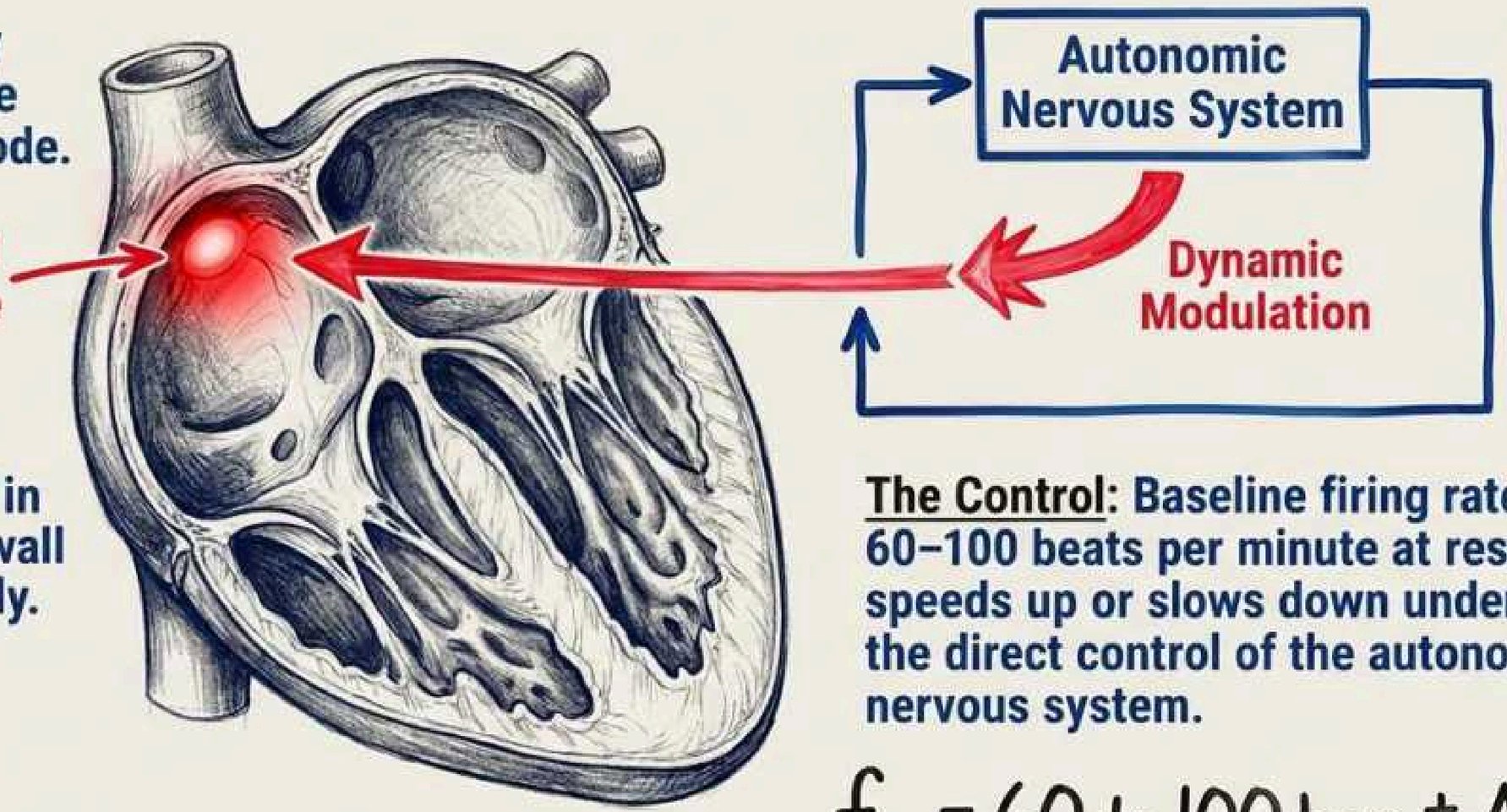
¶ 5.1

The Origin of the Beat: The Natural Pacemaker

The Origin: Every beat begins in the Sinoatrial (SA) node.



The Mechanism: Specialized cells in the right atrium wall fire spontaneously.

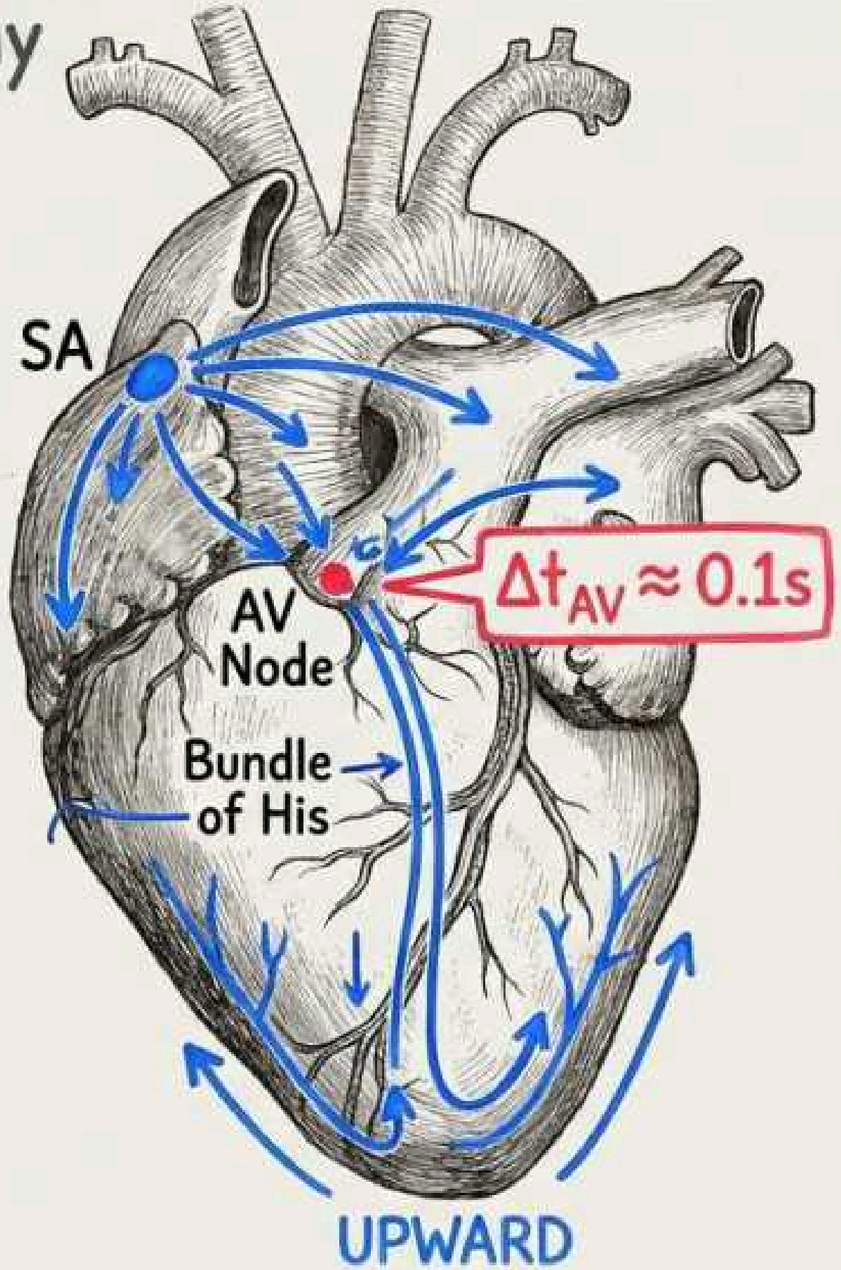
The Control: Baseline firing rate is 60–100 beats per minute at rest. This speeds up or slows down under the the direct control of the autonomic nervous system.

$$f_{SA} = 60 \text{ to } 100 \text{ bpm} \pm \Delta ANS$$

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The Conduction Pathway and Mechanical Timing

¶ 5.2



1. Atrial Contraction: The impulse spreads across both atria first.

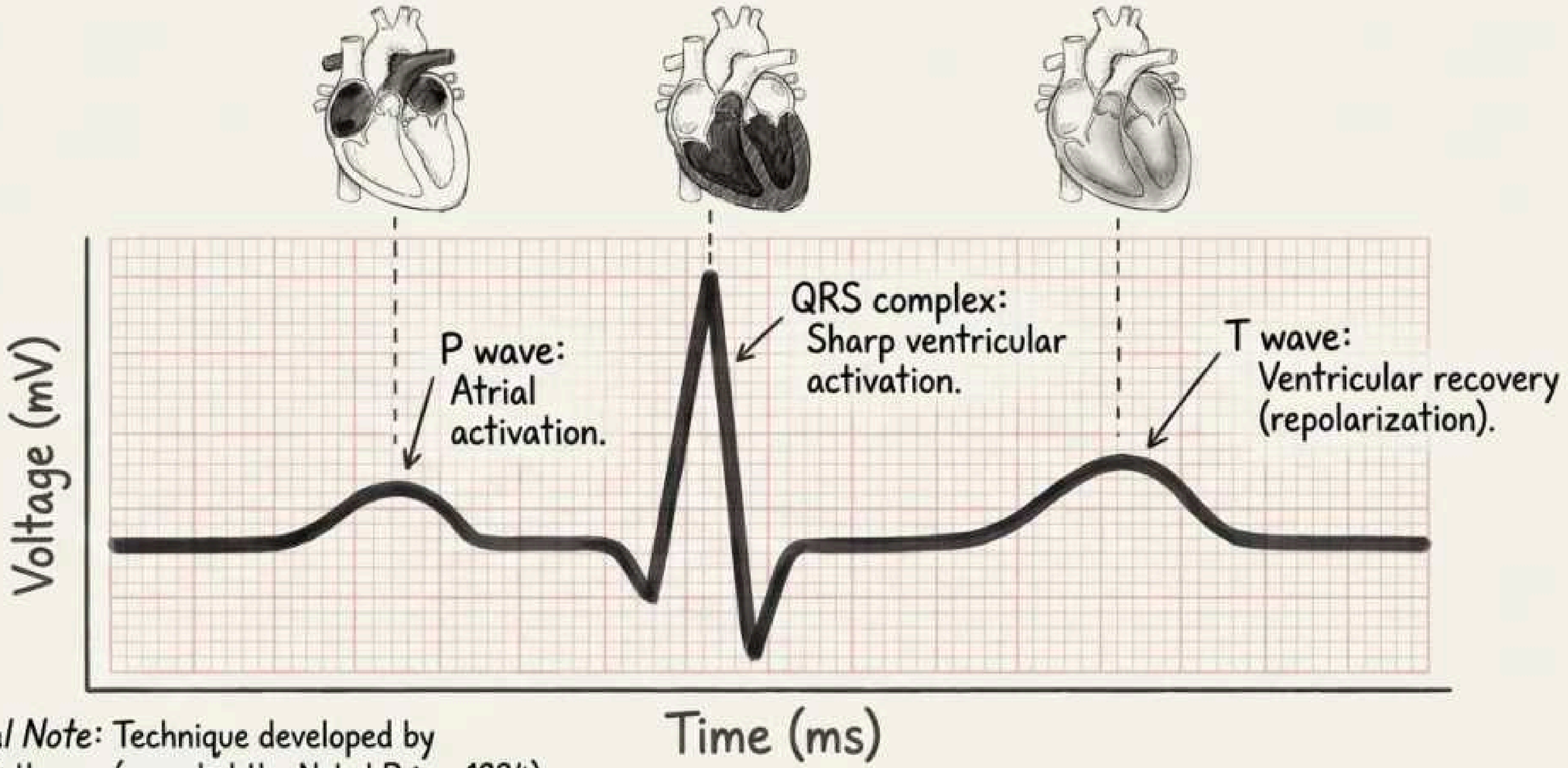
2. AV Node Delay: The signal pauses briefly, allowing the atria to finish filling the ventricles with blood.

3. Ventricular Contraction: The impulse travels rapidly down conducting fibers. Ventricles contract together from the tip upward, squeezing blood out efficiently.

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¶ 5.3

Reading the Electrocardiogram (ECG)

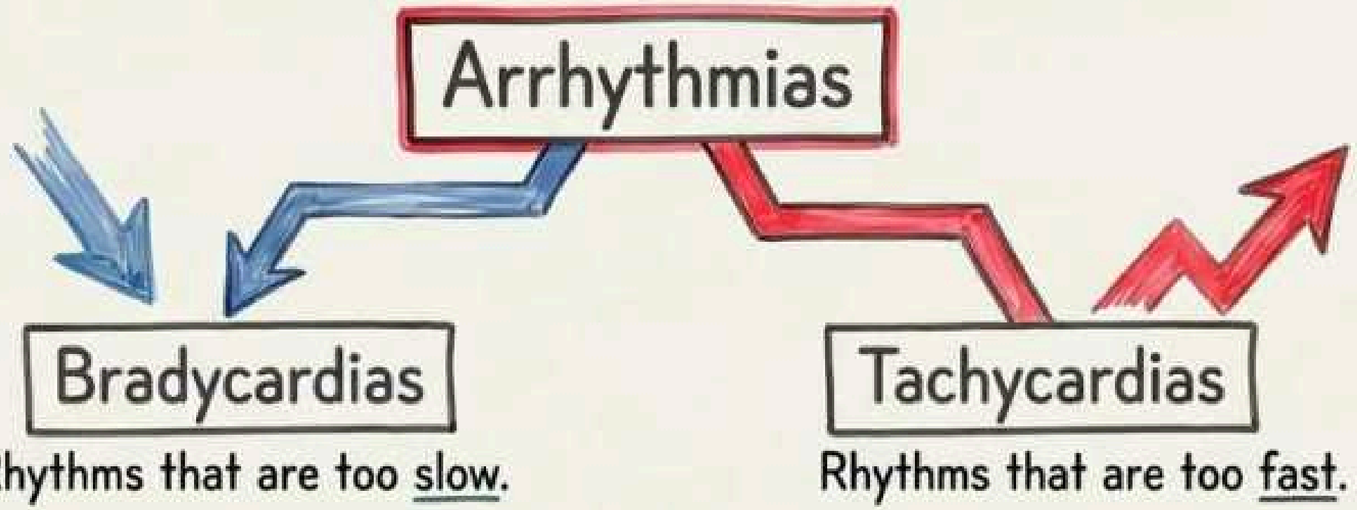


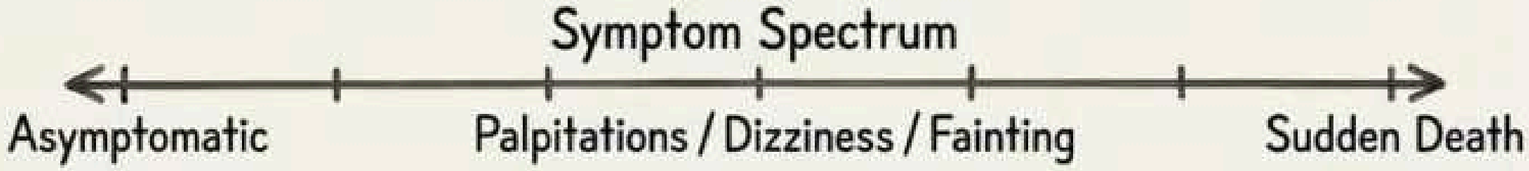
Historical Note: Technique developed by Willem Einthoven (awarded the Nobel Prize, 1924).

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¶ 5.4

The Taxonomy of Arrhythmias





Clinical Presentation: Symptoms entirely depend on how much the arrhythmia reduces the heart's mechanical pumping output.

$$CO = HR \times SV$$

(Cardiac Output = Heart Rate × Stroke Volume). Extremes in HR lower CO.

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Bradycardia and Complete Heart Block

¶ 5.5

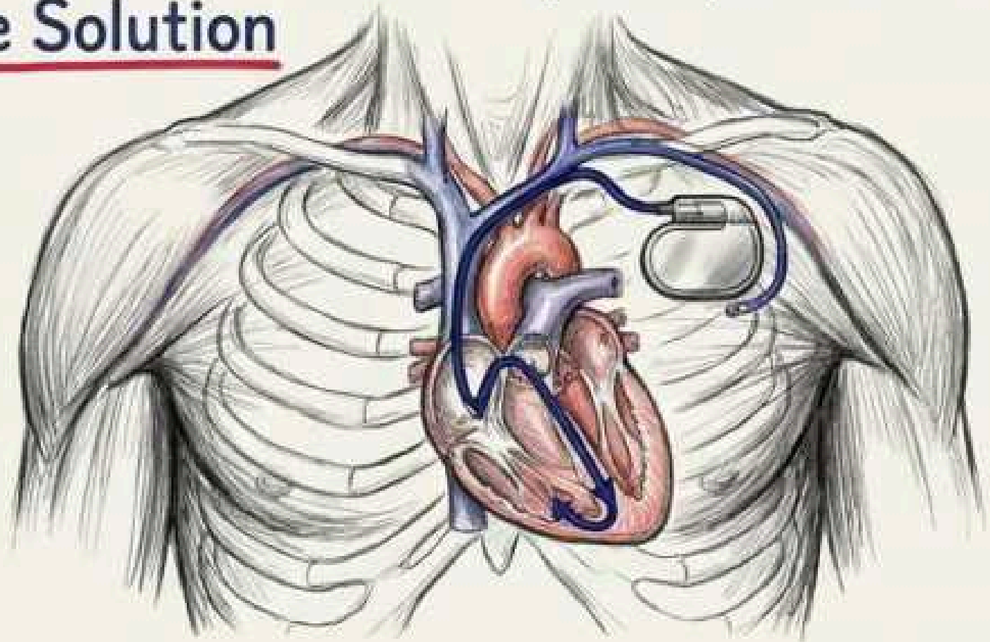
The Failure



The Failure: Arises when the sinus node fails or AV node conduction is delayed or completely blocked.

Complete Block: Zero electrical impulses get through to the ventricles; ventricles beat independently at a dangerously slow rate, risking loss of consciousness.

The Solution

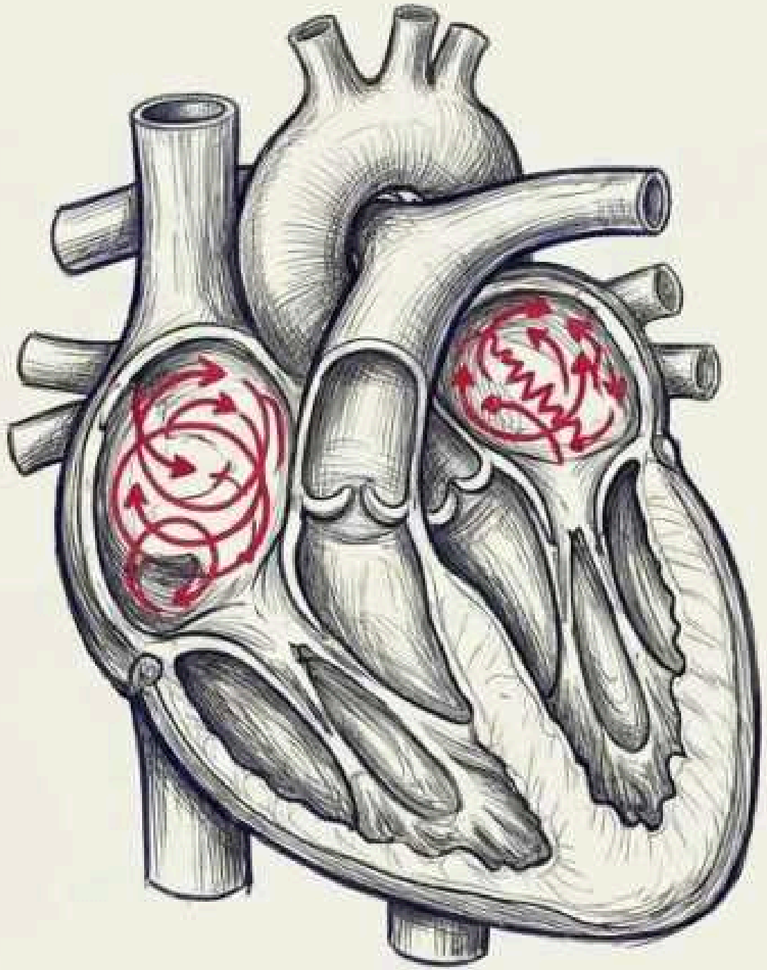


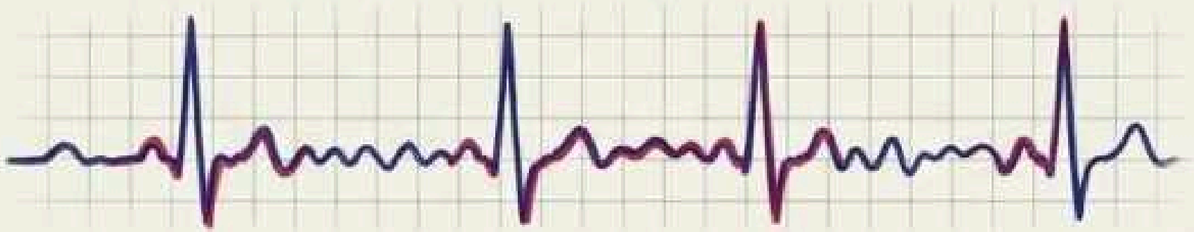
The Solution: Implantation of an artificial pacemaker to restore electrical continuity and an adequate heart rate.

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Atrial Fibrillation: The Chaotic Quiver

¶ 5.6





$$P(\text{AFib}) \propto \text{Age}$$

The Most Common: AFib is the most prevalent sustained arrhythmia, affecting a substantial share of patients >80 years old.

The Chaos: Organized atrial contraction is completely lost; the atria quiver chaotically instead of squeezing.

The Response: Ventricles respond at an irregular, often fast rate. Symptoms range from palpitations and breathlessness to completely asymptomatic.

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The Primary Danger of AFib: Ischemic Stroke ¶ 5.7



Treatment Threshold = f(Stroke Risk Score) > Bleed Risk

The Danger: Because the atria fail to contract properly, blood pools and forms clots in the left atrium.

The Cascade: A dislodged clot travels directly through the arterial system to the brain, causing a stroke.

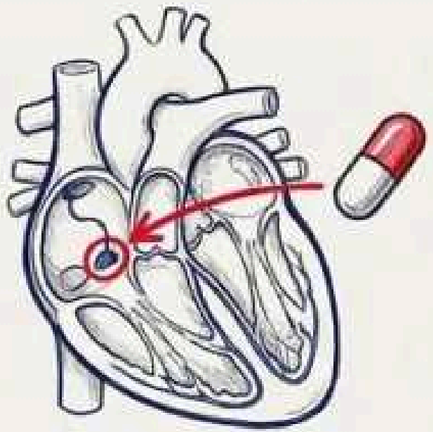
The Prevention: Anticoagulant drugs reduce the blood's tendency to clot. Doctors use clinical scoring systems to weigh the benefits of stroke prevention against the risks of bleeding.

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¶ 5.8

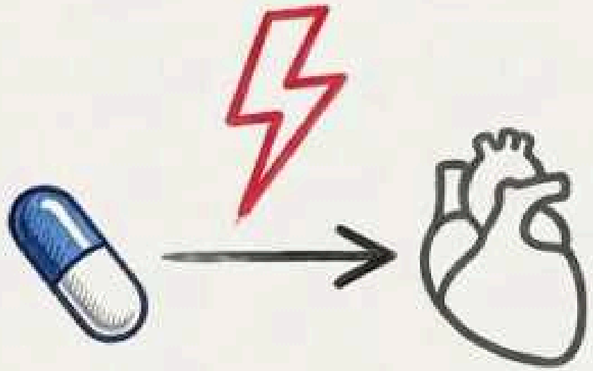
Clinical Management of Atrial Fibrillation

1. Rate Control



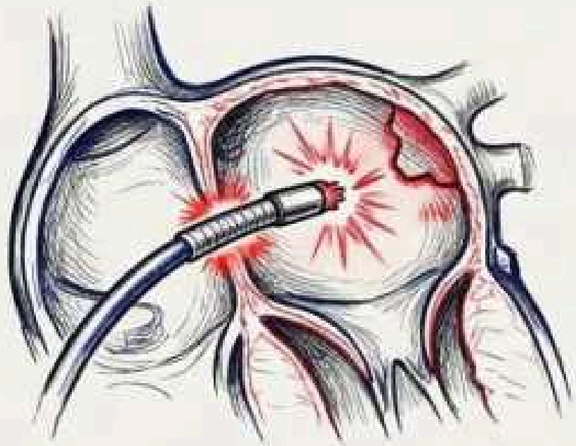
Drugs utilized specifically to slow electrical conduction through the atrioventricular (AV) node.

2. Rhythm Control



Use of specialized drugs or an electrical shock (cardioversion) to restore and maintain normal sinus rhythm.

3. Ablation Procedure



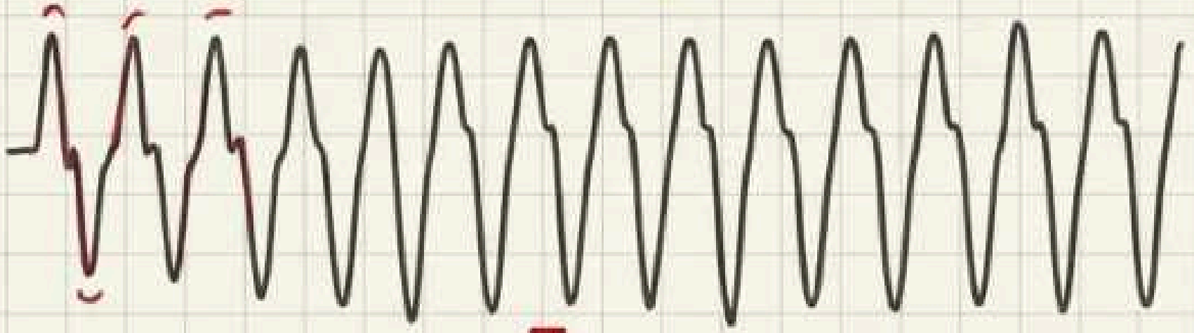
A catheter-based intervention used to destroy small areas of tissue that trigger the abnormal rhythm.

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The Danger Zone: Ventricular Arrhythmias

¶ 5.9

Ventricular Tachycardia (VT)



Severely compromises mechanical output.

A dangerously fast rhythm originating in the ventricles that severely compromises the heart's mechanical output.

Ventricular Fibrillation (VF)



$Q_{output} \approx 0$ L/min → Circulation stops.

Chaotic electrical activity; the ventricles merely quiver without pumping any blood.

The Consequence: Without immediate treatment, circulation completely stops, causing death within minutes.

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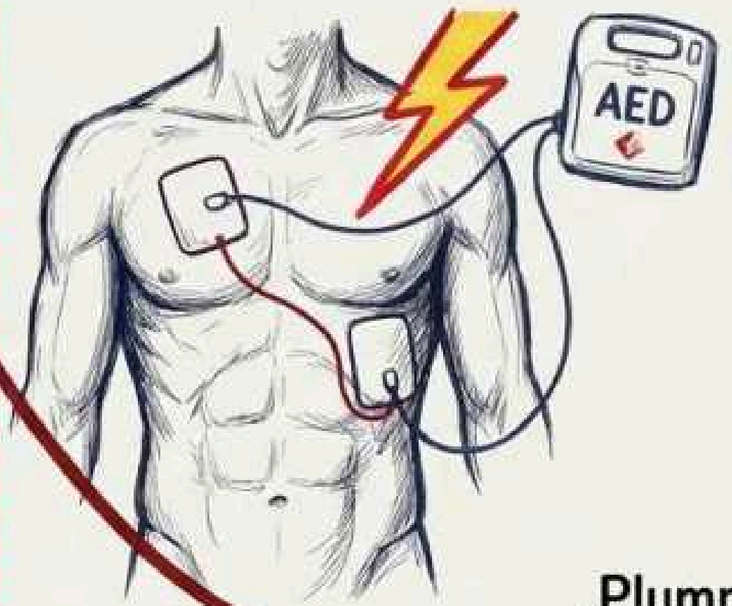
Sudden Cardiac Arrest & Rapid Defibrillation

¶ 5.10

The Crisis:
Usually caused by VFib in patients with coronary artery disease or weakened heart muscle. The patient collapses and stops breathing.

The Chain of Survival:
Survival strictly depends on immediate Cardiopulmonary Resuscitation (CPR) to manually maintain flow.

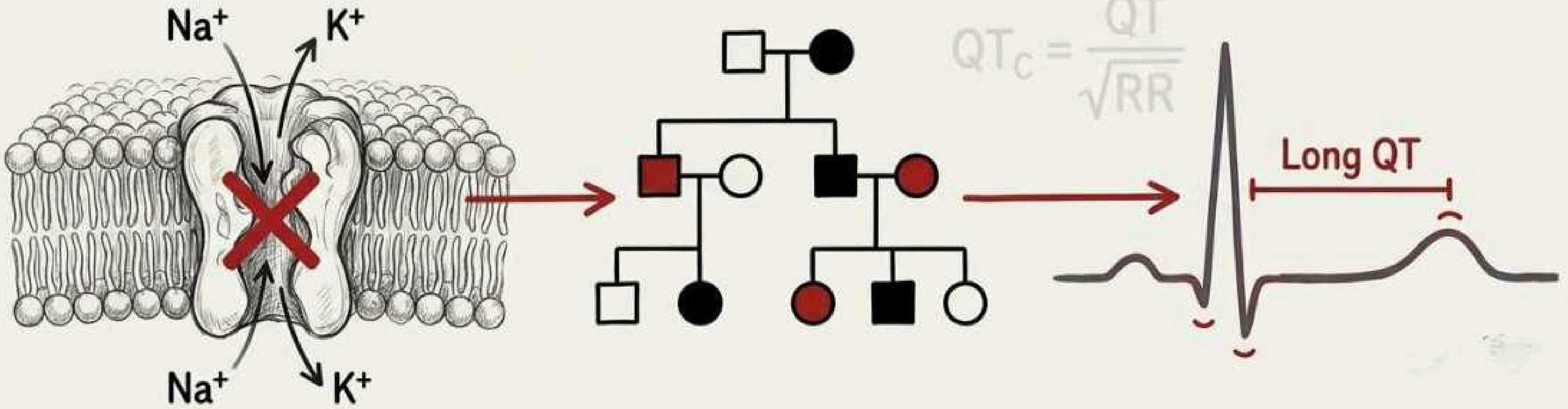
The Reset: Rapid defibrillation (an electric shock) resets the heart's rhythm. Public AEDs are designed for untrained bystanders to save lives.



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Inherited Arrhythmias and Channelopathies

¶ 5.11



The Defect: Conditions like Long QT syndrome alter the microscopic ion channels that shape the heart's electrical activity.

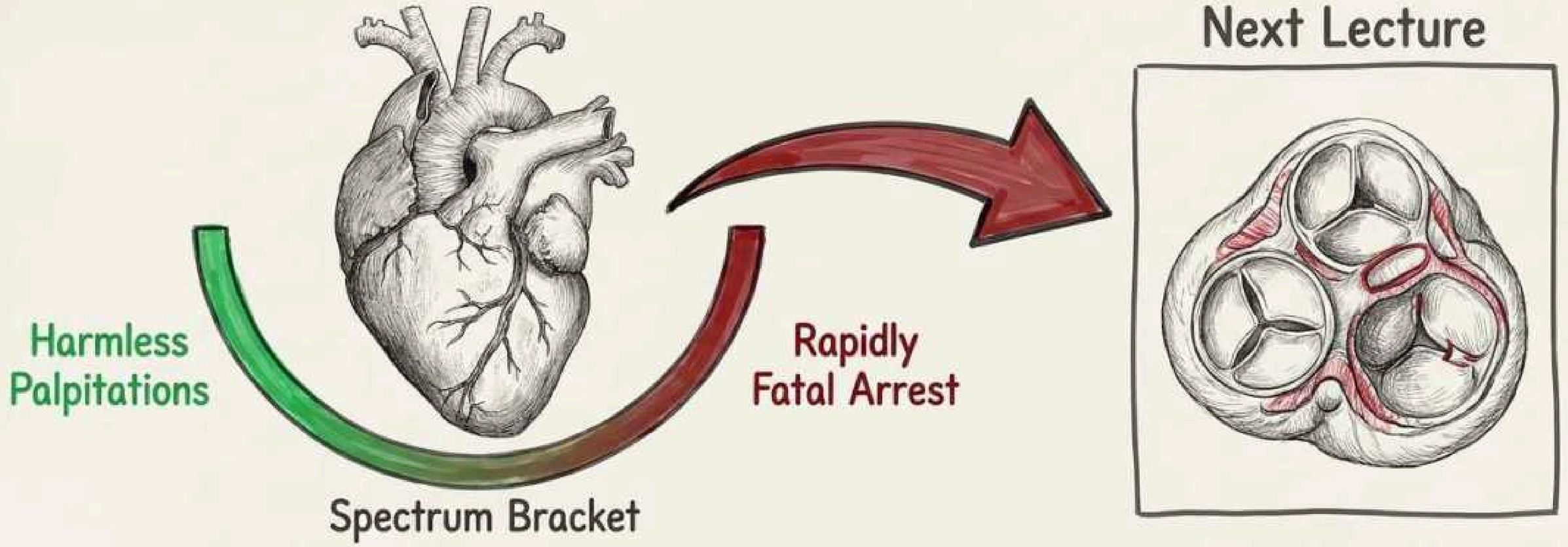
The Tragedy: These inherited defects can cause sudden fainting or death in apparently healthy healthy young individuals.

The Mandate: Recognizing these conditions allows for life-saving treatment and necessitates testing for family members (Link: MED 503 B, Genetics in Modern Medicine).

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System Synthesis and Looking Ahead

¶ 5.12



Summary: The heart relies on an exquisitely precise electrical system. Disorders of this system span a massive spectrum from entirely benign to rapidly fatal.

Looking Ahead: Our final lecture will transition from the heart's electrical wiring to its mechanical hardware (the valves) and the holistic assessment and prevention of cardiovascular disease.

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