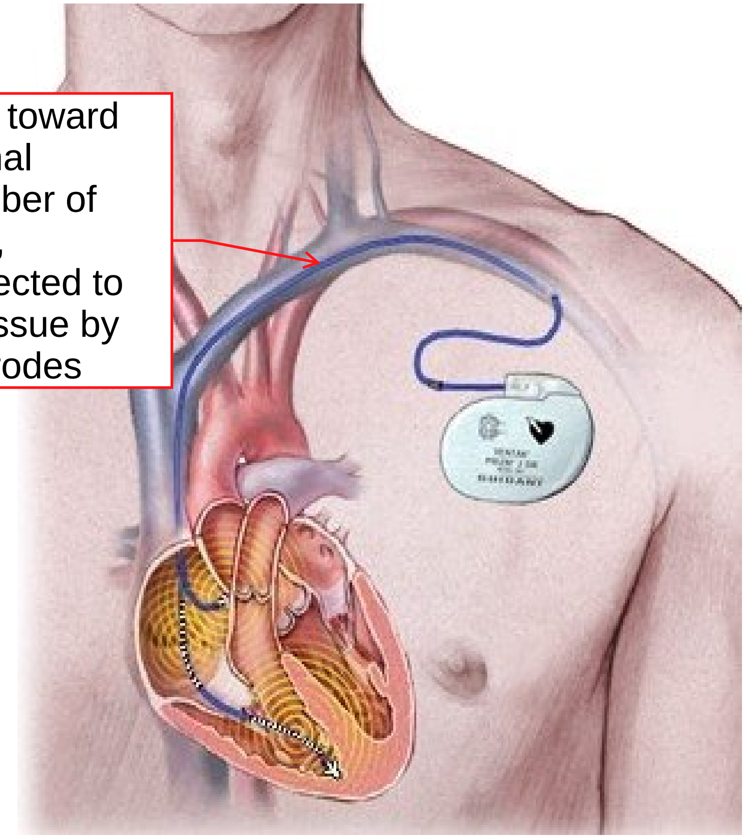
The Pacemaker: a basic introduction

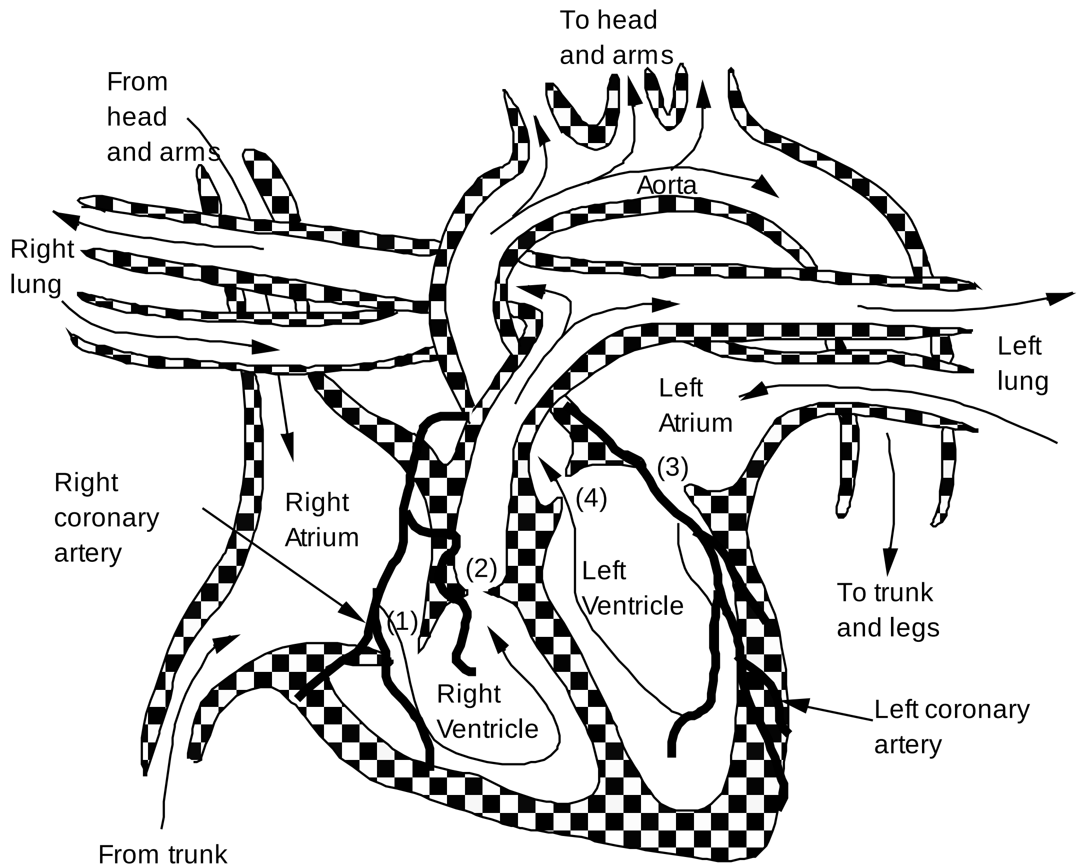
- action potentials in the heart
- arrhythmias
- different topologies of Pacemaker

Reference for Pacemaker:
Design of Cardiac Pacemakers, J.G.Webster, IEEE, available on web

wires toward internal chamber of heart, connected to the tissue by electrodes

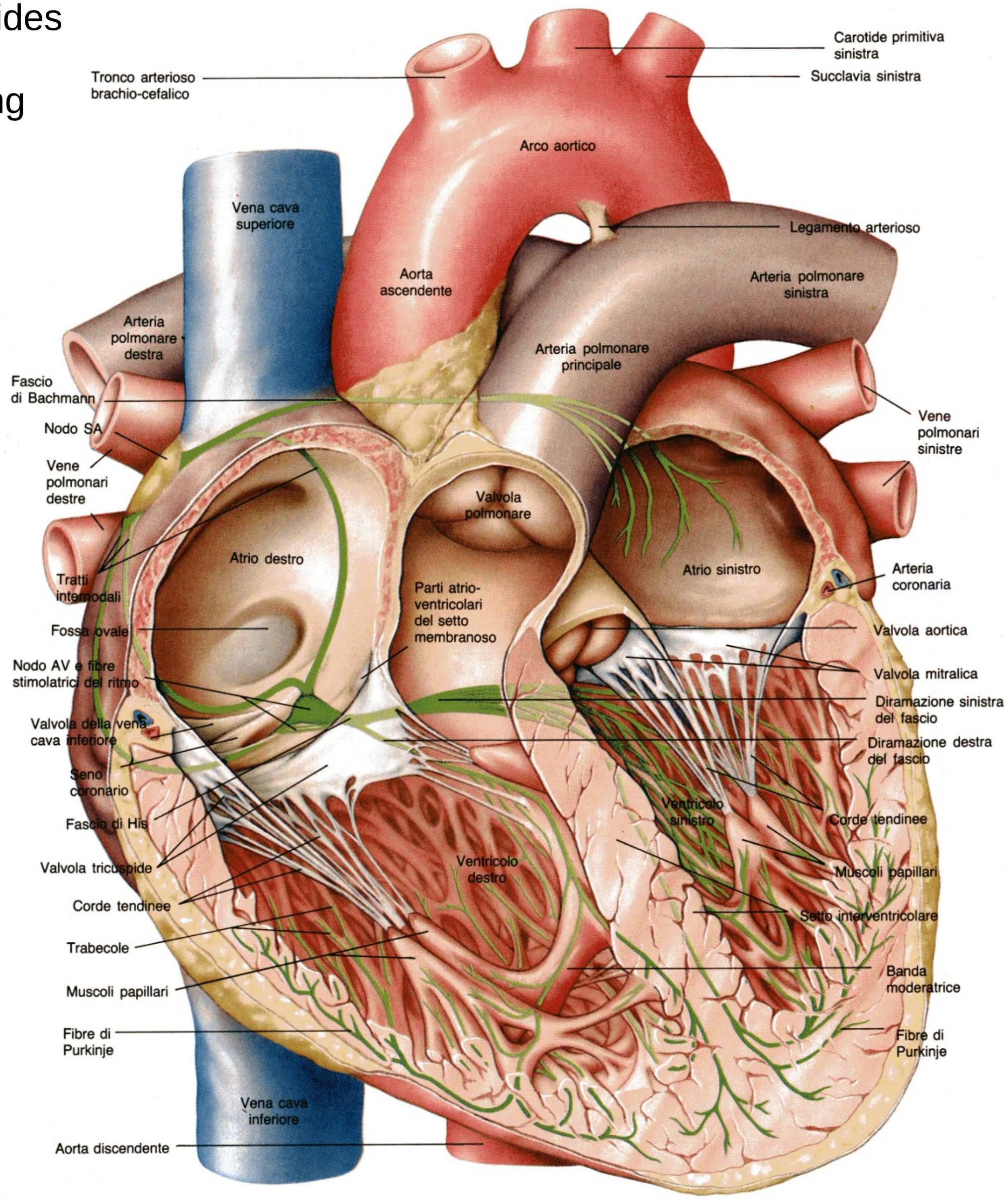


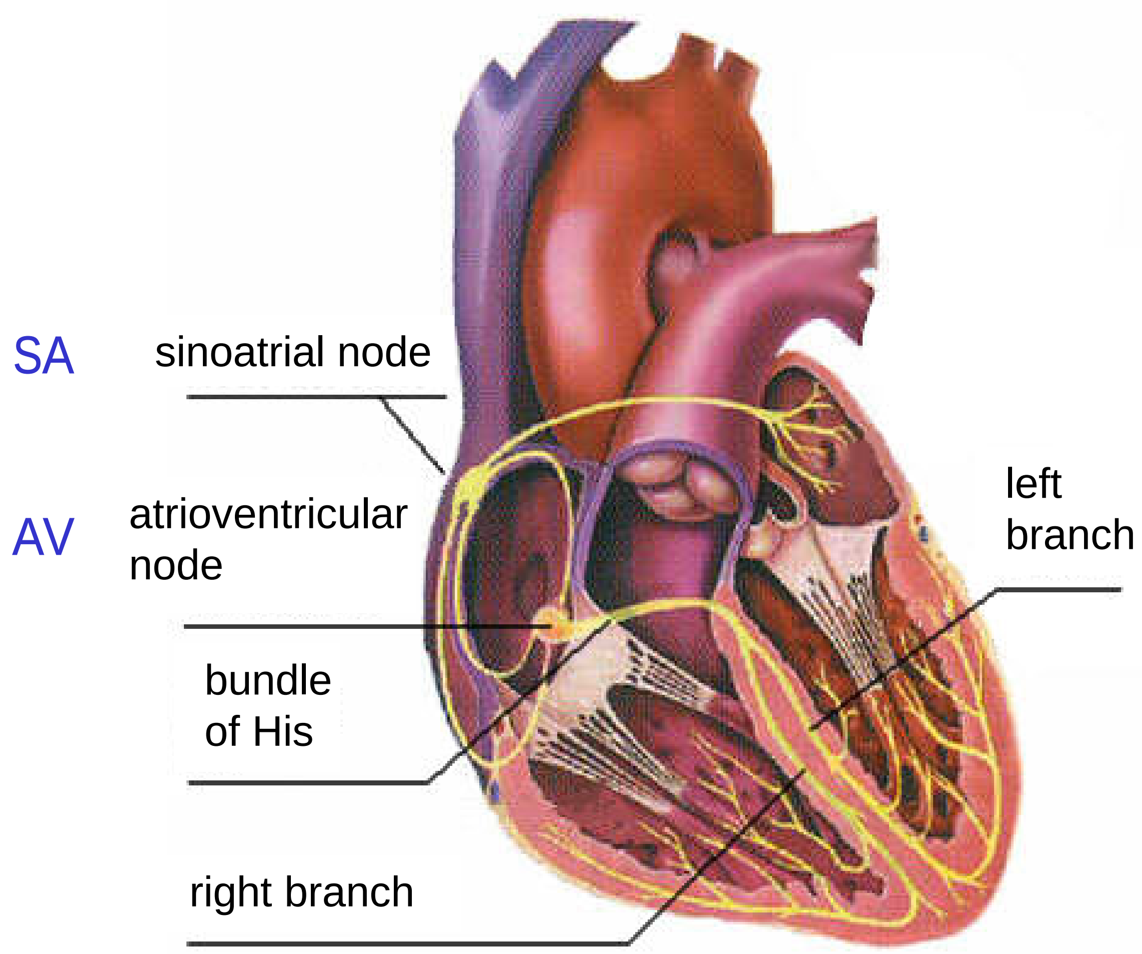
The heart



(1) Tricuspid valve
(2) Pulmonary valve
(3) Mitral valve
(4) Aortic valve

Electrical network, provides the sequence of pulses responsible for the timing





Distribution of the connectivity system in the atria and ventricles responsible of the formation and conduction of the electrical pulses

We have 2 nodes where the electrical activity moves. start SA, then the stimulation move trough the atrium, and then AV "transfer node of electrical activity between atrium and ventricle". Then ventricular tissue + wide connectivity.

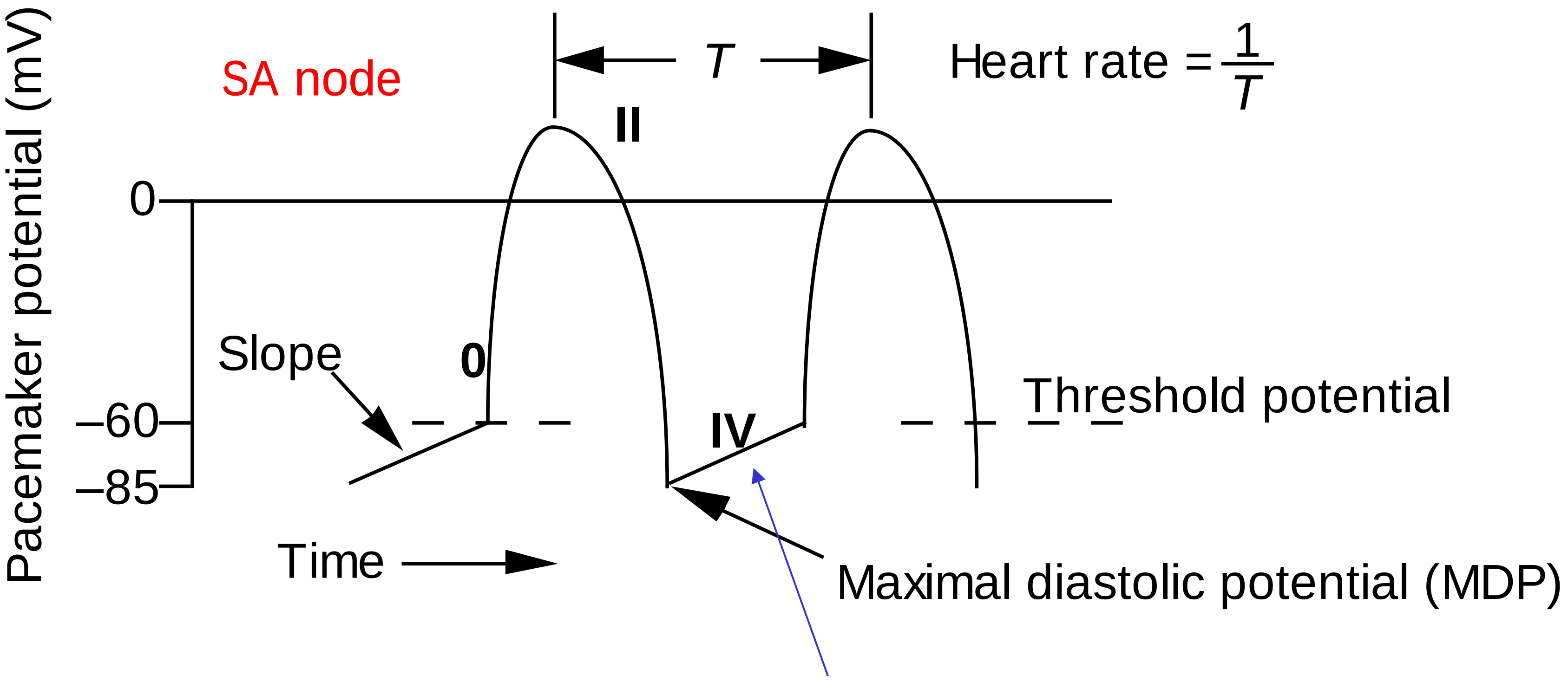
Intrinsic properties of the heart in the stimulus generation:

- automaticity: capability to start spontaneously a beat
- ritmicity: regularity in beats

El activity: sequence of delayed pulses. The cardiac tissues have some properties: -Automaticity: they are capable of re-triggering themselves -Ritmiciy: the beats are regular

How is it possible?

Automaticity, ritmicity



depolarization (leakage of Na+ and Ca++ ions inside)

The heart cells cross the threshold autonomosly, **they dont remain in the resting potential**! They experience a slow ramp, because there's spontaneous leakage through the membrane. [audio] We have the beat period that depends on many things (slide 11). How is the automaticity regulated? why doesnt a cell beats by his own?

Spontaneous depolarization (phase IV)

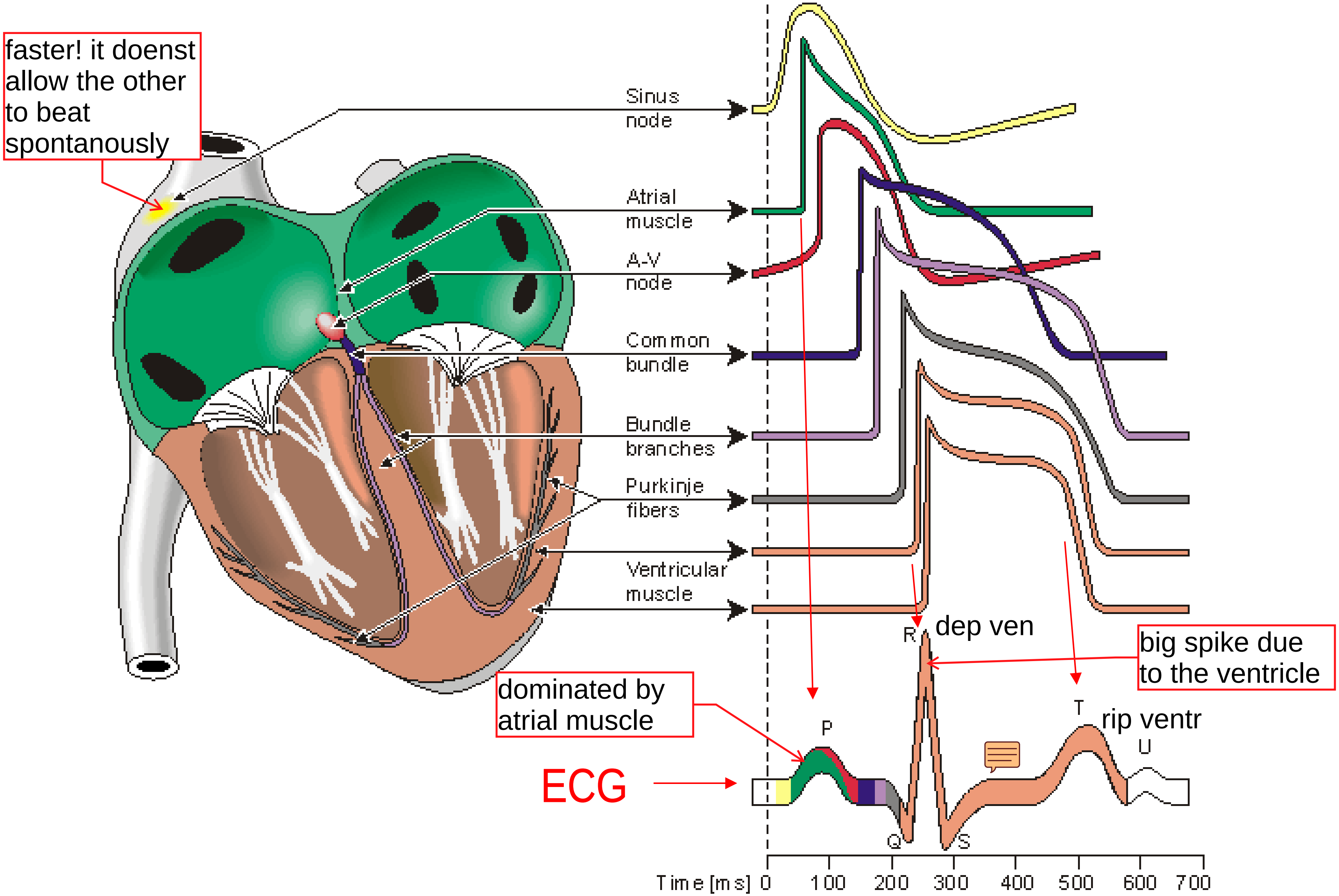
- SA node: about 70 beats/min ← the most frequent
- AV node: about 50-60 beats/min
- Purkinje fibers: about 25-40 beats/min

⇒ the contraction rhythm of the whole cardiac muscle is dominated by the self-ritmicity of the SA node

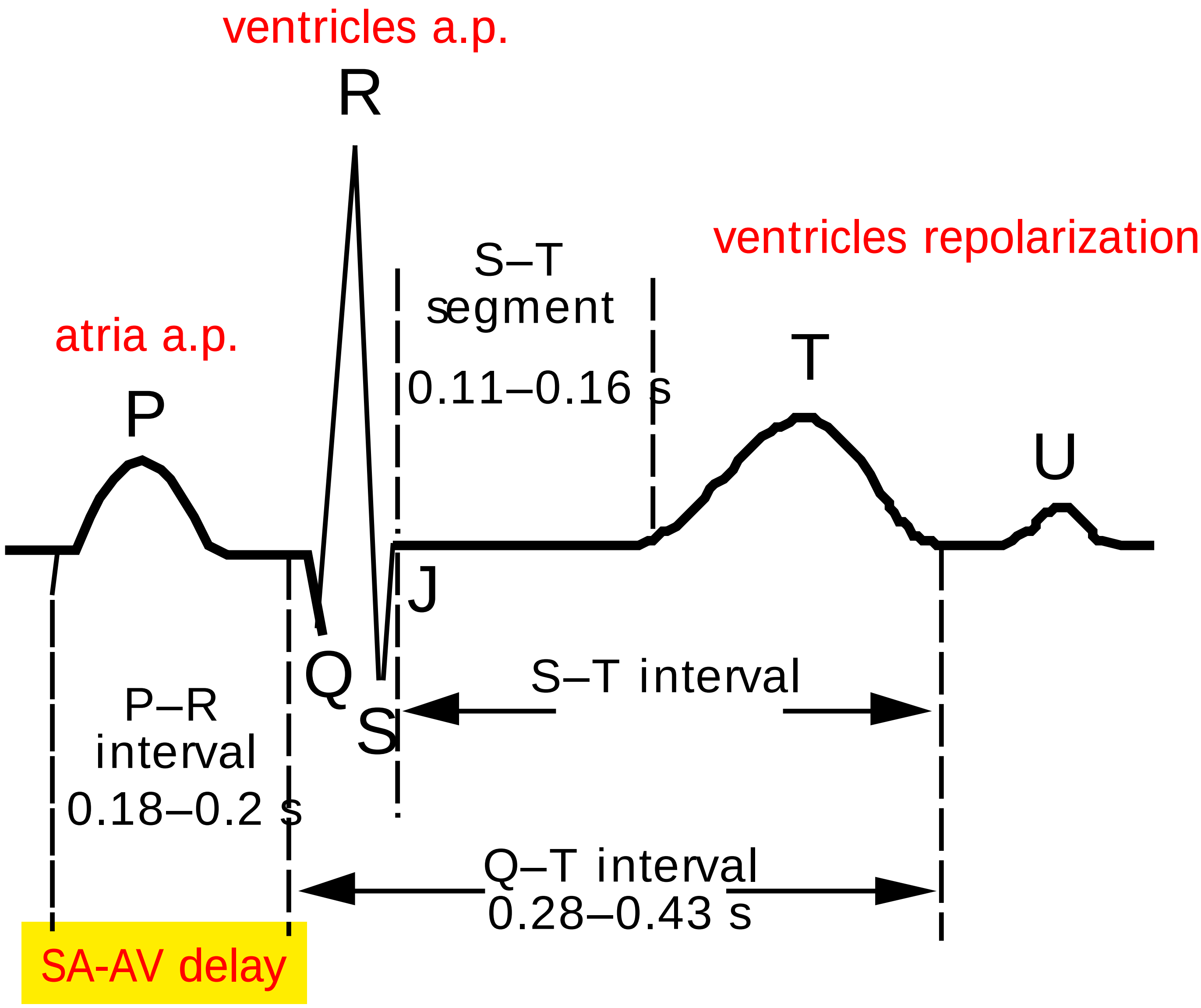
- the cardiac stimulus starts from the SA node and propagates toward the ventricles

- the cardiac frequency is determined by the SA node

Each pacing cell has its own characteristic period, but it's also sensitive to other stimulation! so the MOST FREQUENT DOMINATES the following. The most frequent induce trigger to the others before they are self-triggered.

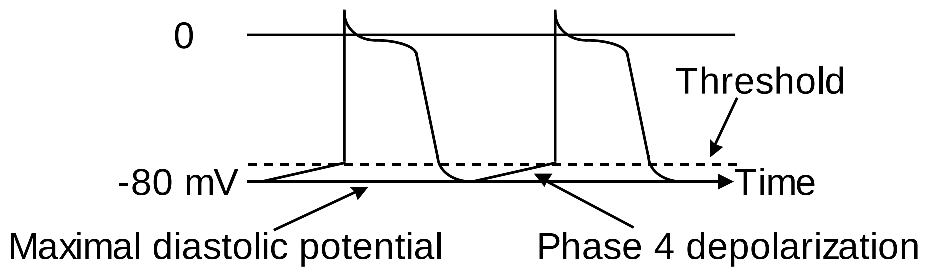


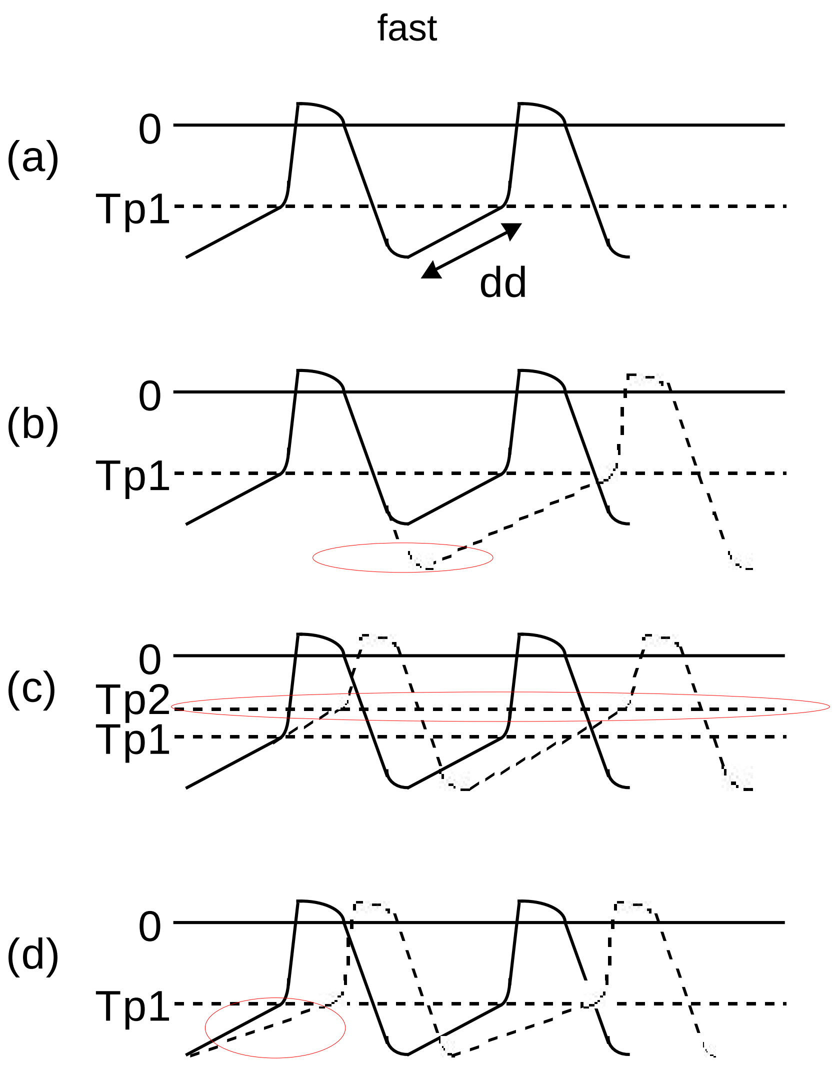
We start with suns node, the atrial muslce (which makes a contraction) the AV node, the common bundle (last piece common) then branches, then p.fibers that makes the contraction. All these pulses are electrically delayed, indeed they propagates. We are actually externally to the body and thus we see the ECG, which is the superimposition of all the waveforms (we can do that with the pacemaker)



We have PQRSTu, we can measure the distances between the peaks, there's a regular timing between atrium contraction and ventrical contraction.

possible factors which influence the cardiac rhythm





a) normal depolarization

b) diastolic potential more negative

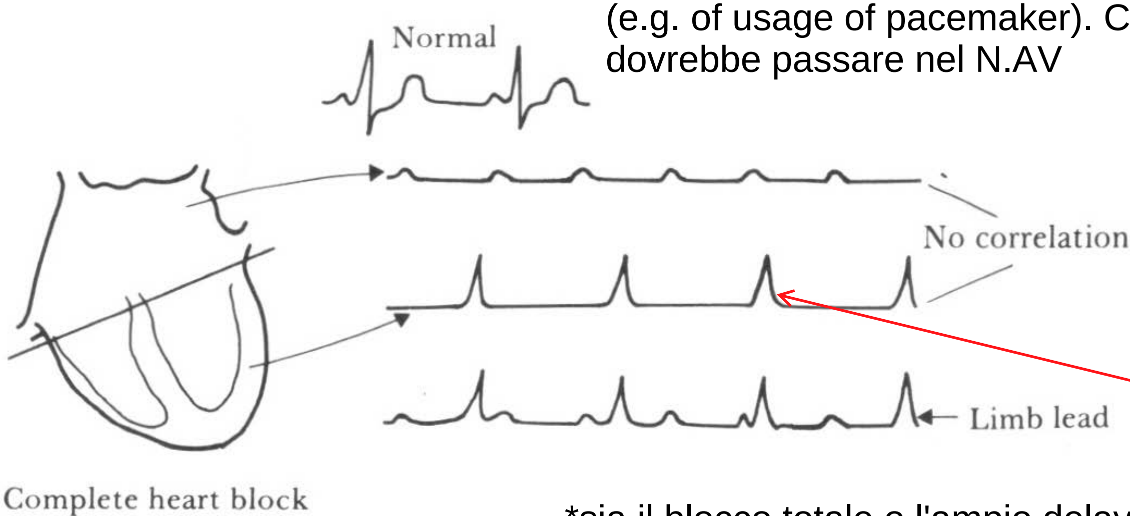
c) threshold more positive

d) lower depolarization slope

Threshold can change, slope can change

Examples of Arrhythmias

pacemaker: sense when atrium has got the pulse and stimulate the ventricle (e.g. of usage of pacemaker). Cioè FA SENSE SULL'ATRIO, lo stimolo poi dovrebbe passare nel N.AV

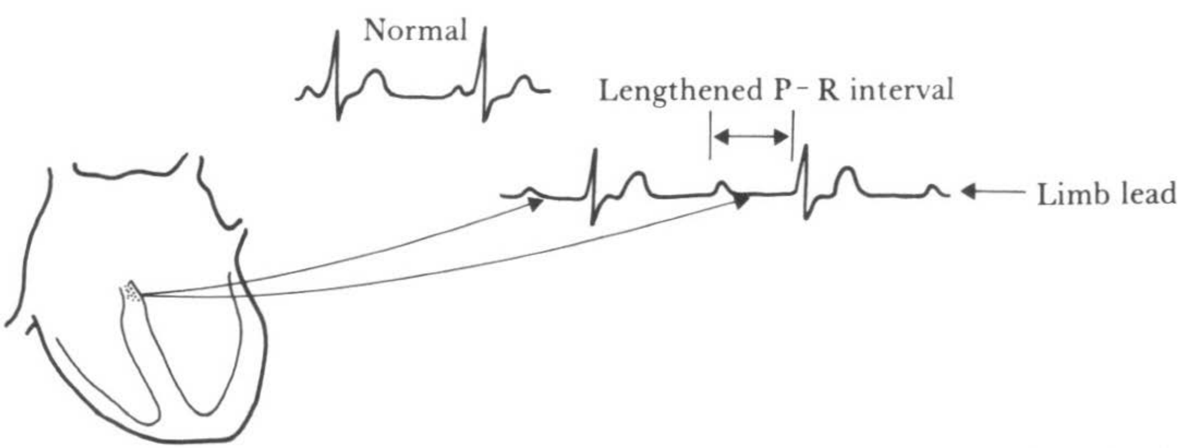


AV node inactive (cardiac block)

il ventricolo stimola ancora, però lo fa autonomamente

fast

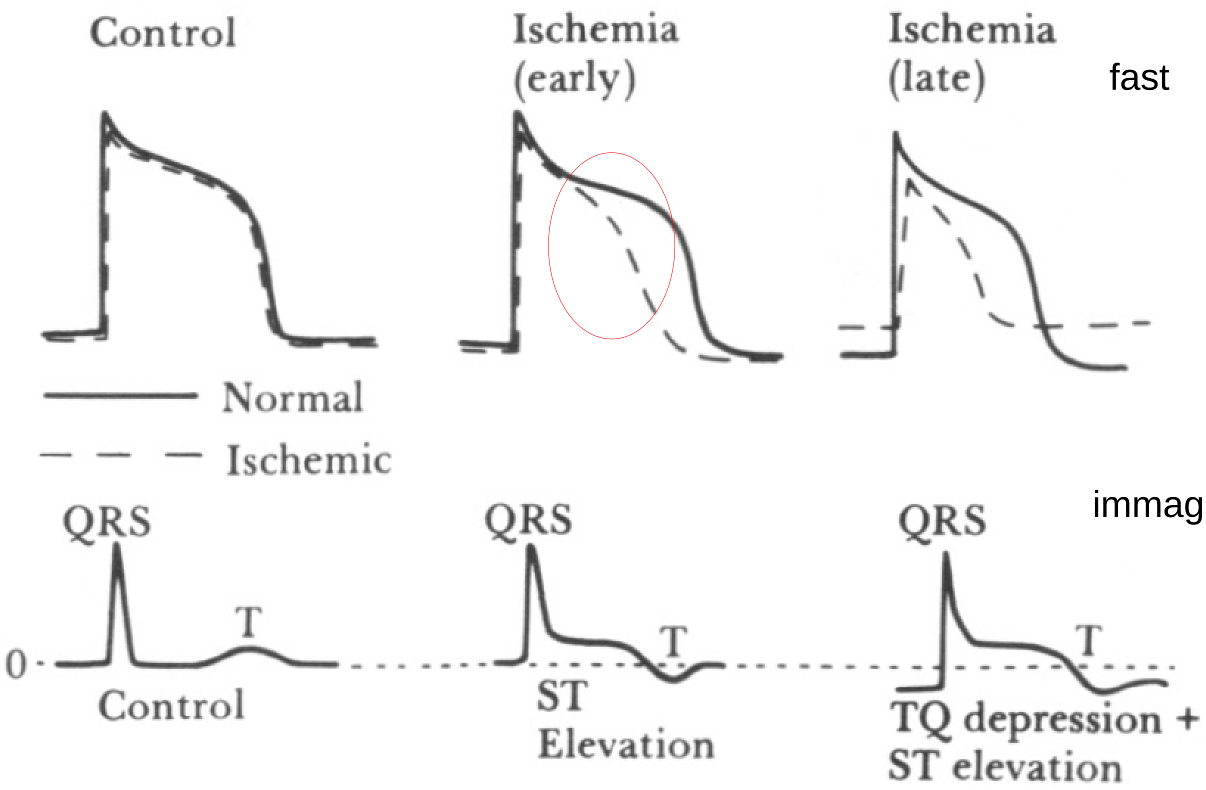
*sia il blocco totale o l'ampio delay sono visibili dall'ECG



AV node partially operative (delayed transfer of stimulus between atria and ventricles)

There can be problems. 1) AV node inactive, stop of propagation between A-V. Each part is beating by his own. We have uncorrelation between the beat of the atrium and of the ventricle!! We may have anormalous delays between Atrium contraction and Ventricle contraction.

*anche l'occlusione delle coronarie è visibile dall'ECG



fast

immagini non analizzate

Ischemia: occlusion of coronary arteries which reduces the blood distribution in the myocardium causing, by the reduced oxygenation, changes in the electrochemical equilibrium of tissues:
reduction of K+, increase of Na+, ⇒ increase of resting potential and changement of shape of action potential

coronary: refurnish blood to the heart, if it's not oxigenated there's a perturbation in flow of ions and the waveforms change in shape. Again, deviation in the signal are shown in the ECG signal

The Pacemaker

Cardiac stimulator which produces electrical pulses on electrodes placed on surface (epicardium), in the muscle (myocardium) o inside the cavity (endocardium) of the heart. Such pulses have the purpose to normalize the regular and periodic contraction of the heart in patients in which the cardiac activity is not properly self-stimulated because of pathologies (arrhyithmias).

"most significant contribution of el. to medicine": fully el device, provides regulation to heart functionality. Plus total number of people using it is high. Provides el pulses to the tissue where elctrd are placed. Main goal is stimulation, but we can also sense the signal.

3 CLASSES:

"kind of clock fixed rhtytm". It's aysnc to respect anything in the body. Async from the patient

- ASYNCHRONOUS (*fixed rhythm*)
- SYNCHRONOUS (*triggered by the heart*)
- RATE-ADAPTIVE (*variable*)

The stimulus is provided by trigger of the heart

standard now, operates with what happens in the body

it can be programmed. "which chamber has to be stimulated". It could even work just as local electrocardiograph

fast

STIMULATION CODES:

I Chamber Paced	II Chamber Sensed	III Response to Sensing	IV Programmable Functions; Rate Modulation
V–ventricle	V–ventricle	T–triggers pacing	P–programmable rate and/or output
A–atrium	A–atrium	I–inhibits pacing	M–multiprogrammability of rate, output, sensitivity, etc.
D–dual (A + V)	D–dual (A + V)	D–dual (T + I)	C–communicating functions (telemetry)
O–none	O–none	O–none	R–rate modulation
S*–A or V	S*–A or V		O–none

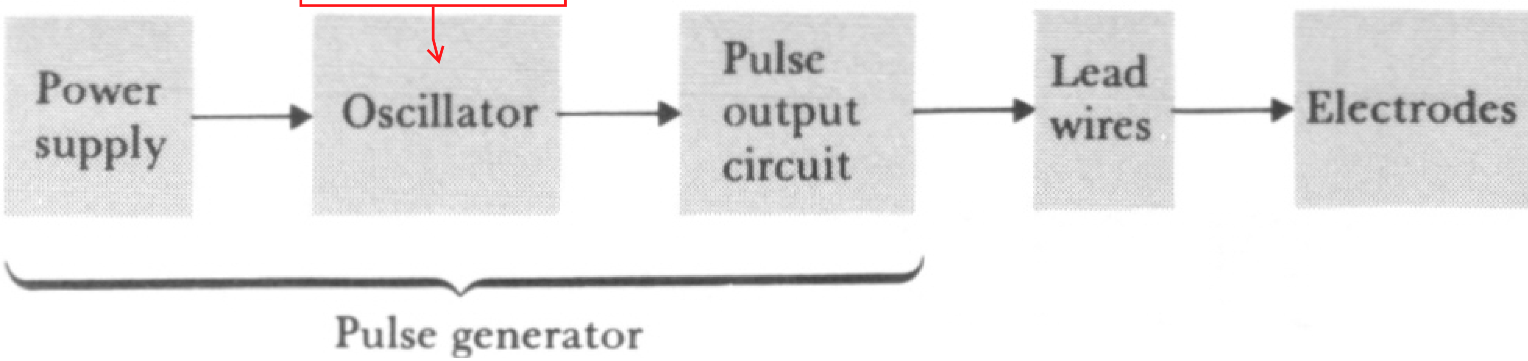
just elctrcardiog

*Used by Manufacturers

Asynchronous Pacemaker

works based on osc, fixed freq of stimulation

free running stimulation at fixed period

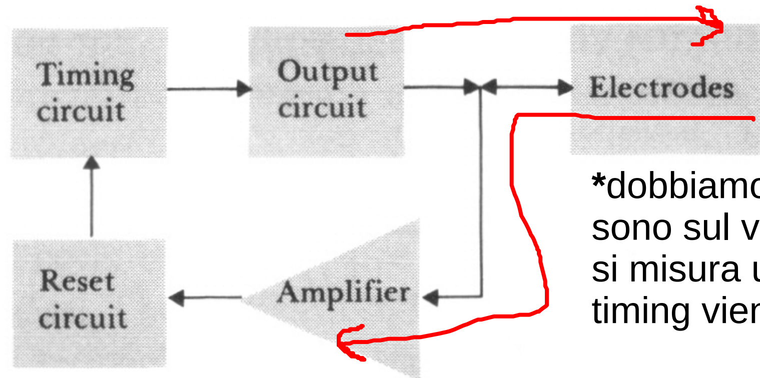


It supplies pulses in a free-running modality and at a given frequency without referring to physiological parameters occurrence in the heart or in the body.

type of **async** pacemaker

***nota: è async perché in realtà non fa sensing dell'ATRIO, ma del VENTRICOLO**

Demand-type Pacemaker



***dobbiamo stimolare il ventricolo. Gli elettrodi sono sul ventricolo. Facciamo anche sense: se si misura una contrazione ventricolare allora il timing viene resettato.

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.

It supplies pulses at a regular frequency, except in the case a spontaneous heart beat is detected. In this last case, it resets the timer and re-start waiting a whole period before giving a new pulse.

Provides a stimulus only if needed: if the heart has not provided a stimulus by his own. We have a timinig circuit, which would be ready to provide pulses at a regular period. But it contains also a sensing amplifier, connected to the **SAME electrode** that stimulates (this is common). If the heart produces a spontaneous beat, the timing is resetted. "if the heart is working this pacemaker never fires". **e.g.** for patient that suffer of potentially low beating rate, maybe while they sleep.

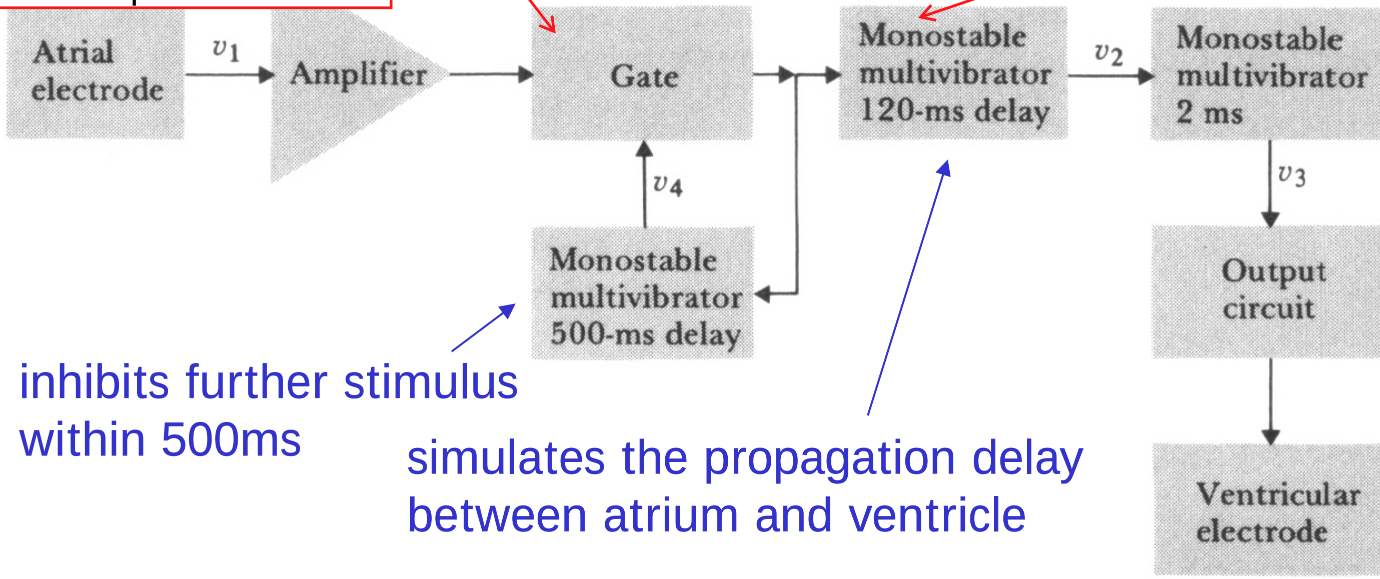
For **500ms** the connection between A-V is disconenected (After the A signal is passed through). Prevents a new pulse to stimulate again the V. We could have for eg **crosstalk** from the stimulation and read. It would become a loop.

for e.g.: AV node inactive: cardiac block. We **sense the atrium** and **stimulate the ventricole**. **2 separate electrodes**

Synchronous Pacemaker

just provides a **delay of 120ms**. Supply physiological delay b/w A-V

actually provides the stimulus, 2ms



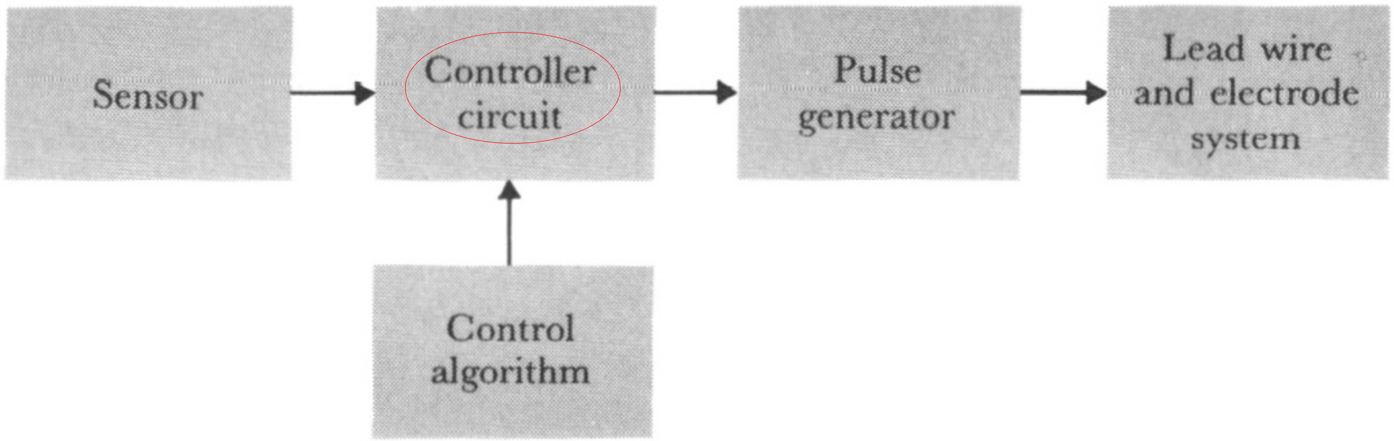
inhibits further stimulus within 500ms

simulates the propagation delay between atrium and ventricle

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.

it substitutes a not correct transmission of the stimulus from the atrium to the ventricle by means of the AV node pulse not fixed in freq, depends on physiological parameters. Running-> increase beat freq

Rate-adaptive Pacemaker



It operates according to the acquisition by sensors of physiological parameters of the patient, adjusting its own stimulus to the actual status of such parameters by means of a control system.

List of possible physiological variables.

Table 13.1 Physiological Variables That Have Been Sensed by Rate-Responsive Pacemakers (*Not Commercially Available)

Physiological Variable	Sensor
Right-ventricle blood temperature	Thermistor
ECG stimulus-to-T-wave interval	ECG electrodes
ECG R-wave area	ECG electrodes
*Blood pH	Electrochemical pH electrode
*Rate of change of right ventricular pressure $\left(\frac{dp}{dt}\right)$	Semiconductor strain-gage pressure sensor
*Venous blood oxygen saturation	Optical oximeter
Intracardiac volume changes	Electric-impedance plethysmography (intracardiac)
Respiratory rate and/or volume	Thoracic electric-impedance plethysmography
Body vibration	Accelerometer

Corresponding sensor to place

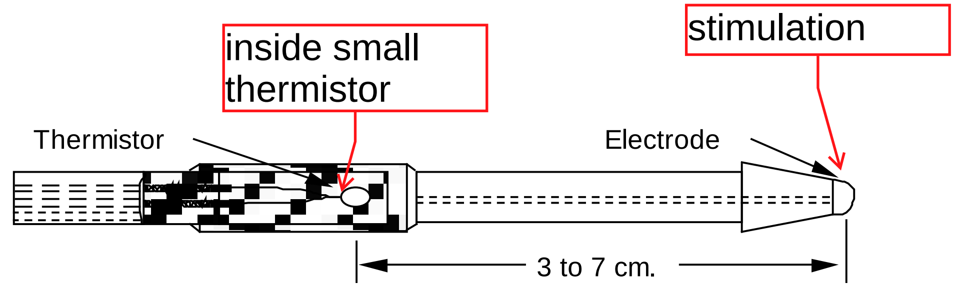
*he's not an expert ;)

fast

1 eg of temperature sensor; Resistor with a temperature coefficient

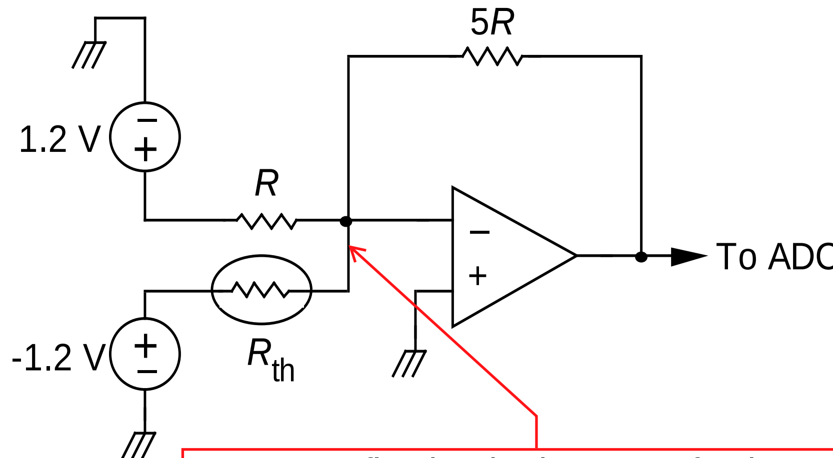
RATE-ADAPTIVE PACEMAKER sensitive to the measurement of the temperature with a thermistor

negative temperature coefficient of – 4%/°C, assumed linear in the temperature range between 35–40°C



CIRCUIT EMPLOYED TO DETERMINE THE VARIATION OF TEMPERATURE TO CHANGE THE STIMULATION FREQUENCY

explanation of circuit



no current flowing in the "eq". If Rth changes we have unbalance of current, thus flowing of current and a voltage feedback

Basic components of a Pacemaker