Artificial organs – internal & external (PACEMAKER)

Demand triggered PM:

- Ventricular demand-type pacemakers are the most commonly used. This delivers a fixed rate pacing stimulus only when the normal QRS waves fail to follow the natural P-wave stimulus. It can therefore never trigger ventricular fibrillation by delivering a stimulus to relaxing heart muscle. This relaxing period is known as the "vulnerable period". See figure below.

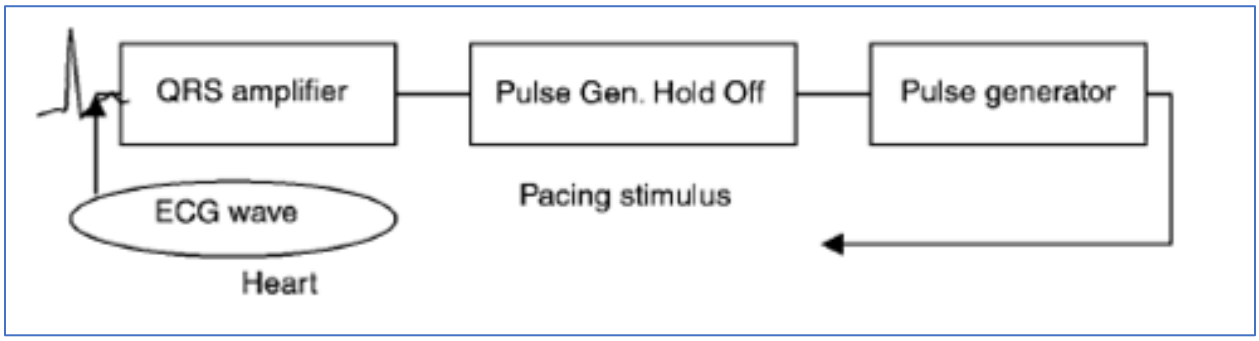

Figure 3. Demand Triggered pacemaker-Block diagram**.**

Atrialy triggered PM:

- Atrial-triggered devices are used in complete heart block. In order to record the P-wave, electrodes have to be placed in the atria in addition to the pacing electrodes in the ventricles. Natural excitation P-wave from atrium is somehow prevented from reaching the ventricles. Pacemaker amplifies this wave, delays it for an appropriate interval, and then fires a pulse into the ventricular muscle, as in figure below.

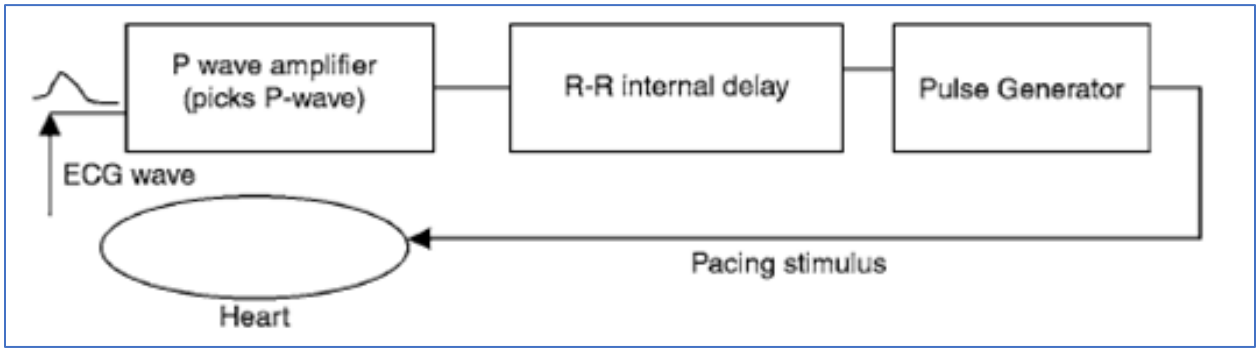

Figure 4. Shows the block diagram for the artificially triggered Pacemaker unit.

Principle of Sensing and Controlled Stimulation

- The failure of excitation generating and spreading may be permanent or temporary. In case of temporary failure, the pacemaker must be able not only to stimulate, but also to recognize whether a spontaneous action takes place or not.

- This task of recognition is called ‘‘sensing.’’ The signal that is recorded by sensing is actually the electrocardiogram (ECG). If this potential is recorded directly from the heart, the signal is called an intramyocardial electrogram (IEGM).
- Sensing is achieved by electrodes comparable with those that are used for stimulation, and frequently the same electrode is employed for sensing and stimulating.

- If the failure is permanent, sensing is not required at the site where stimulation is applied.
- Atrial sensing is not required for permanent SA node failure, but for temporal failure that must be detected in order to apply atrial stimulation. Ventricular sensing is not required for permanent AV conduction failure, but for temporary failure that must be detected in order to apply ventricular stimulation.
- In case of temporary and permanent failure, the atrial signal is used to achieve synchronization of the ventricular with the atrial contraction.
- For such IPMs, the term ‘‘synchronous’’ or even ‘‘rate responsive’’ devices has been introduced because the ventricular heart rate is synchronized with and also determined by the spontaneous SA node rate. In case of temporary failure, the atrial signal can additionally be employed to start the interval during which the arrival of the excitation in the ventricles inhibits the ventricular stimulation.

- In both cases, atrial sensing renders possible matching of the AV delay with the actual sinus rate because the AV delay becomes shorter with higher heart rate.
- The most essential units of a PM are (Fig. 3):
- – One or more sensing channels (i.e., signal amplifiers with appropriate transmission characteristics);
- – One or more stimulating channels (i.e., pulse shapers with output amplifiers);
- – A microprocessor for signal processing and timing control together with a clock, usually quartz-controlled, and memories (RAM, ROM);
- – A power unit (i.e., a battery with voltage converter, together with an ‘‘end-of-life’’ indicator); a bidirectional telemetry unit for the communication with an external (i.e., extracorporeal) transmitter-receiver unit in order to check the actual operational parameters and to use the flexible programming capability; and
- – One or more electrodes [i.e., leads that connect the PM directly or, in case of external PM, indirectly] with the heart for sensing and stimulation.

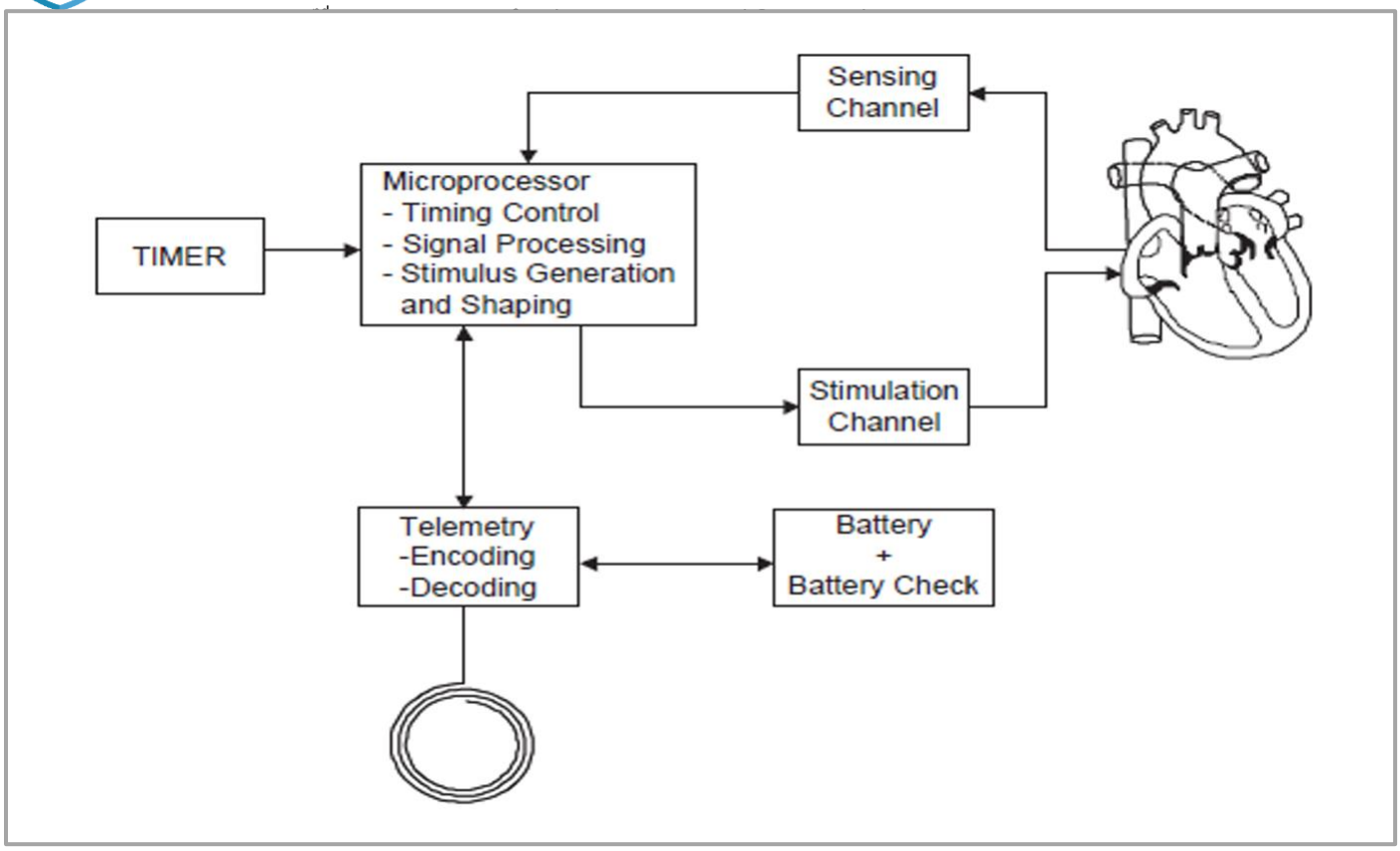

Figure 5. Simplified schematic diagram with the basic functional units of a remotely programmable PM.

Computer Algorithms

- Pulse generators usually can be seen as small microprocessor devices. As such they contain computer code or computer algorithms to control their function, delivering advantages to the patient and clinician, as the pacemaker's mode of operation can be changed.

Telemetry Circuit

- Today's pulse generators are capable of both transmitting information from an RF antenna and receiving information with an RF decoder. This two-way communication occurs between the pulse generator and the programmer at

approximately 300 Hz. Real-time telemetry is the term used to describe the ability of the pulse generator to provide information such as pulse amplitude, pulse duration, lead impedance, battery impedance, lead current, charge, and energy. The programmer, in turn, delivers coded messages to the pulse generator to alter any of the programmable features and to retrieve diagnostic data. Coding requirements reduce the likelihood of inappropriate programming alterations by environmental sources of radiofrequency and magnetic fields. It is also prevents the improper use of programmers from other manufacturers.

Power sources

- It is essential that the pacemaker has a reliable power source which will last as long as possible. It is possible to replace an exhausted pacemaker but surgery is necessary and battery failure if it is not detected at an early stage can give rise to a life-threatening situation.
- The ideal power source should be very small, have a long life, i.e. a high capacity, be unaffected by body temperature, be easy to test so that exhaustion can be predicted, be cheap, be unaffected by autoclaving and give an output of at least 5 V. No gases must be produced.
- Types which have been used include mercury cells, nuclear-powered thermoelectric generators and lithium cells.
- The battery check has two functions. One is to detect a low battery voltage and use this to reduce the fixed-rate output as a means of signaling a low battery. The other is to increase the output pulse width when the battery voltage falls so that the output pulse energy remains constant

Leads

- Implantable pacing leads must be designed not only for consistent performance within the hostile environment of the body but also for easy handling by the implanting physician.
- Every lead has four major components (Fig. 77.6): the electrode, the conductor, the insulation, and the connector pin(s).
- The electrode is located at the tip of the lead and is in direct contact with the myocardium. Bipolar leads have a tip electrode and a ring electrode (located about 2 cm proximal to the tip); unipolar leads have tip electrodes only.
- A small-radius electrode provides increased current density resulting in lower stimulation thresholds. The electrode also increases resistance at the electrode-myocardial interface, thus lowering the current drain further and improving battery longevity.
- The radius of most electrodes is 6–8 mm^2.

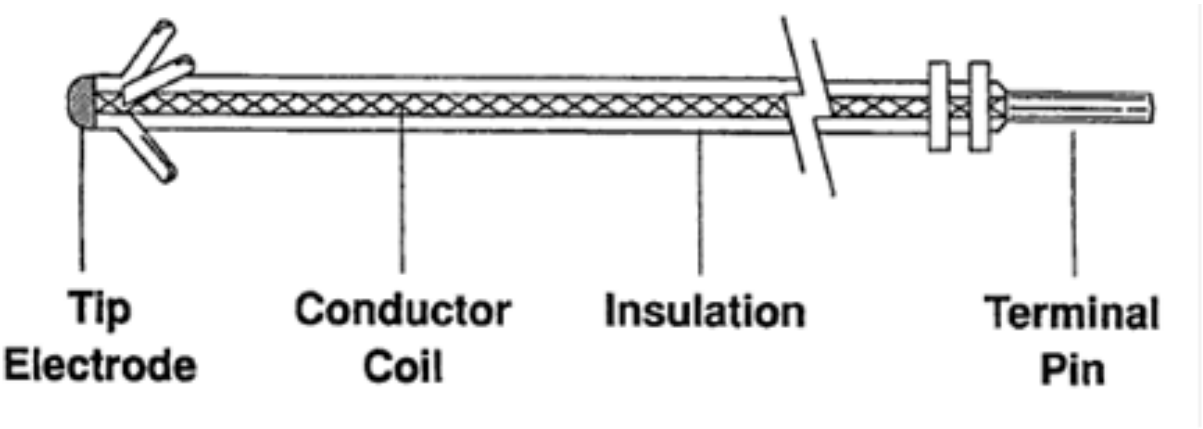

Figure 6. The four major lead components.

Classification codes for pacemaker:

- To make it easier to understand the gross-level system operation of modern pacemakers, a five-letter code has been developed by the North American Society of Pacing and Electrophysiology and the British Pacing and Electrophysiology Group. The first letter indicates the chamber (or chambers) that are paced. The second letter reveals those chambers in which sensing takes place, and the third letter describes how the pacemaker will respond to a sensed event. The pacemaker will "inhibit" the pacing output when intrinsic activity is sensed or will "trigger" a pacing output based on a specific previously sensed event. For example, in DDD mode:
- D: Pacing takes place in the atrium and the ventricle.
- D: Sensing takes place in the atrium and the ventricle.
- D: Both inhibition and triggering are the response to a sensed event.

An atrial output is inhibited with an atrial-sensed event, whereas a ventricular output is inhibited with a ventricular-sensed event; a ventricular pacing output is triggered by an atrial-sensed event (assuming no ventricular event occurs during the A-V interval).The fourth letter in the code is intended to reflect the degree of programmability of the pacemaker but is typically used to indicate that the device can provide rate response. For example, a DDDR device is one that is programmed to pace and sense in both chambers and is capable of sensor-driven rate variability. The fifth letter is reserved specifically for antitachycardia functions (as in the Table).

TABLE: The NASPE/NPEG Code

Position	I	II	III	IV	V
Category	Chamber(s) paced O = None A = Atrium V = Ventricle D = Dual (A+V)	Chamber(s) sensed O = None A = Atrium V = Ventricle D = Dual (A+V)	Response to sensing O = None T = Triggered I = Inhibited D = Dual (T+I)	Programmability rate modulation O = None P = Simple programmable M = Multiprogrammable C = Communicating R = Rate modulation	Antitachyarrhythmia function(s) O = None P = Packing S = Shock D = Dual (P+S)
Manufacturers' designation only	S = Single (A or V)	S = Single (A or V)			