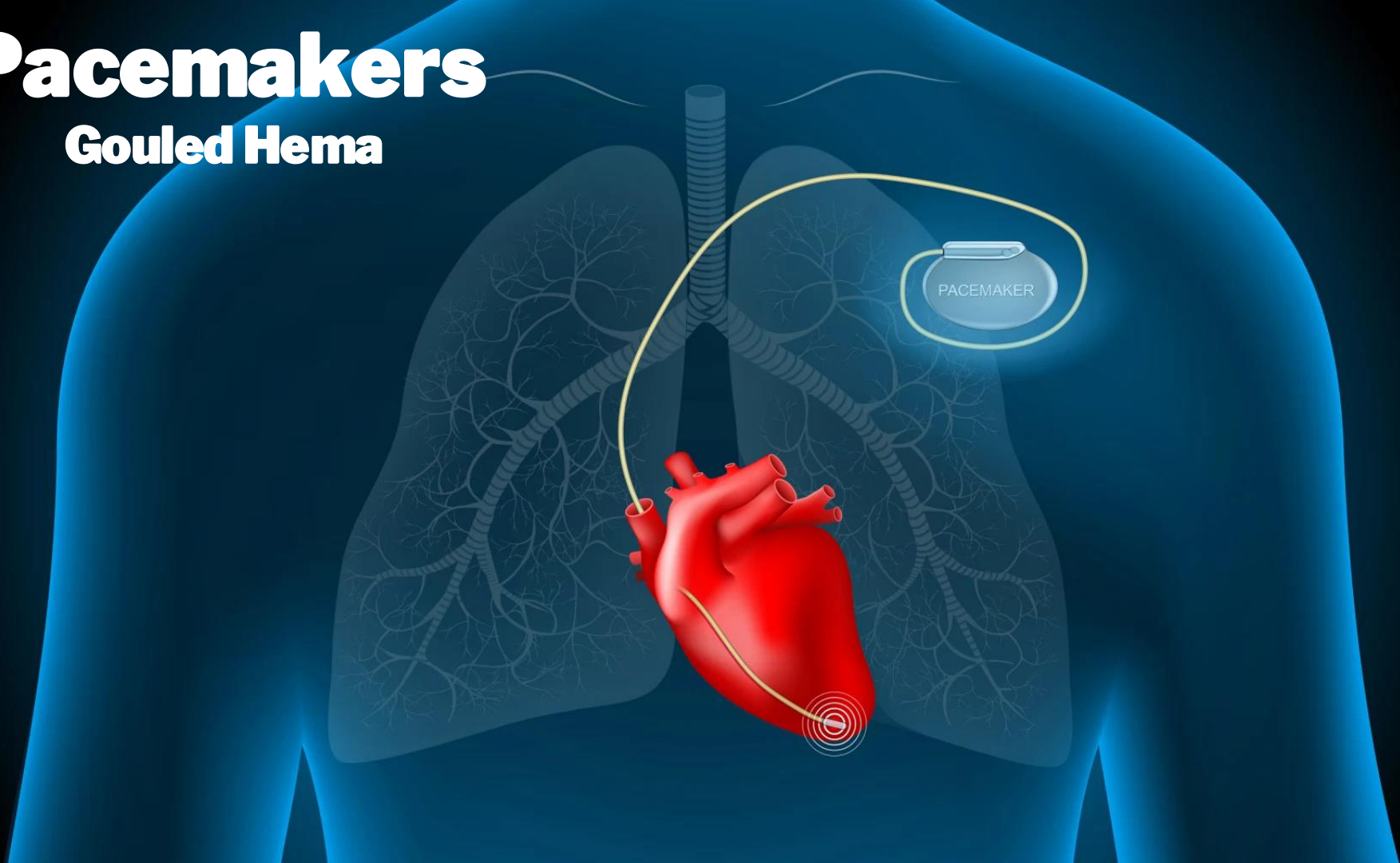


# Pacemakers

Gouled Hema



## Sources:

Encyclopedia of medical devices and instrumentation

Handbook of Medical Physiology, Guyton

<https://www.medicaim.com/fr/procedure/pose-de-pacemaker>

<https://www.yalemedicine.org/conditions/cardiac-pacemaker>

[https://www.youtube.com/watch?v=53\\_jyoA47Eg](https://www.youtube.com/watch?v=53_jyoA47Eg)

[https://www.haltonhealthcare.on.ca/site\\_files/content/services/pdf/cardiology/pacemaker-clinic/pacemaker\\_booklet.pdf](https://www.haltonhealthcare.on.ca/site_files/content/services/pdf/cardiology/pacemaker-clinic/pacemaker_booklet.pdf)

<https://www.legifrance.gouv.fr/jorf/id/JORFTEXT000038176318>

[https://news.medtronic.com/image/Micra\\_vs\\_dime\\_USsm.jpg](https://news.medtronic.com/image/Micra_vs_dime_USsm.jpg)

<https://www.youtube.com/watch?v=DgApUflgB88>



# Outline



- **Introduction**
- **Physiology aspects**
- **Technical Description**
- **Specifications**
- **Medical significance**
- **Clinical Applications**
- **Product aspects**
- **Future Perspectives**
- **Conclusion**

# Introduction

**Bradyarrhythmias:**  
when the heart stop or  
responds slowly in a  
continuous or  
intermittent way



## How to define a pacemaker ?

- where you want the device to pace the heart—in the ventricle?
- in which chamber or chambers you would like the pacemaker to sense?
- how you want the device to work when it encounters natural heartbeats?

# Physiology aspects

## Normal physiology: Heart & ECG

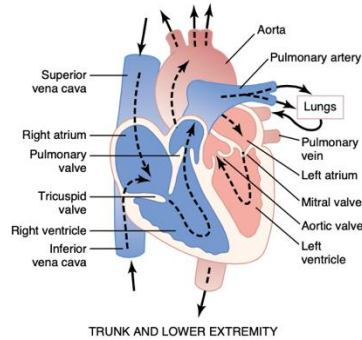


Figure 9-1

Structure of the heart, and course of blood flow through the heart chambers and heart valves.

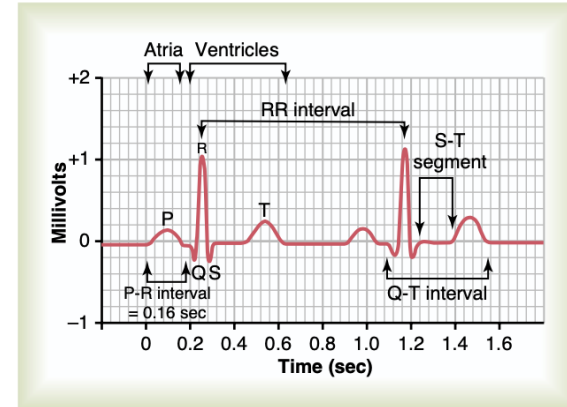


Figure 11-1

Normal electrocardiogram.

### Three major types of cardiac muscle:

- Atrial muscle
- Ventricular muscle
- Specialized excitatory and **conductive** muscle fibers.

The **cardiac cycle** is initiated by spontaneous generation of an **action potential** in the **sinus node**.

This allows the **atria** to **contract** ahead of ventricular contraction.

The **ventricles** provide the major source of power for moving blood through the body's vascular system

Cardiac impulse => electrical current  
Electrical potentials generated by the current can be recorded it's the **electrocardiogram**

**P wave** <= electrical potentials generated when the atria depolarize before atrial contraction begins.

**QRS complex** <= potentials generated when the ventricles depolarize before contraction

**T wave** <= potentials generated as the ventricles recover from the state of depolarization.

# Physiology aspects

## Patophysiology & Physiological parameters involved

**Sinus Bradycardia:** the sinus node fires too slowly

**Atrioventricular (AV) block:** conduction between the atria and ventricles is interrupted

**Sick sinus syndrome:** alternation of bradycardia and cardiac pauses or arrest.

**Impact on human health:** The heart rate becomes too slow → cardiac output decreases → organs are no longer adequately perfused => dizziness, syncope, fatigue, or even sudden death.

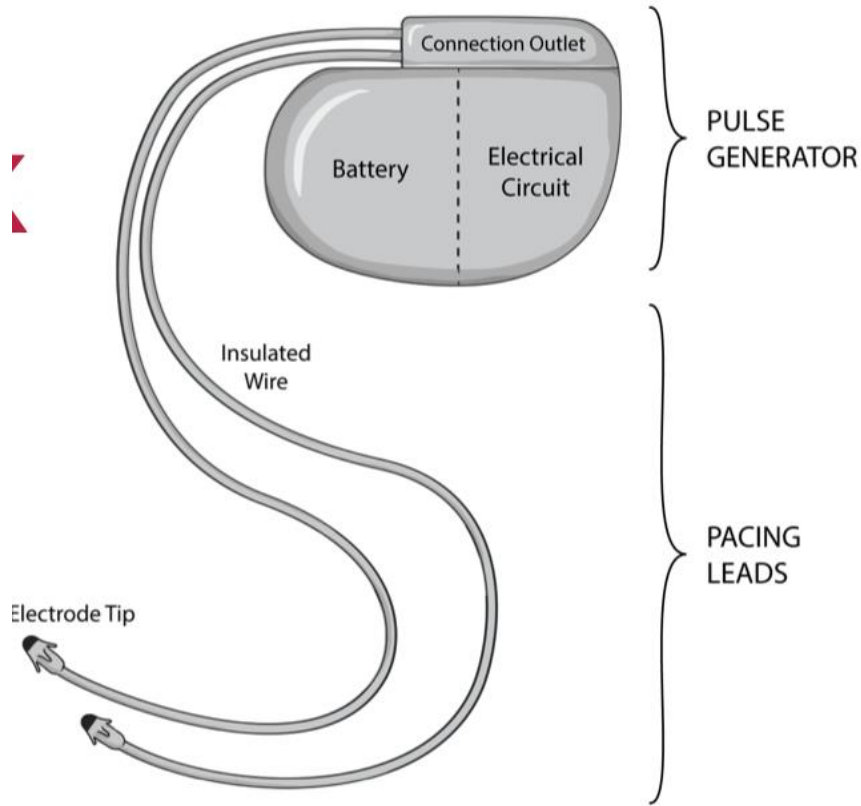
### Physiological parameters involved:

- Heart rate
- AV delay
- Electrical Activity of the myocardium (ECG signal)

### Role of the pacemaker:

- **Control:** delivers electrical impulses to trigger ventricular contraction.
- **Measurement:** detects the heart's natural electrical activity
- **Functional repair:** replaces the role of a failing sinoatrial or atrioventricular node.

# Technical description



## The Pulse Generator:

- small metal container that contains the battery and electronic circuitry
- placed under the skin, most often below the collar bone.

The pulse generator stores information about heart, the battery and leads.

## The Pacing Leads (Wires):

- flexible insulated wires
  - placed in one or two chambers of your heart.
- They detect the heart's natural rhythm, deliver the electrical signal from the pulse generator to the heart when necessary.

# Technical description: Evolution

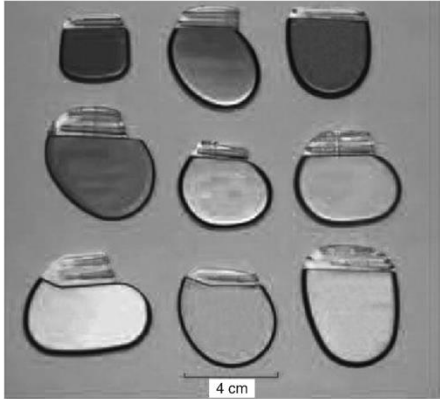


Figure 2. Illustration of some pacemaker shapes and sizes.

**1950s:** First external pacemakers, connected to main power supply.

**1958:** *Elmqvist & Senning* implanted the first internal pacemaker — short lifespan but proof of concept.

**1960s:** *Greatbatch & Chardack* developed improved implantable devices used clinically.

Beginning: Fixed-rate pacing, ignoring natural heart rhythm.

Next advances: stimulates only when needed, adapting to physical activity, Integration into of defibrillators (ICDs)

**Now:** Miniaturized devices ( $\approx 6$  mm), and pediatric use. adaptive pacemakers using advanced sensors and algorithms.

# Technical description: Mode of action

## Generalities:

- The pacemaker senses the heart's electrical activity via its electrodes.
- If no natural beat is detected within a programmed time interval, it delivers an electrical pulse to stimulate the myocardium.
- The impulse causes depolarization of cardiac cells, triggering contraction (similar to a natural action potential).

The specific mode of action depends on the pacemaker type, identified by the International Pacemaker Code

**Table 1. International Pacemaker Codes**

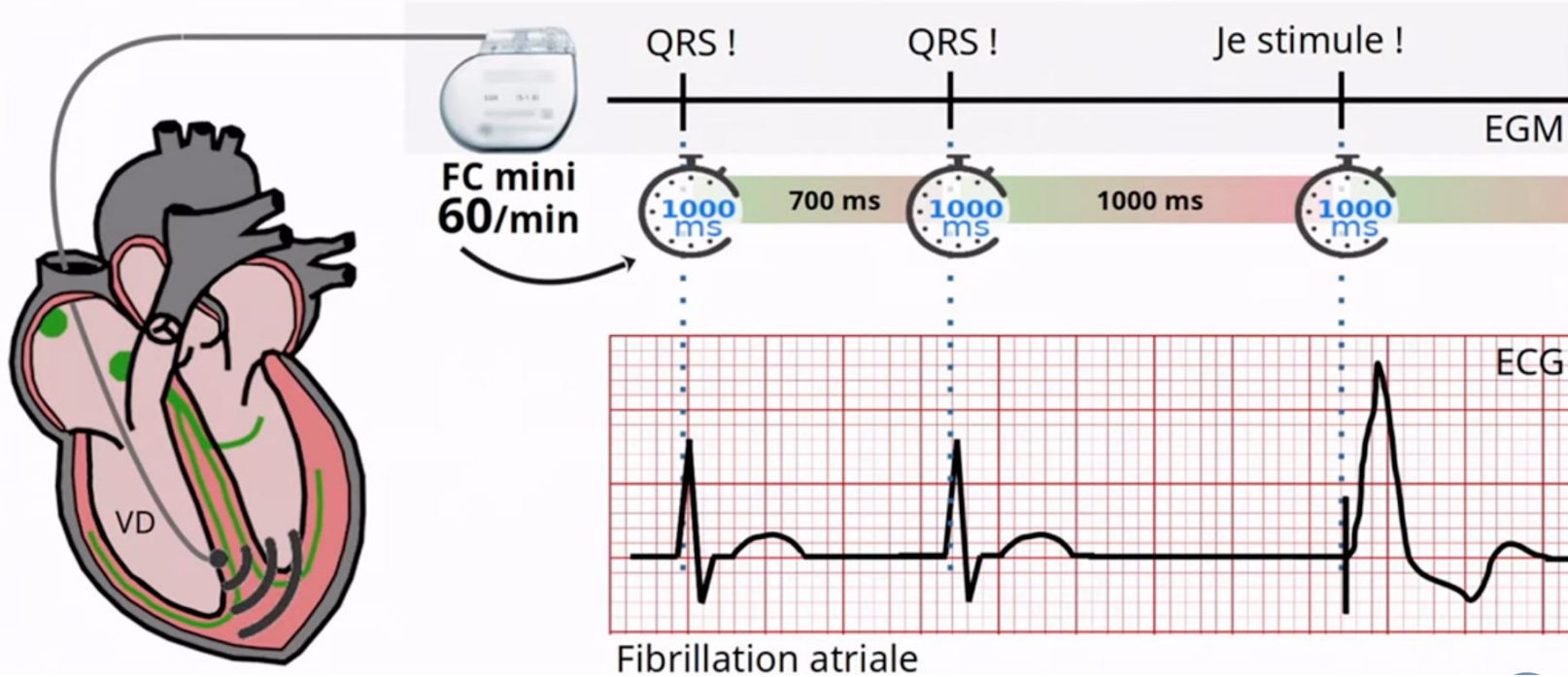
1	2	3	4	5
Chamber paced	Chamber sensed	Response	Rate modulation	Multisite pacing
O = none	O = none	O = none	O = none	O = none
A = atrium	A = atrium	I = inhibited	R = rate modulation	A = artium
V = ventricle	V = ventricle	T = triggered		V = ventricle
D = A+V	D = A+V			D = A+V

The following letters are used sequentially in 5 positions.

# Technical description:

## Mode of action : Comparison of different principle

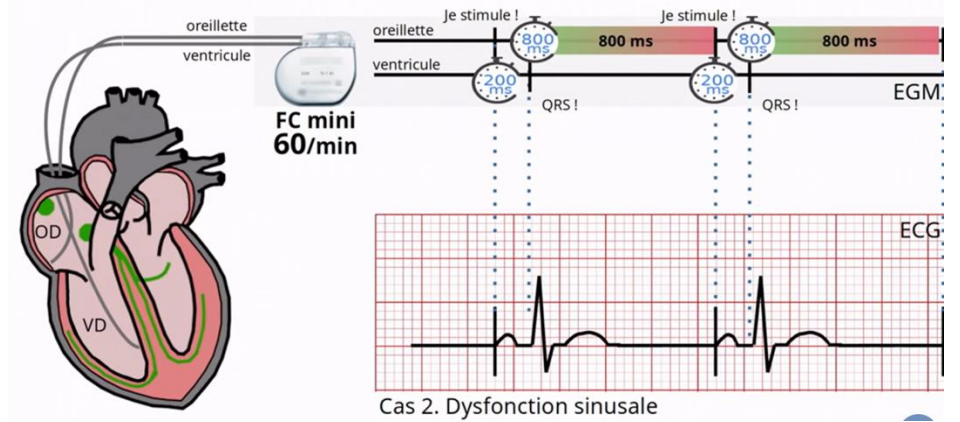
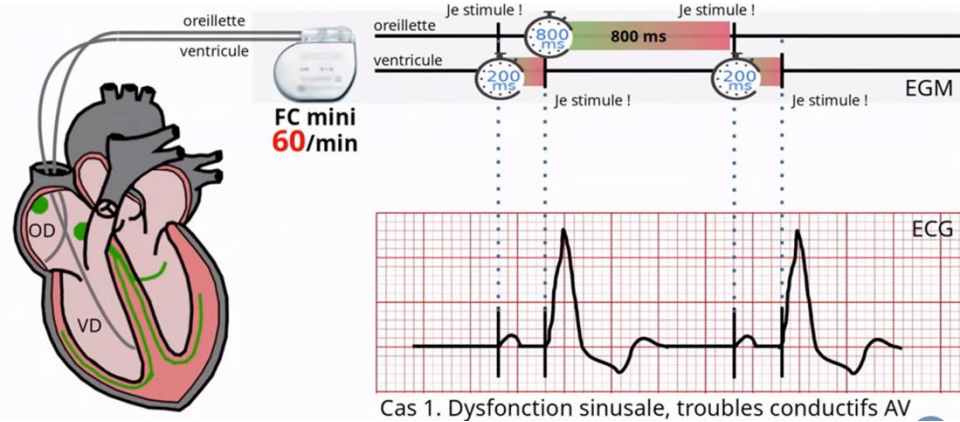
SINGLE CHAMBER: VVI



# Technical description:

## Mode of action : Comparison of different principle

### DOUBLE CHAMBER: DDD



# Specifications

**Table 2. Example Ranges of Pulse Generator Features**

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Volume	6–20 ml
Length/Width	30–60 mm
Depth	6–14 mm
Mass	13–50 g
Battery	0.8–2 Ah
Life	5–14 years
Sense threshold	0.1–15 mV
Refractory period	100–800 ms
Lower pulse rate	approximately 20/min
Upper pulse rate	approximately 185/min
Pulse amplitude	0–10 V
Pulse width	0.1–2 ms

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# Medical significance

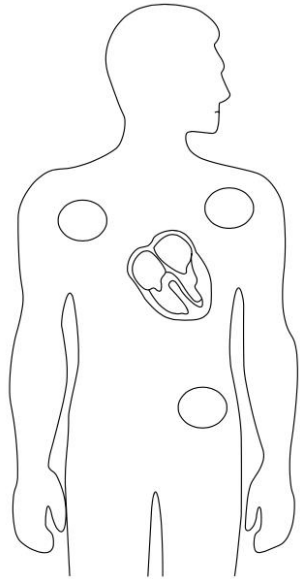
## **Indication & benefice:**

Use in Treatment of bradyarrhythmias => reduction of the risk of syncope, or even sudden death.

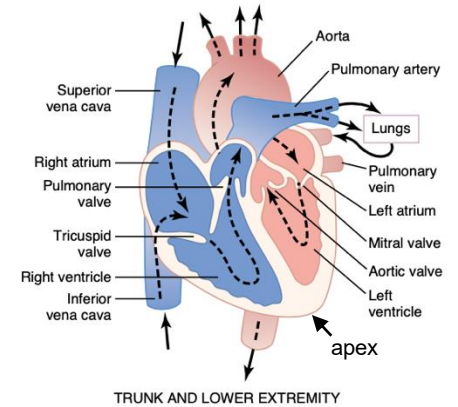
## **Statistic:**

Over half a million new patients worldwide receive a pacemaker each year

# Clinical application



**Figure 1.** The location of normal pulse generator implantation sites.



## **Implantation Sites:**

- Pacemakers are typically implanted at one of three common sites.

## **Implantation procedure:**

- implanted by a cardiologist or cardiac surgeon under aseptic conditions.
- The pulse generator and leads are supplied in sterile packaging with a clear expiry date.

## **Lead placement:**

- Leads are introduced via a vein and guided through the right atrium and tricuspid valve into the right ventricle.
- The ventricular lead is generally positioned at the apex, where displacement risk is minimal.

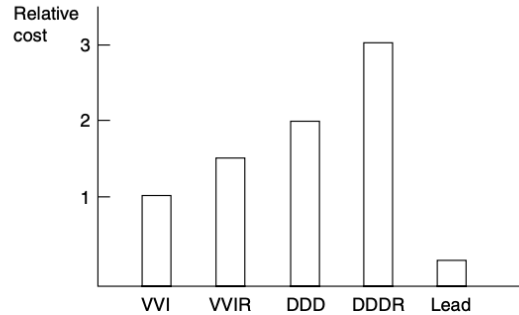
## **Atrial lead:**

- When an atrial lead is used, it is positioned in the right atrium.
- Stable wall contact is harder to achieve, active fixation systems are often preferred over passive fixation.

## **Post-implantation follow-up**

Regular check-ups are required to verify correct device function period of months initially, and then annually, with more frequent follow-up visits toward the end of the device's life.

# « Product » aspects



**Figure 3.** Relative approximate costs of pulse generators and pacing leads. The demand pacemaker (VVI) is taken as the reference.

## **Cost:**

For a health-care system, the cost of devices is important. Costs vary significantly in different countries and also relate to the numbers purchased.

For exemple in France a VVI is 6300euros

**Key players:** Medtronic is the historic leader with 40% of the mondial market

# Future perspectives

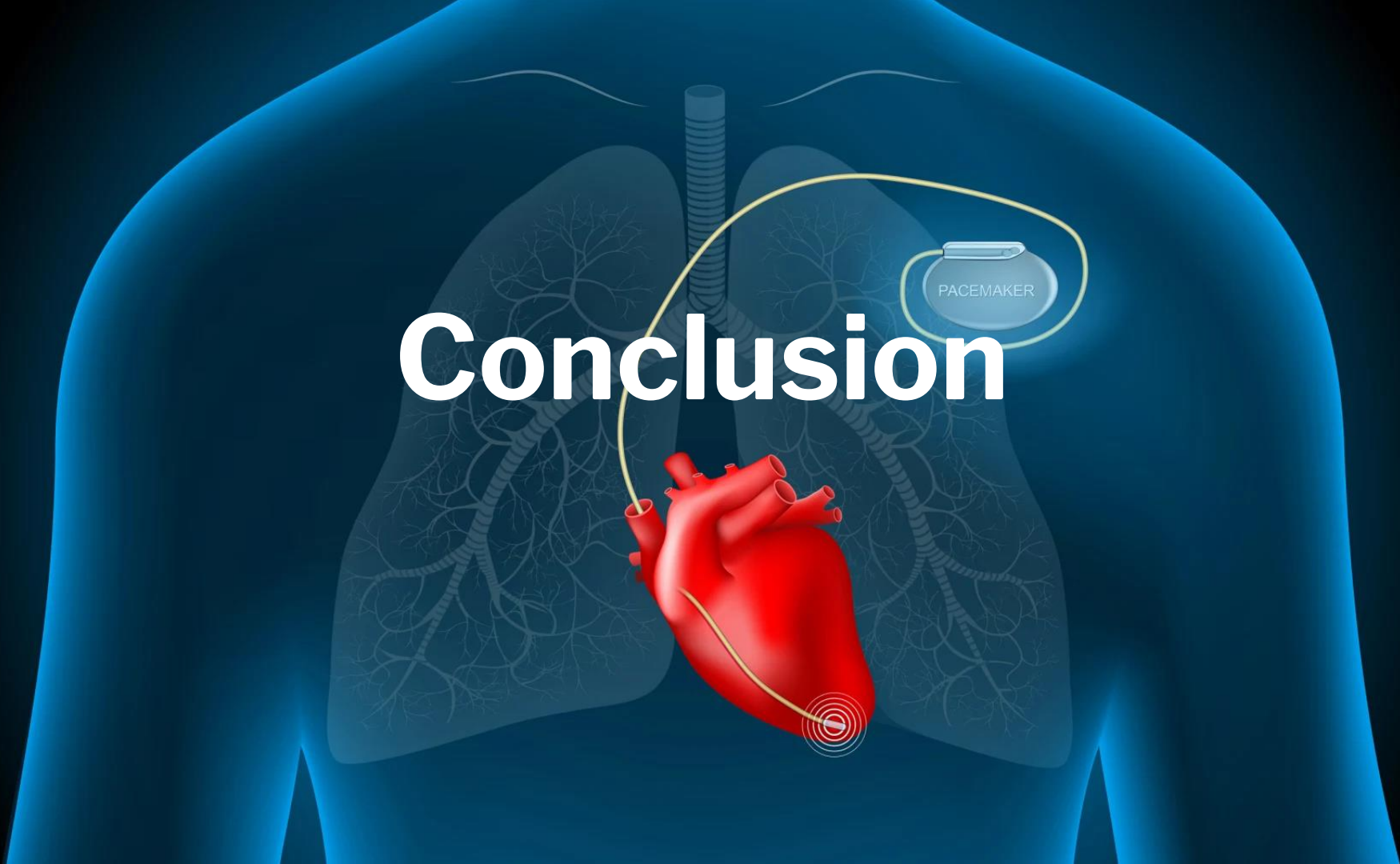
- Demand will increase with an aging population.
- Development and production of pacemakers will remain a major medical device industry.

## Technical advances depend on:

- Improved batteries: smaller, longer-lasting, or powering more advanced microprocessors.
- Electrode design: reduce energy requirements and pacing pulse energy.
- Optimized AV delay settings, beneficial especially for active patients and children.
- Enhanced data storage for intracardiac monitoring and research.



# Conclusion



# Questions

