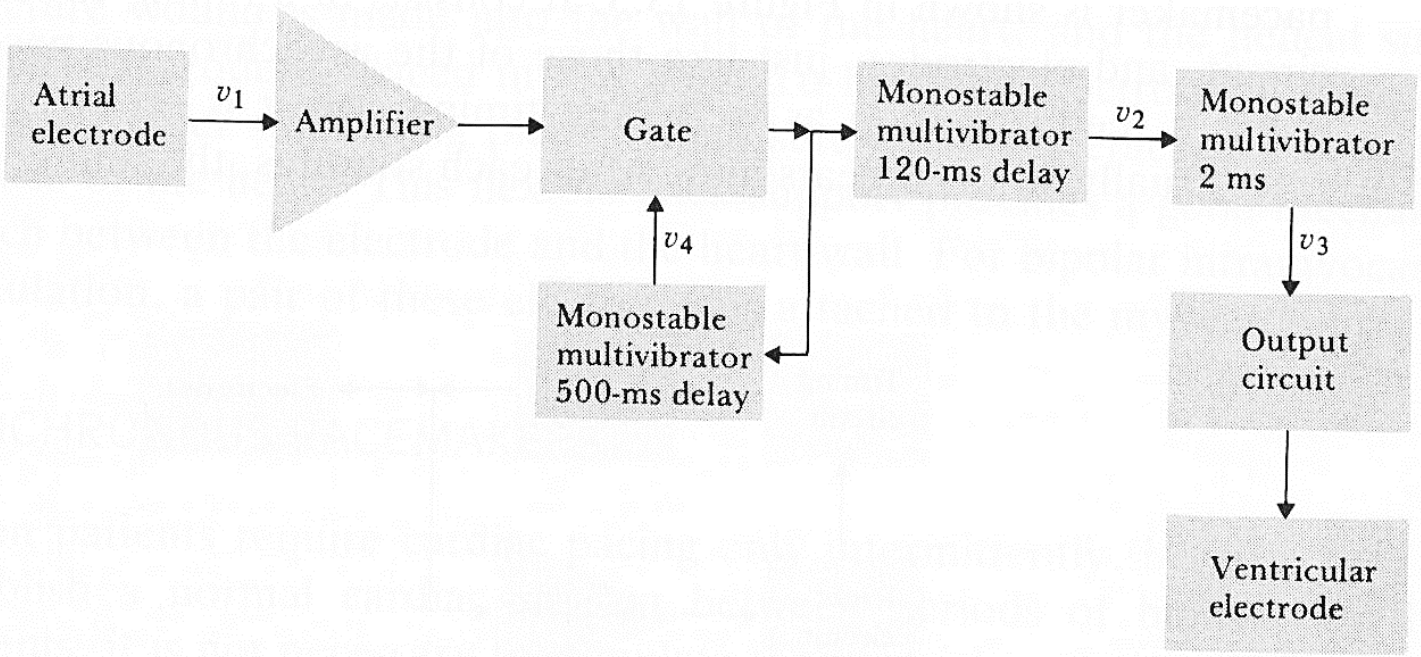


Figure 13.4 An atrial-synchronous cardiac pacemaker, which detects electric signals corresponding to the contraction of the atria and uses appropriate delays to activate a stimulus pulse to the ventricles. Figure 13.5 shows the waveforms corresponding to the voltages noted.

Second type: Atrial-synchronous pacemaker
Replace blocked conduction system of the heart, system is refractory
Fixed rates if atrial stimulus is lost -> combine demand pm with as pm

Physiologically controlled pacemaker

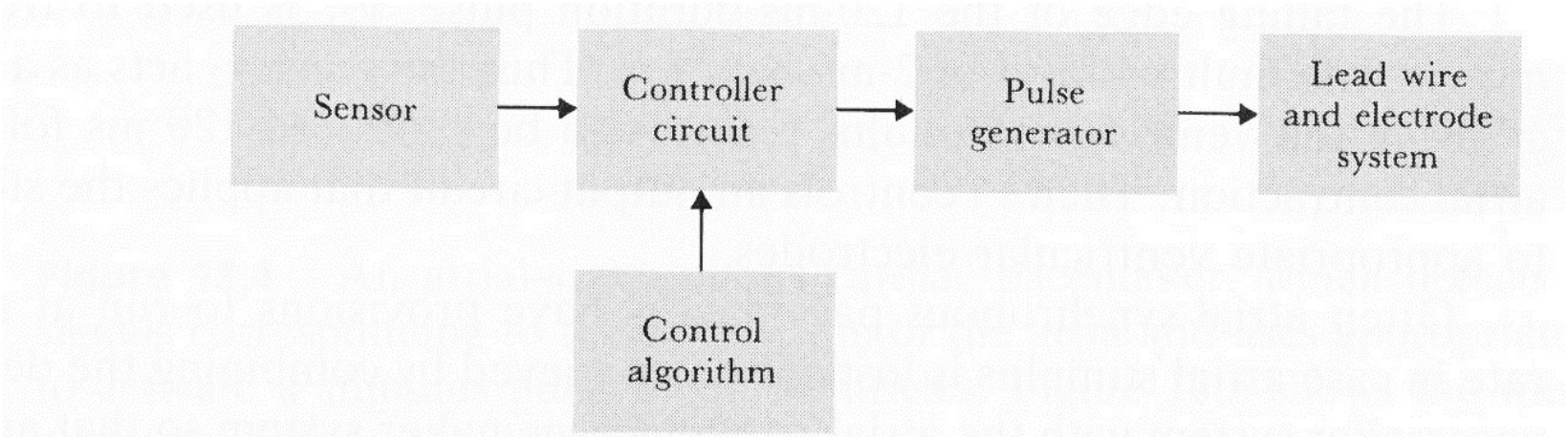
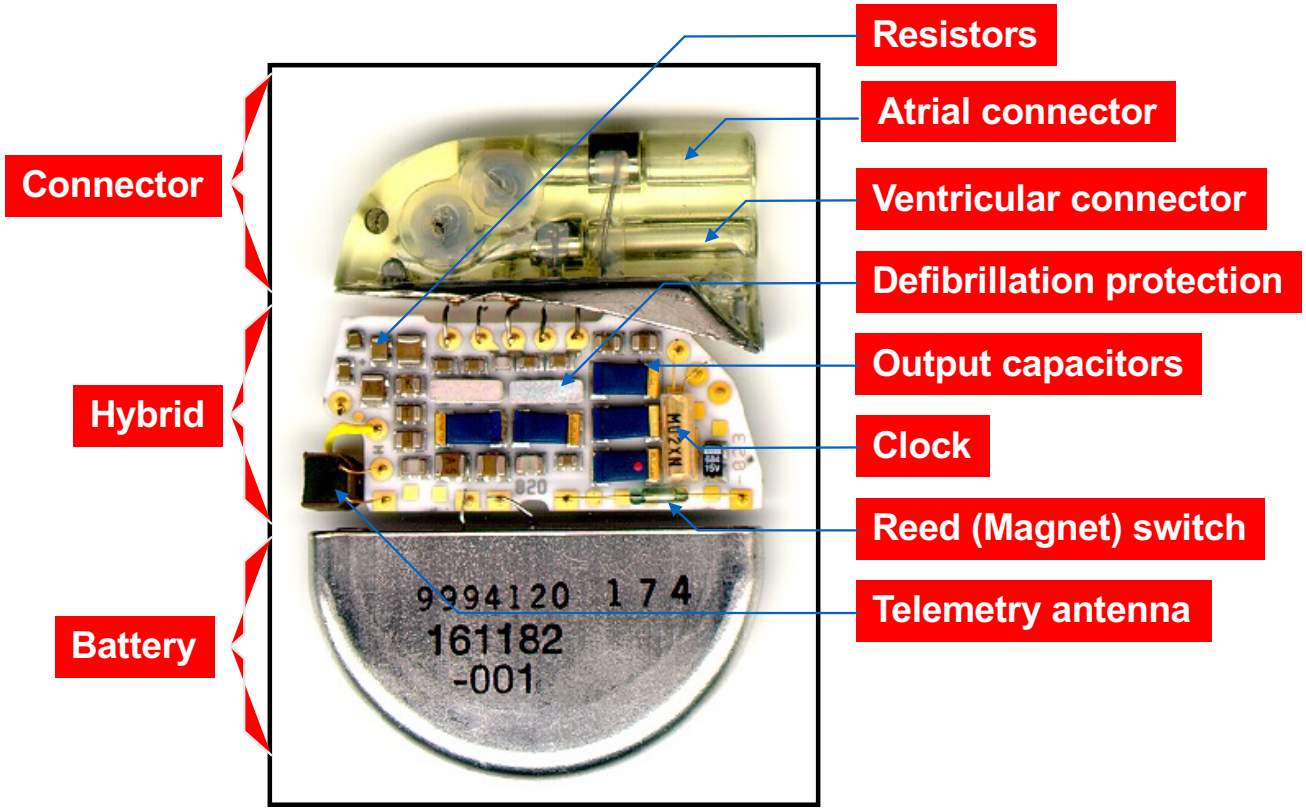
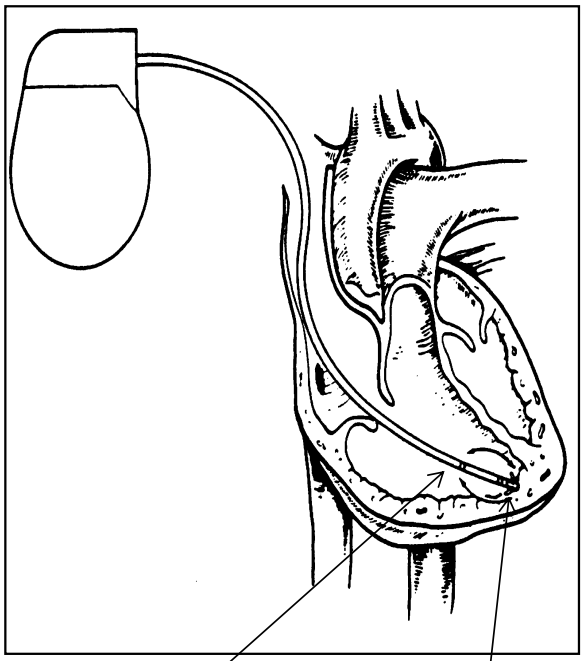


Figure 13.6 Block diagram of a rate-responsive pacemaker

Anatomy of a pacemaker



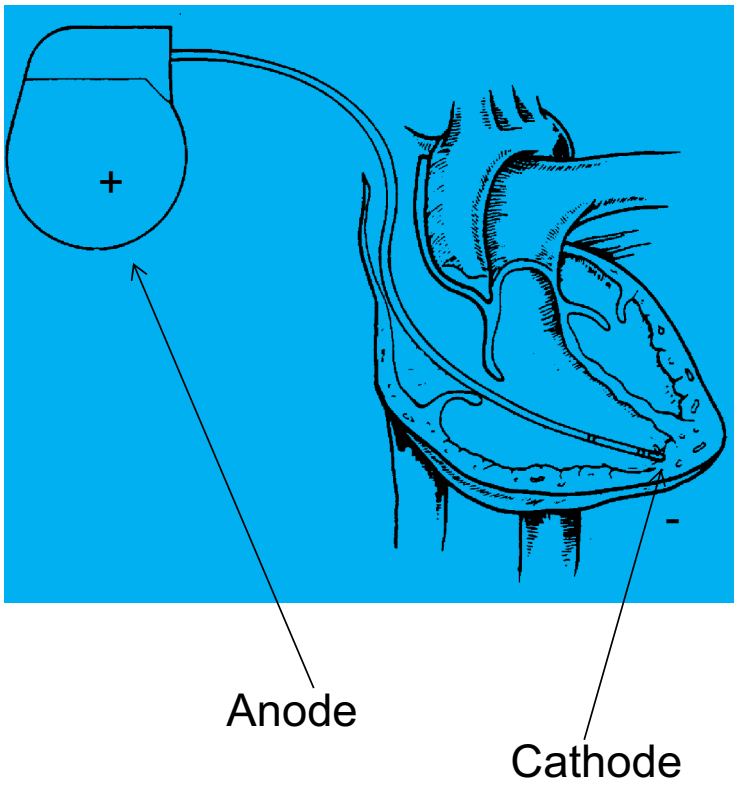
Two types, bipolar type



Source: www.Cardiologycmc.in

- Cathode is the electrode proximal to apex, negatively charged
- Anode is the electrode closer to the can that receives the electrical impulse after depolarization of the cardiac tissue. This is positively charged when the electric current is flowing

Two types, unipolar type



Source: www.Cardiologycmc.in

- Current is flowing through the cathode electrode through the myocard to stimulate the ventricle contraction of the heart
- Returns through the tissue and body fluids to the PG anode.

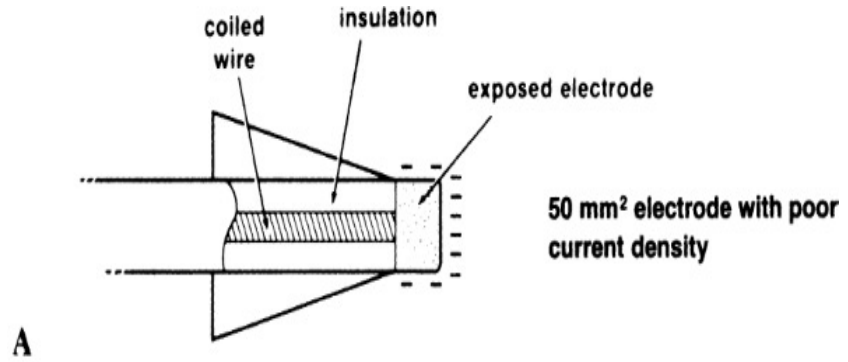
Unipolar vs Bipolar

	Unipolar	Bipolar
Advantages	Smaller diameter Easier to implant Large spike	No pocket stimulation Less susceptible to EMI Programming flexibility
Disadvantages	Pocket stimulation Far-field oversensing No programming flexibility	Larger diameter Stiffer lead body Small spike Higher impedance Voltage threshold is 30% higher

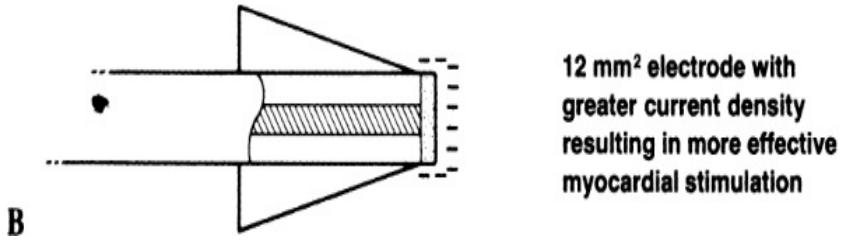
Source: www.Cardiologycmc.in

Impedance and electrodes

- Large electrode tip
  - Threshold ↑
  - Impedance ↓
  - Polarization ↓



- Small electrode tip
  - Threshold ↓
  - Impedance ↑
  - Polarization ↑



Metal / electrolyte = electron / ion transitions

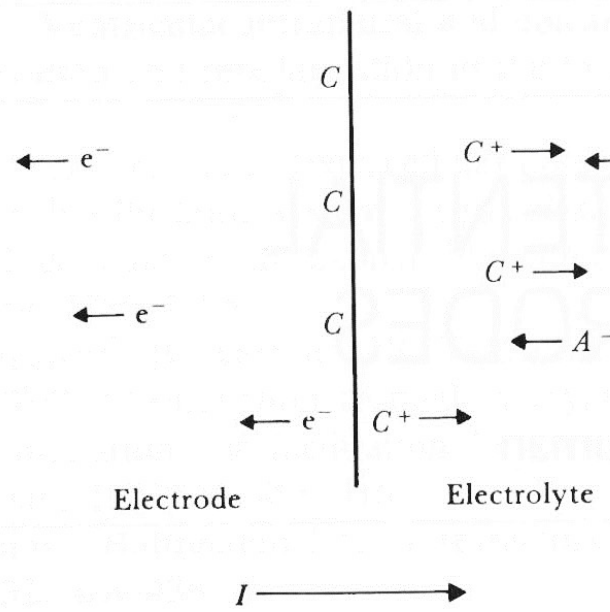


Figure 5.1 Electrode-electrolyte interface The current crosses it from left to right. The electrode consists of metallic atoms C. The electrolyte is an aqueous solution containing cations of the electrode metal C^+ and anions A^-.

A **half-cell** is a structure that contains a conductive electrode and a surrounding conductive electrolyte separated by a naturally occurring Helmholtz double layer. Chemical reactions within this layer momentarily pump electric charges between the electrode and the electrolyte, resulting in a potential difference between the electrode and the electrolyte

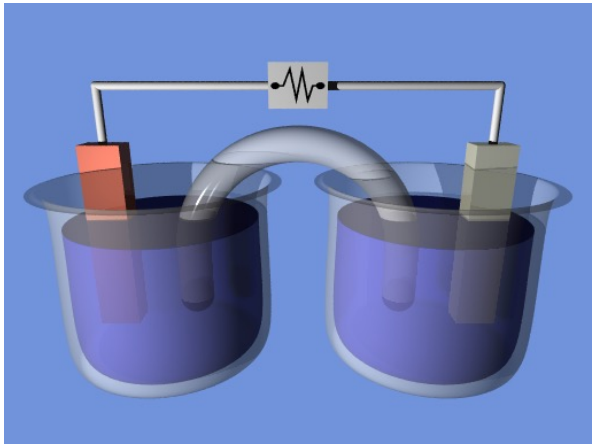
Half-cell potential is described for non-current situations
Current will alter the half-cell potential -> due to the polarization of the electrode

Overpotential = Diff betw observed half cell potential and the equilibrium zero-current half-cell potential
Three basic components:

1. Ohmic overpotential: Resistance of the electrolyte, voltage drop along current path in the electrolyte
2. Concentration overpotential: Due to changes in distribution of ions in the electrolyte in the vicinity of the electrode-electrolyte interface. The difference between current induced half-cell potential and equilibrium half-cell potentia = concentration overpotential
3. Activation overpotential: Charge-transfer process in oxidation-reduction reaction are not entirely reversible. (Energy barrier in order to start reaction). Current direction decides if oxidation or reduction predominates and thus the energy barrier = difference in voltage between electrode and electrolyte

All three mechanisms are additive

Theoretically two types of electrodes: Perfectly polarizable and perfectly non-polarizable
PP: no actual charge cross electrode electrolyte interface when current applied. (Behaves as a capacitor) (Platinum, noble metals)
PNP: Current passing freely across electrode-electrolyte interface (Ag/Agcl, slightly soluble in water = stable)



https://www.coursehero.com/study-guides/introchem/free-energy-and-cell-potential/

Ag / AgCl
Non-polarizable electrode

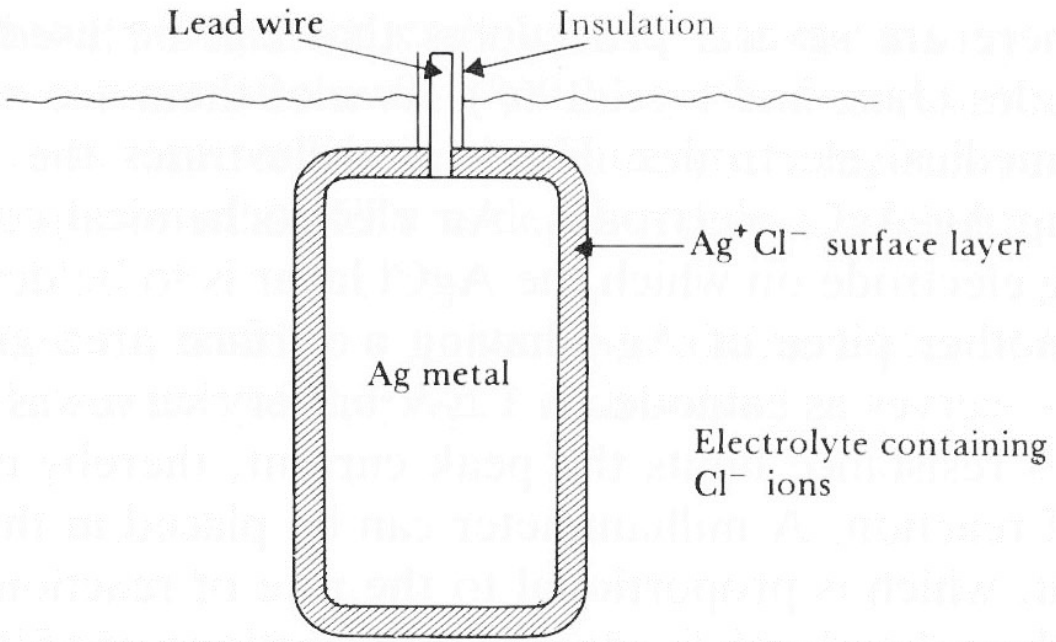
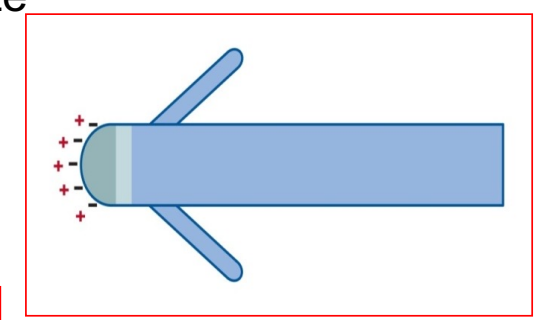


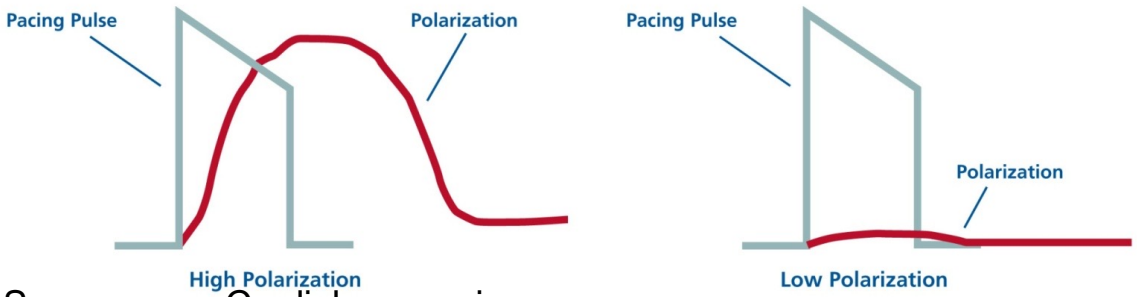
Figure 5.3 A silver–silver chloride electrode, shown in cross section.

Polarization

- After an output pulse, positively charged particles gather near the electrode.
- The amount of positive charge is
  - Directly proportional to pulse duration
  - Inversely proportional to the functional electrode size (i.e. smaller electrodes offer higher polarization)

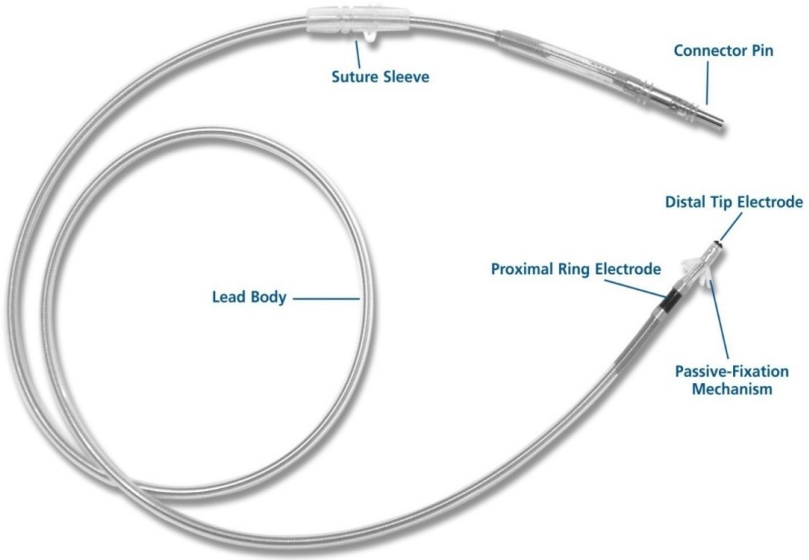


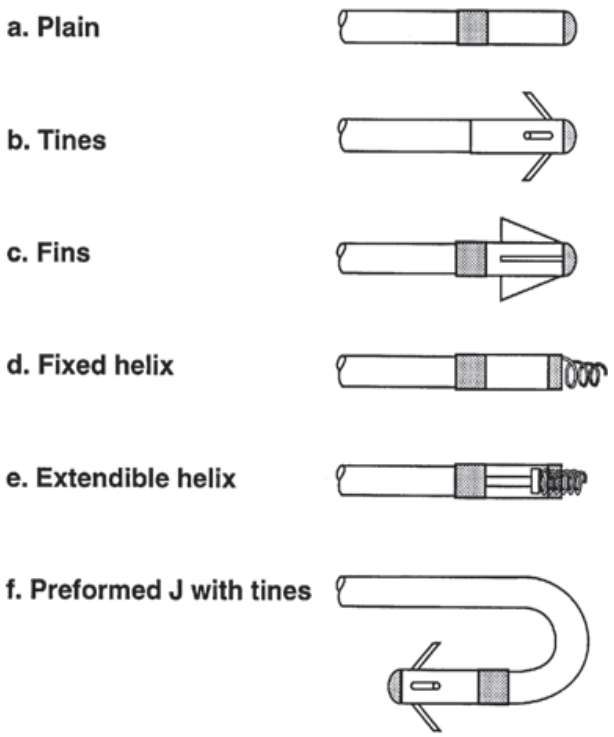
Polarization effect may represent 30–40% of the total pacing impedances as high as 70% for smooth surface, small surface area electrodes



Source: www.Cardiologycmc.in

Lead components and fixation mechanisms



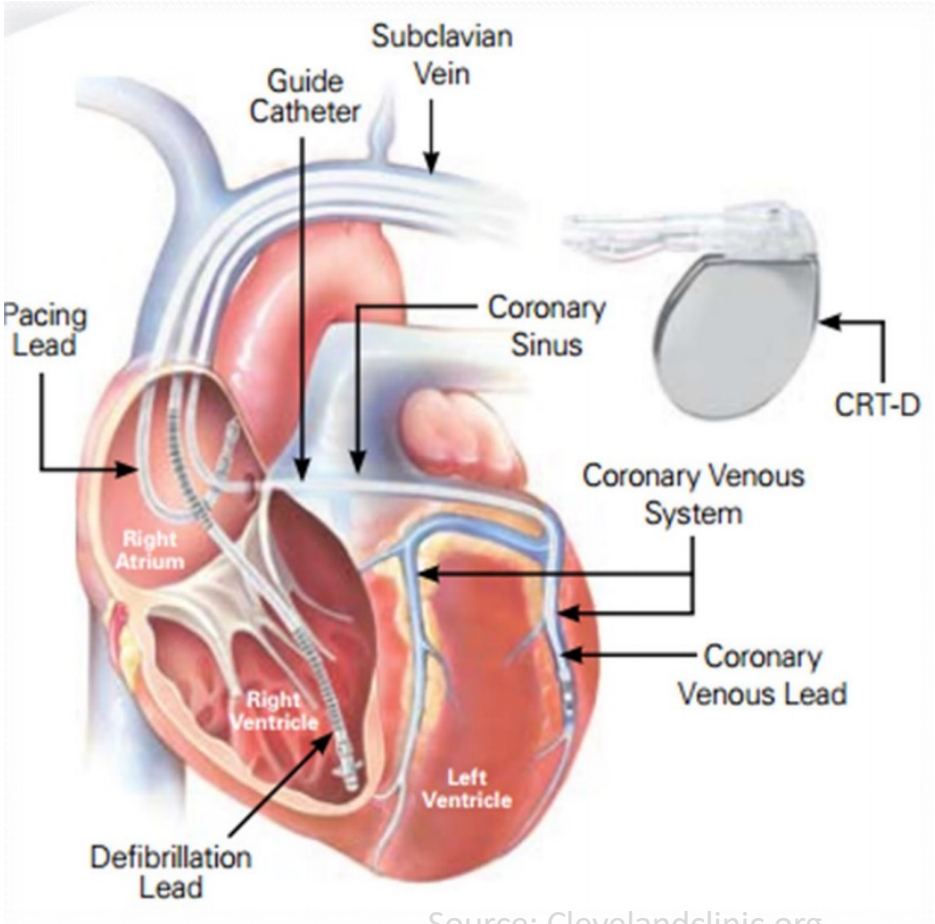


Implantable cardioverter defibrillator

Main aims:
To synchronize stimulation of both ventricles

To synchronize contraction of both ventricles

Combination of a pacemaker and a defibrillator, and it is implantable



Source: Clevelandclinic.org

Exercise

Form groups of 2 or 3 students, and discuss:

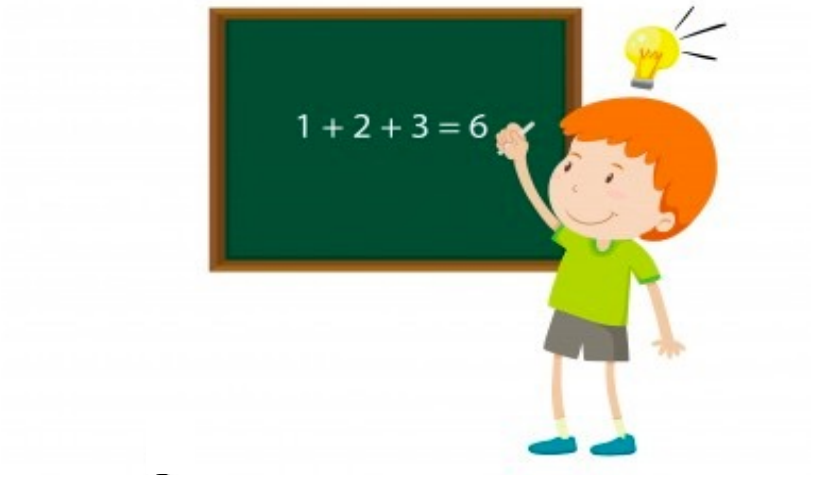
1. If a patient with a pacemaker is undergoing a surgical procedure including electrosurgery, what are the main risks?

2. If a patient with a pacemaker with an implantable defibrillator is undergoing a surgical procedure, what are the main risks?



http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answer



1. *Current from the elecrosurgery may be misinterpreted as heart activity and may stop a stimulating pulse, and current from the electrosurgery may follow the leads and burn the tissue at the end of the electrode*
2. *Current from the electrosurgery may be misinterpreted as ventricular fibrillation which can release a shock from the ICD*

Case 1



- After the surgery, implanting a dual chamber pacemaker, the heart rate is yet again under control. However, she has a persistent high grade fever and elevated serum C-reactive protein and lactate dehydrogenase levels despite absence of any signs of pacemaker infection, which would otherwise be a normal explanation.
- The patient is vomiting and has pain in the upper right abdomen
- The abdomen is swelling
- She is disoriented and confused
- Her eyes are yellow and the skin too
- She is constantly sleepy

What does this mean?

The liver

A giant chemical factory in the body: Detoxifies metabolites (end product of metabolism, metabolism= chemical reactions in the cell (forbrenning)), synthesizing proteins and production of biochemicals needed in digestions, regulation of glycogen storage, removing red blood cells from the blood and production of different bile (galle, helps breakdown of fat) to the digestion and hormones.

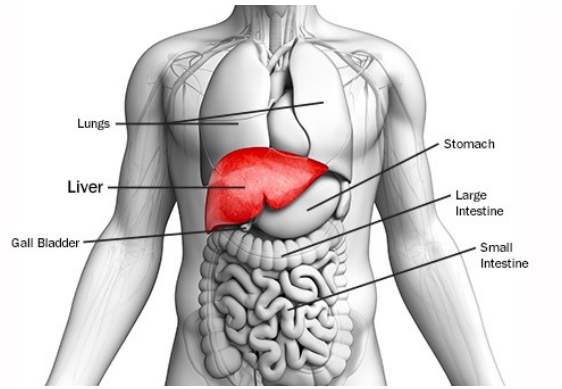


Image: Steemit.com

Acute liver failure

Acute liver failure is a sign of a liver with severe damage (loss off function of 80-90% of liver cells). Leads to hepatic encephalopathy, cerebral edema, coma, brain herniation and eventually death.

Problem:

- A buildup of toxic substances like ammonia, mercaptan, benzodiazepines ++ affecting neurotransmitter function.
- Coagulopathy, the coagulation system is affected (the cardinal feature of ALF)
- Kidney failure (50% of the patients)
- Low sodium concentrations in the blood

Treatment:

- Liver transplantation



Image: webmd.com

Liver dialysis: Promotheus

The problem with hemodialysis is that it does not remove toxins because they are bound to albumin.

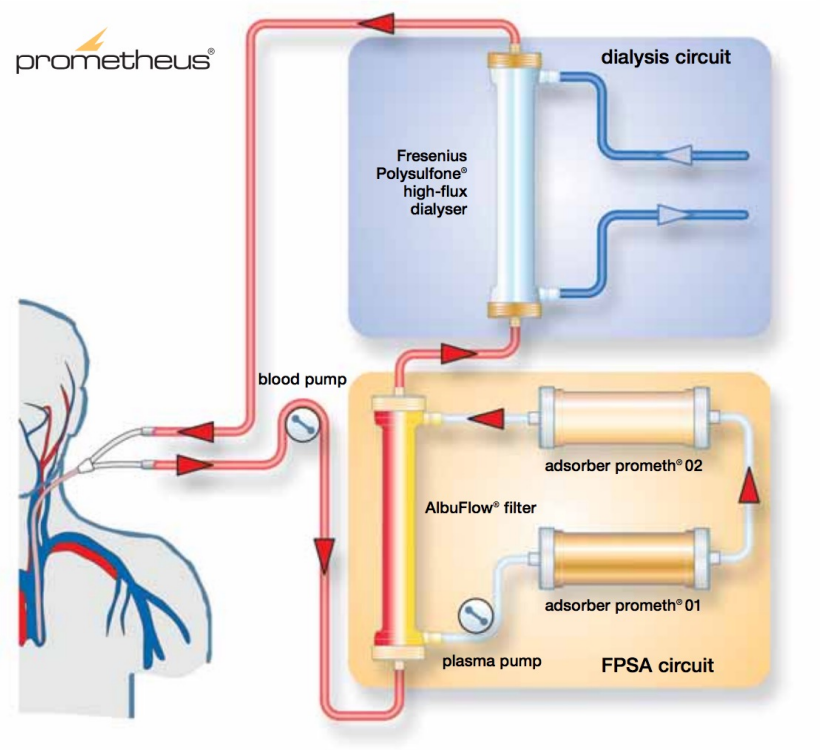


Image: Frescenius kabi

Promotheus:
Can be used for hemodialysis or in combination with liver support therapy

Inserting three filters:
Particles up to the size of albumin can pass into the second loop, albuflow

Two absorbers in a row, directly absorbing liver toxins

Hemodialysis to remove watersoluble toxins

Case 1



Answer:

- The problem with the liver was a consequential error of her initial treatment. Due to the pain after surgery and fear for strong medication, she had taken an overdose of paracetamol which is toxic in large quantities

- One of the most common causes of acute liver failure is paracetamol overdose



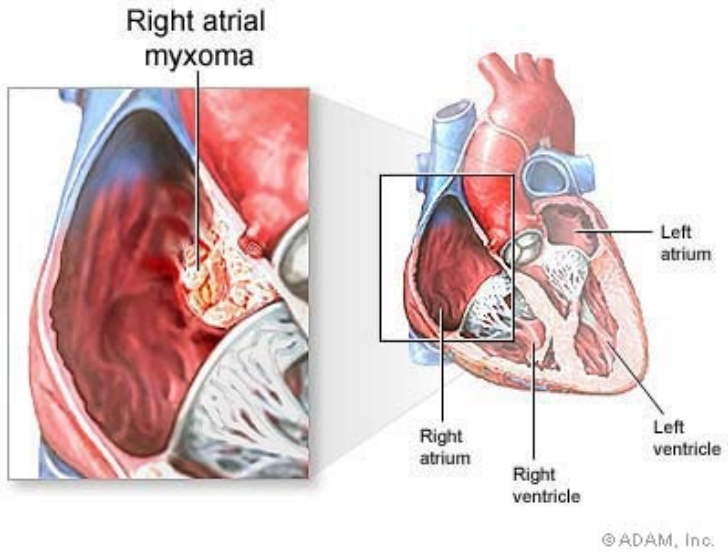
www.nytimes.com

Case 1



Answer:

- Finally, a CT scan is performed. The scan revealed a tumor in the right atrium, the mediastinal lymph nodes and bilateral adrenal glands. After examination of a tissue sample by a pathologist, she was diagnosed as having a benign myxoma with a right atrial tumor causing the sick sinus syndrome (SSS).
- After surgical recession of the tumor, treatment with continuous liver dialysis, and seven days in hospital, she was discharged and is now fully recovered.



www.nytimes.com