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Fundamentals of Pacing Therapy

Electrical Terms and Concepts

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- This presentation is provided with the understanding that the slide content must not be altered in any manner as the content is *subject to FDA regulations*.
- This presentation is to be used in conjunction with other resource material including the applicable Boston Scientific device *physician's manual* and any *implant accessories instructions* for use.
- This presentation is not intended to replace implant training.
- Proper surgical procedures and techniques are the responsibilities of the medical professional.
- If this presentation is not used in its entirety, the following information must be included:
 - Appropriate Indications
 - Contraindications
 - Warnings
 - Precautions and Adverse Events

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When we complete this program you will be able to:

- *Define* basic electrical terms
- *Explain* how these terms relate to device function
- *Discuss* the relationship between voltage, current, and resistance
- *Define* stimulation threshold and factors affecting it
- *Explain* pacemaker sensing and factors affecting it

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Electrical Terms and Concepts:

- Ohm's Law
 - Voltage
 - Current
 - Impedance
- Energy
- Stimulation Threshold
- Sensing
 - Slew Rate

Ohm's Law: $V = I \times R$

Describes the relationship between voltage, current, resistance: $V = I \times R$; $I = V/R$; $R = V/I$

Voltage	The electrical force that makes current move through a conductor – <i>measured</i> in volts (V)
Impedance	The total opposition presented to the flow of current by an electrical circuit or device – <i>measured</i> in ohms (R)
Current	The transfer of electrical charge (electrons) through a cross-section of a conductor – <i>measured</i> in amperes (I)

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Voltage:

- The force or “push” that causes electrons to move through a circuit
- Measured in volts
- Represented by the letter “V”
- Often referred to as amplitude

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Current:

- The flow of electrons in a completed circuit
- Measured in mA (milliamps)
- Represented by the letter "I"

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Impedance:

- The opposition to current flow
- Measured in ohms
- Represented by the letter "R" (W for numerical values)
- Often referred to as resistance

Ohm's Law

Can Be Used to Find Current

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Example 1:

Voltage	=	5 V
Impedance	=	500 Ω

What will the current be?

$$I = V/R \quad 5 \text{ V} \div 500 \Omega = 0.010 \text{ Amperes} \times 1000 = 10 \text{ mA}$$

Ohm's Law

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Example 2:

Voltage	=	2.5 V
Impedance	=	500 Ω

What will the current be?

$$I = V/R \quad 2.5 \text{ V} \div 500 \Omega = 0.005 \text{ Amperes} \quad 0.005 \times 1000 = 5 \text{ mA}$$

Ohm's Law

Can Be Used to Find Current

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Example 3:

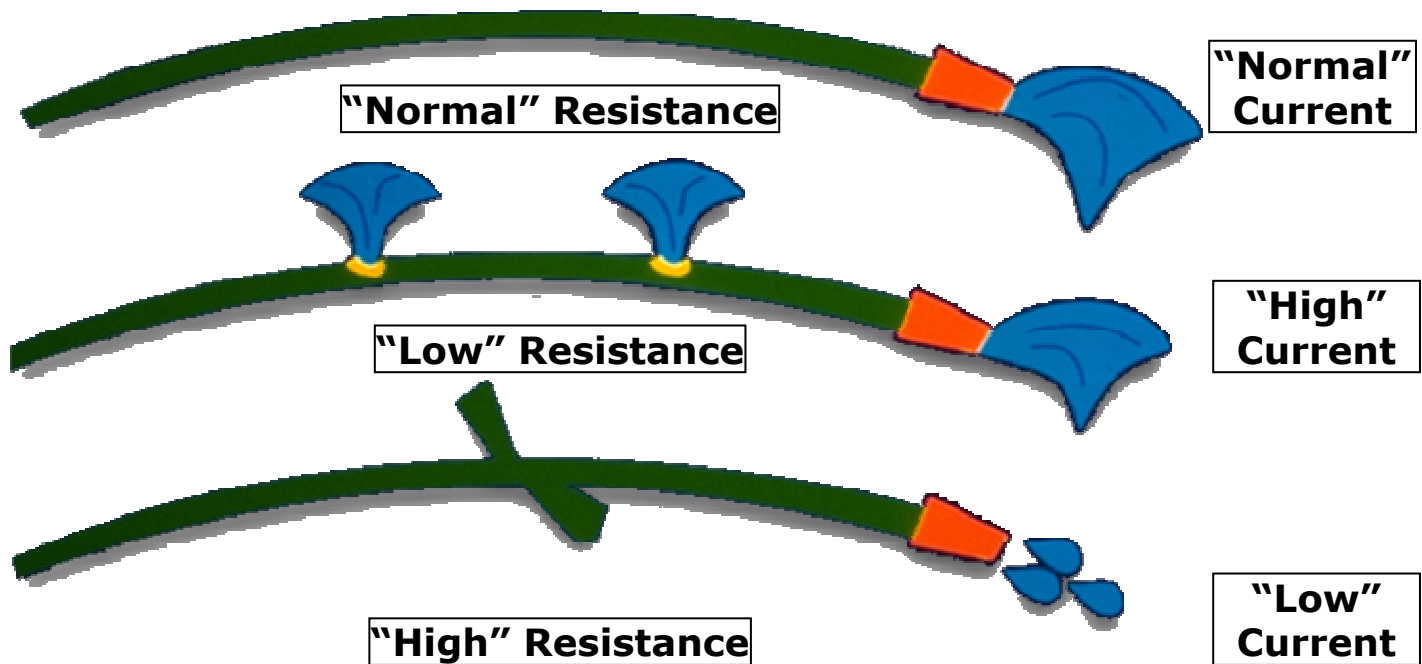
Voltage	=	5 V
Impedance	=	250 Ω

What will the current be?

$$I = V/R \quad 5 \text{ V} \div 250 \Omega = 0.020 \text{ Amperes} \quad 0.020 \times 1000 = 20 \text{ mA}$$

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$

- Current is similar to the flow of water
- Voltage is analogous to water pressure
- Resistance can be compared to resistance to flow



Device Function

Insulation Break

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Ohm's Law

▶ Device Function

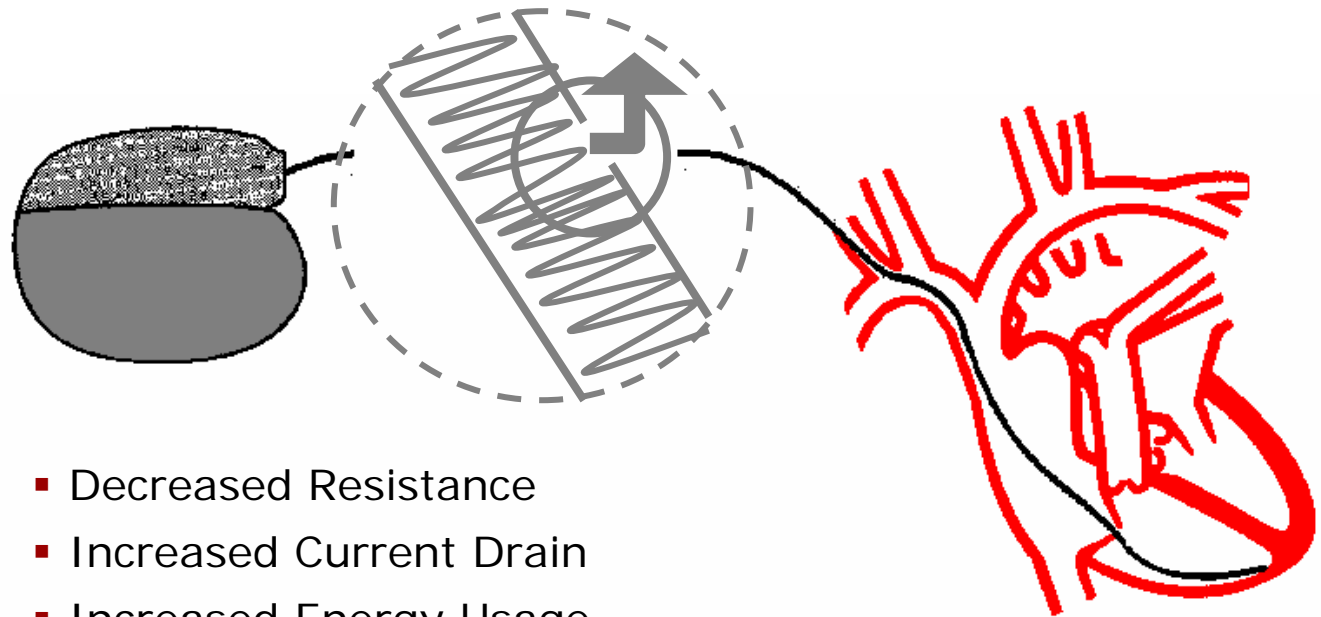
Stimulation
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Current is Escaping:



- Decreased Resistance
- Increased Current Drain
- Increased Energy Usage

Device Function

Lead Fracture

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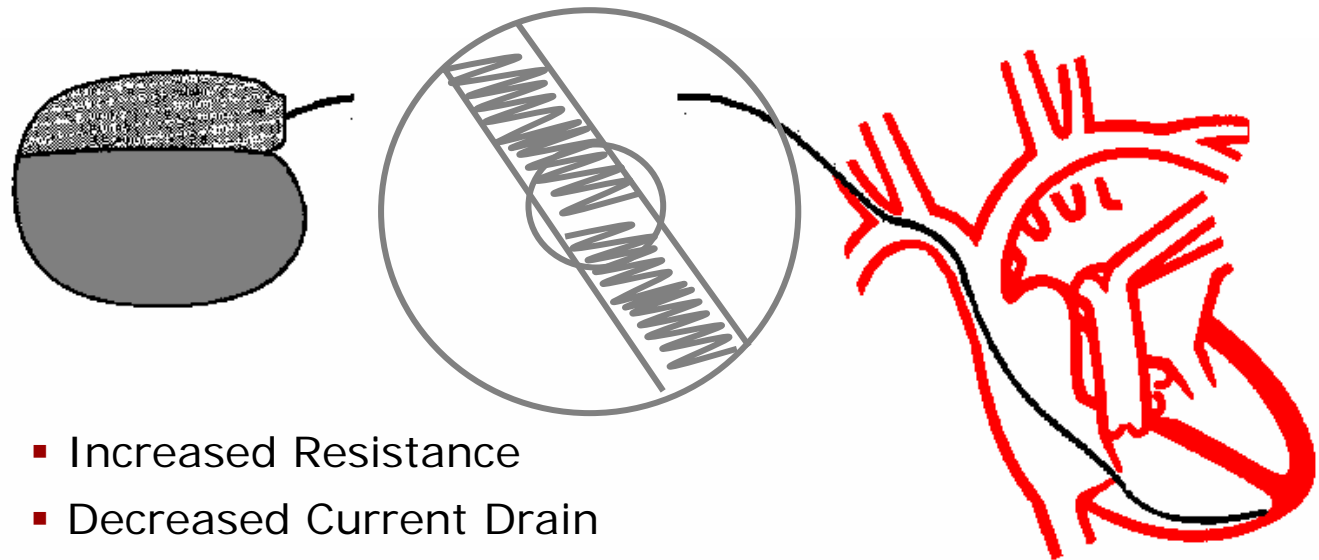
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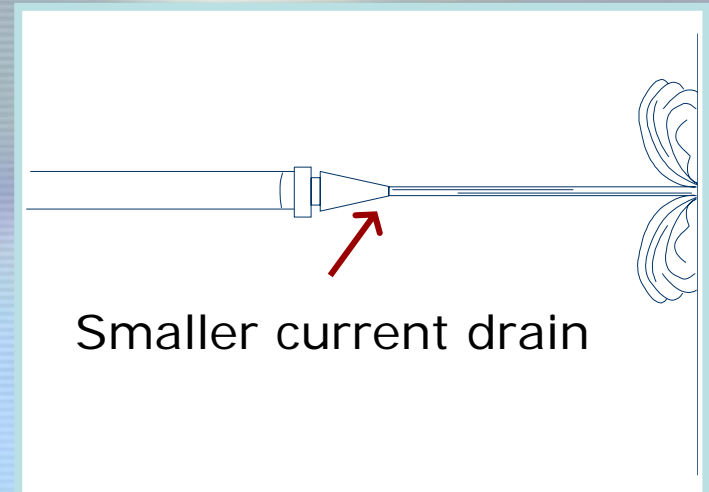
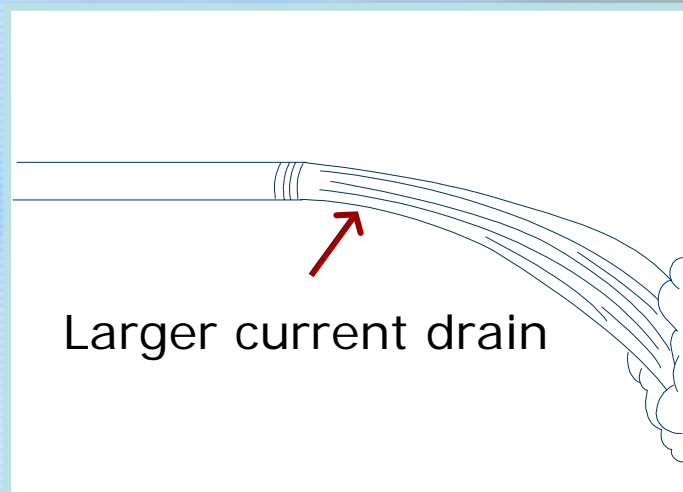
Current Cannot Reach Heart:



- Increased Resistance
- Decreased Current Drain
- Decreased Energy Usage

Reducing Electrode Size:

- Increases impedance
- Decreases current drain
- Increases longevity



Device Function

Impedance

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High
Impedance

Decreases battery current drain,
increases longevity

Low
Impedance

Increases battery current drain,
decreases longevity

Device Function

Constant Voltage Pacemakers

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\bar{V}	=	↓	IR	↑
\bar{V}	=	↑	IR	↓

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Definition:

The minimum electrical stimulus needed to consistently capture the heart outside of the heart's refractory period

Stimulation Threshold

Pulse Amplitude

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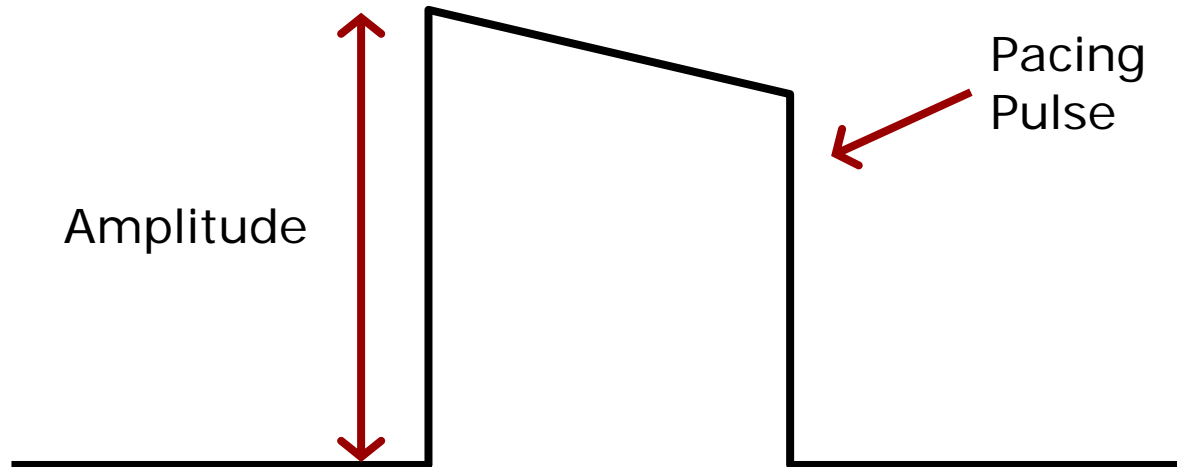
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The voltage delivered by the electrical pacing stimulus (volts)



Stimulation Threshold

Pulse Width

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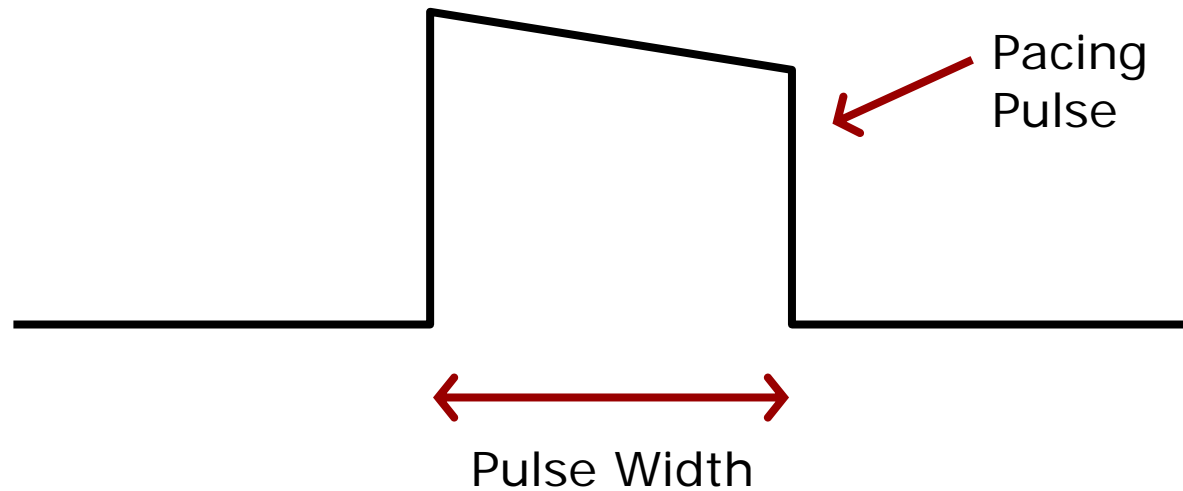
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Duration of the electrical pacing pulse (milliseconds)



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- Amplitude (V) + Pulse Width (ms) = Output
- Lowest Output that Captures Outside of Refractory = Threshold

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Why Measure?

- Assure proper lead placement
- Determine safety margin

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Affected by:

- Lead Maturation
- Lead Technology
- Medications
- Lead Location

Stimulation Threshold

Lead Maturation

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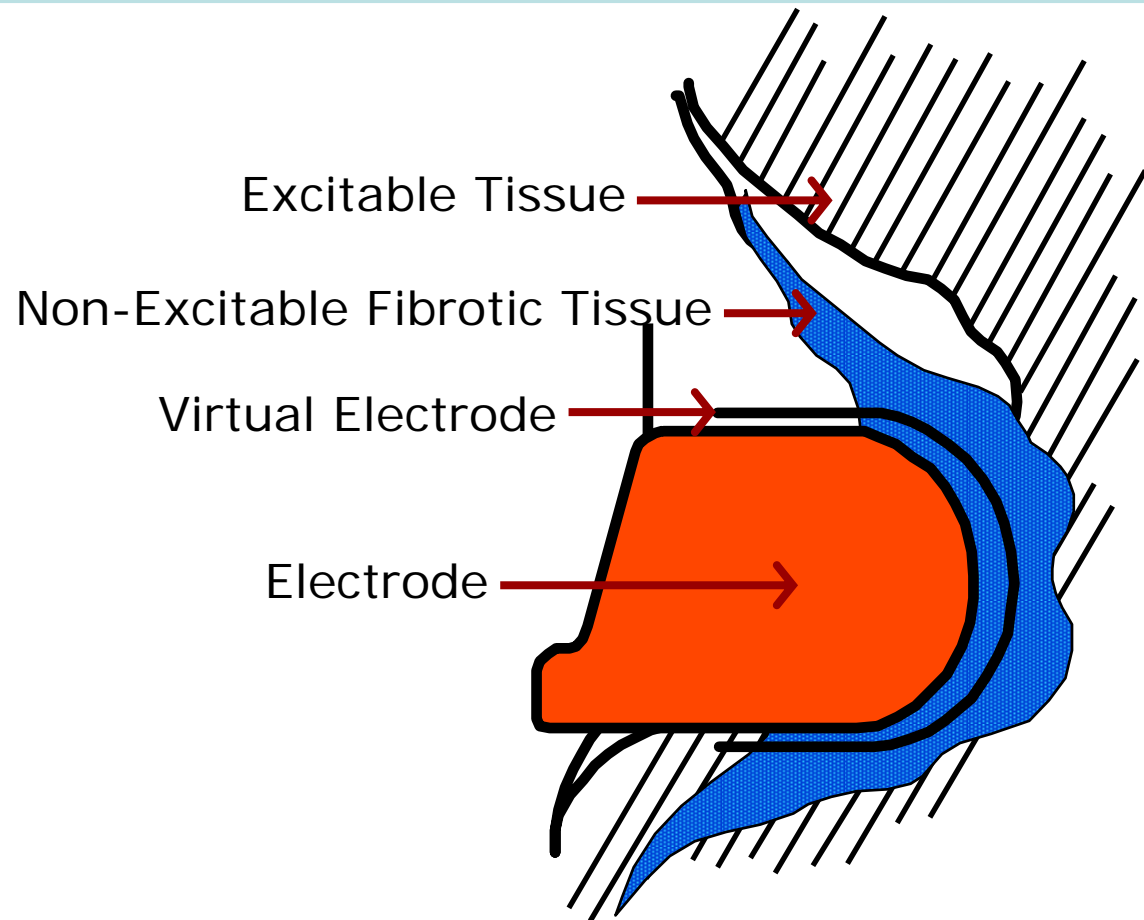
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Chronic Electrode:



Stimulation Thresholds

Effect of Steroid

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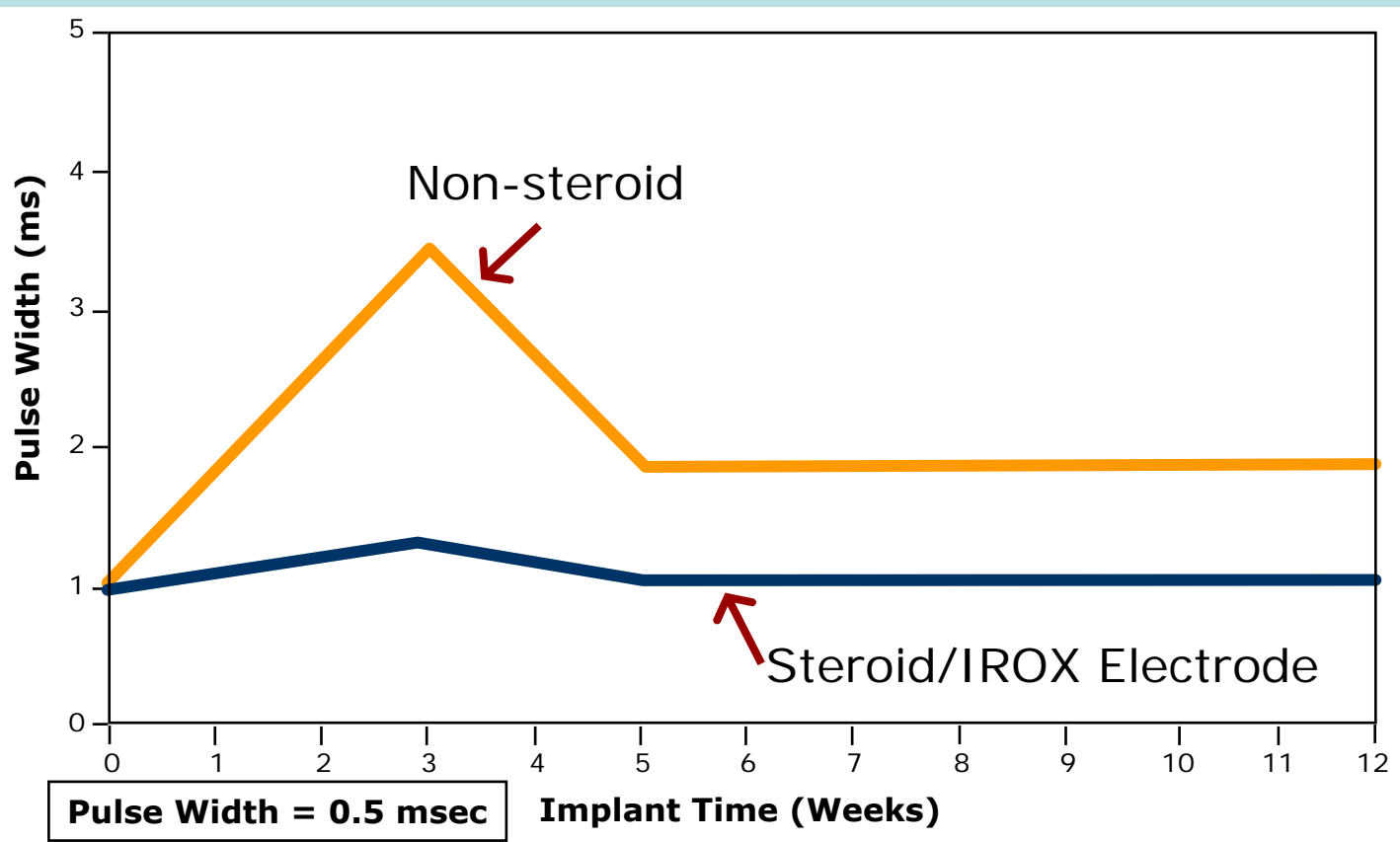
Device Function

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S. Furman, D. Hayes, D Holmes; "A Practice of Cardiac Pacing" 2nd Revision, 1989; p.36

Stimulation Threshold Strength Duration Curve

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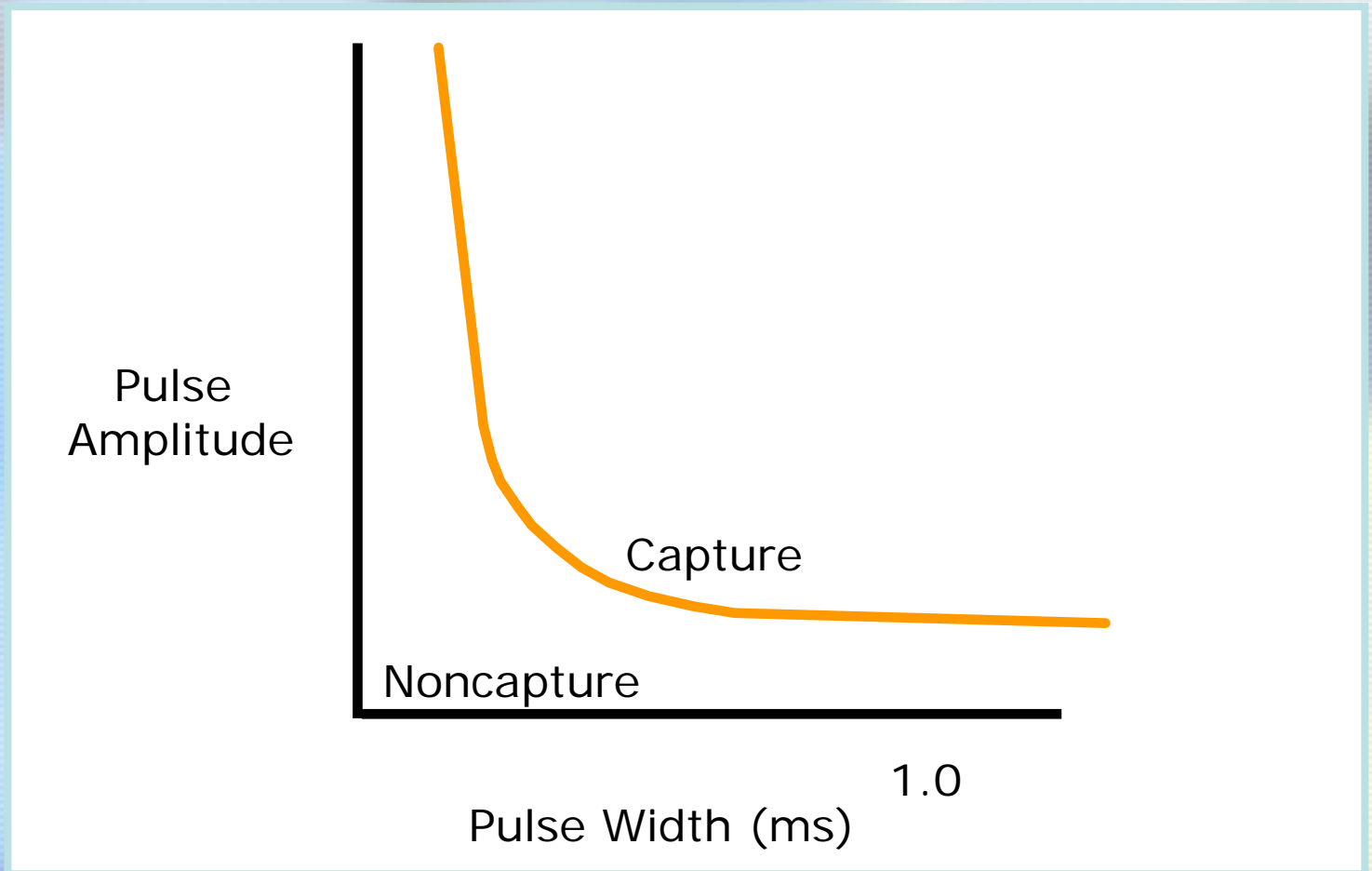
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Stimulation Threshold Strength Duration Curve

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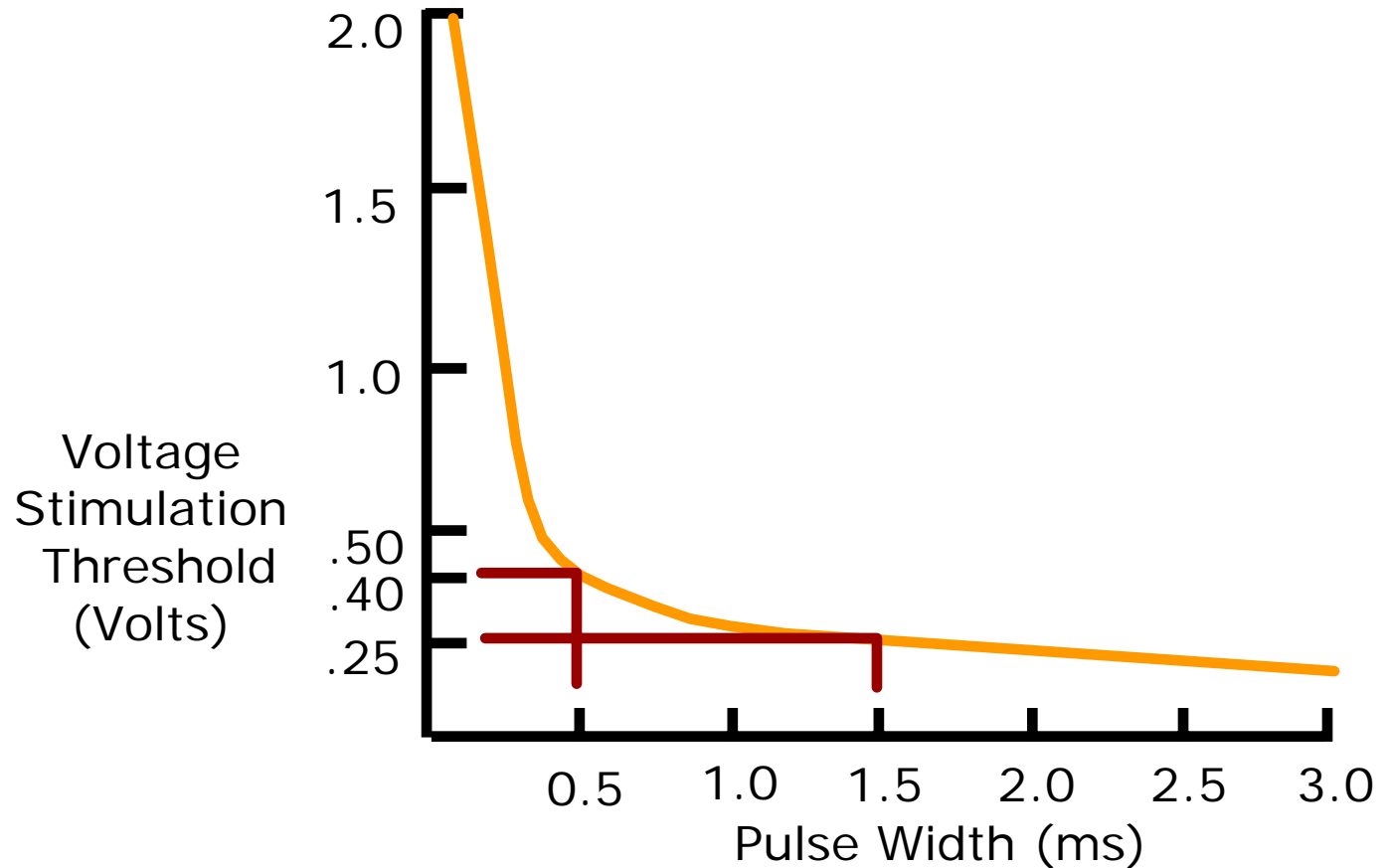
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$$E = \frac{V^2 T}{R}$$

E = Energy

V = Voltage

T = Time

R = Resistance

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2x Voltage = 4x Energy

2x Pulse Width = 2x Energy

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$$25 \mu\text{J} = \frac{5.0^2 (.50\text{ms})}{500}$$

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6.25 μJ

$$\frac{2.5^2 (.50\text{ms})}{500}$$

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12.5 μJ

$$\frac{5.0^2 (.25\text{ms})}{500}$$

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Definition:

Sensing is the ability of the pacemaker to “see” when an intrinsic depolarization is occurring

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Accurate sensing requires filtering out extraneous signals

Unwanted signals include:

- T-waves
- Far-field events
- Myopotentials

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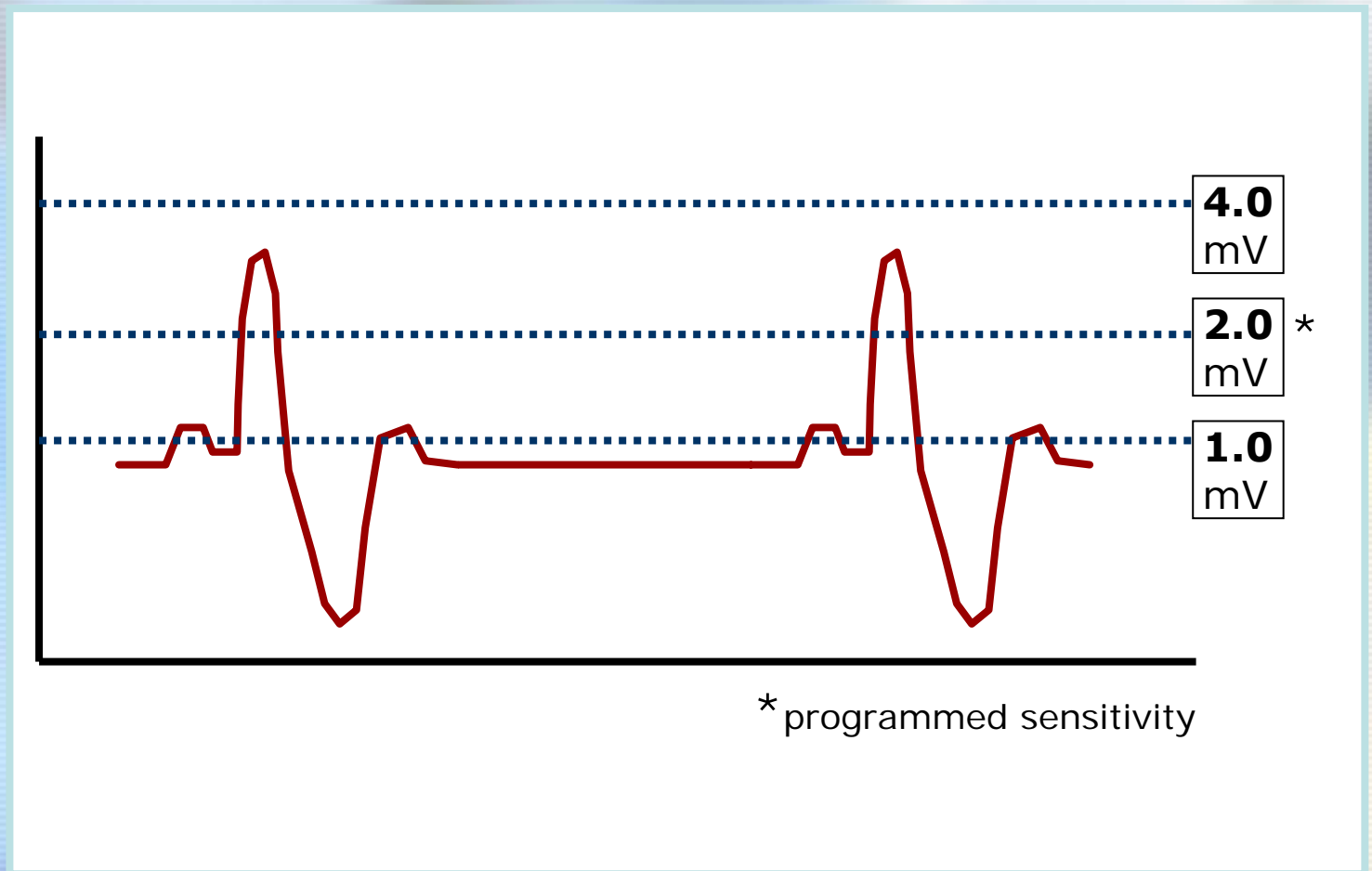
▶ Sensing

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Sensing may be affected by:

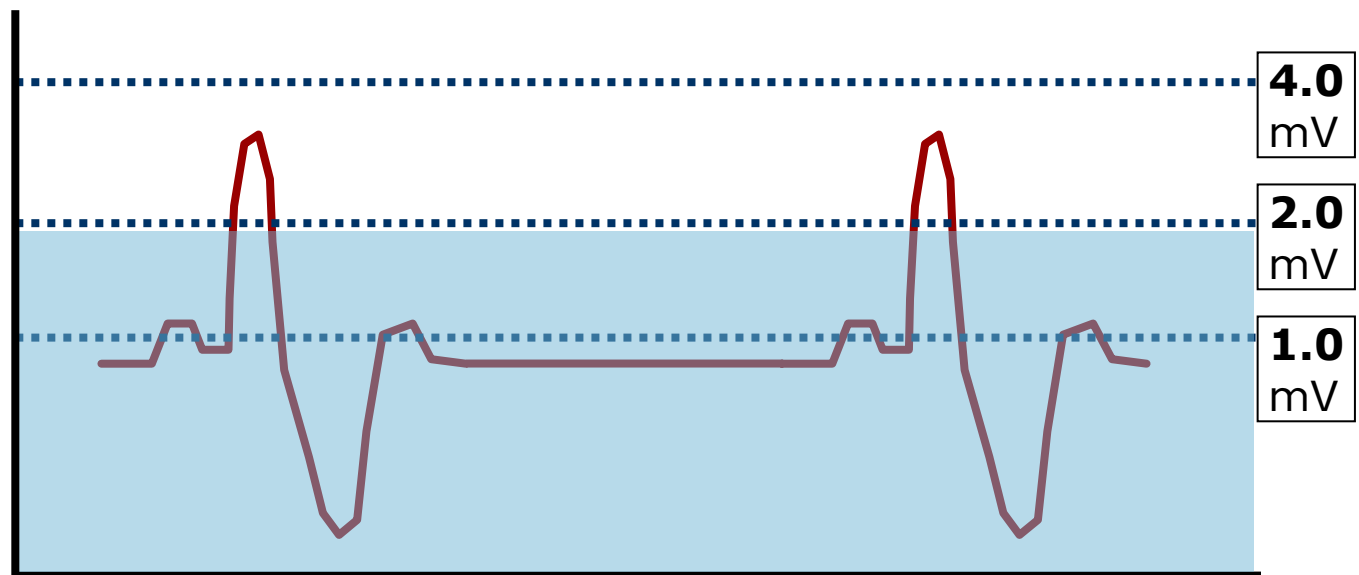
- Electrophysiological properties of the myocardium
- Characteristics of the electrode
- Lead placement
- Sensing amplifiers of the pacemaker
- Lead polarity
- Lead integrity
- EMI

Review of Sensitivity:



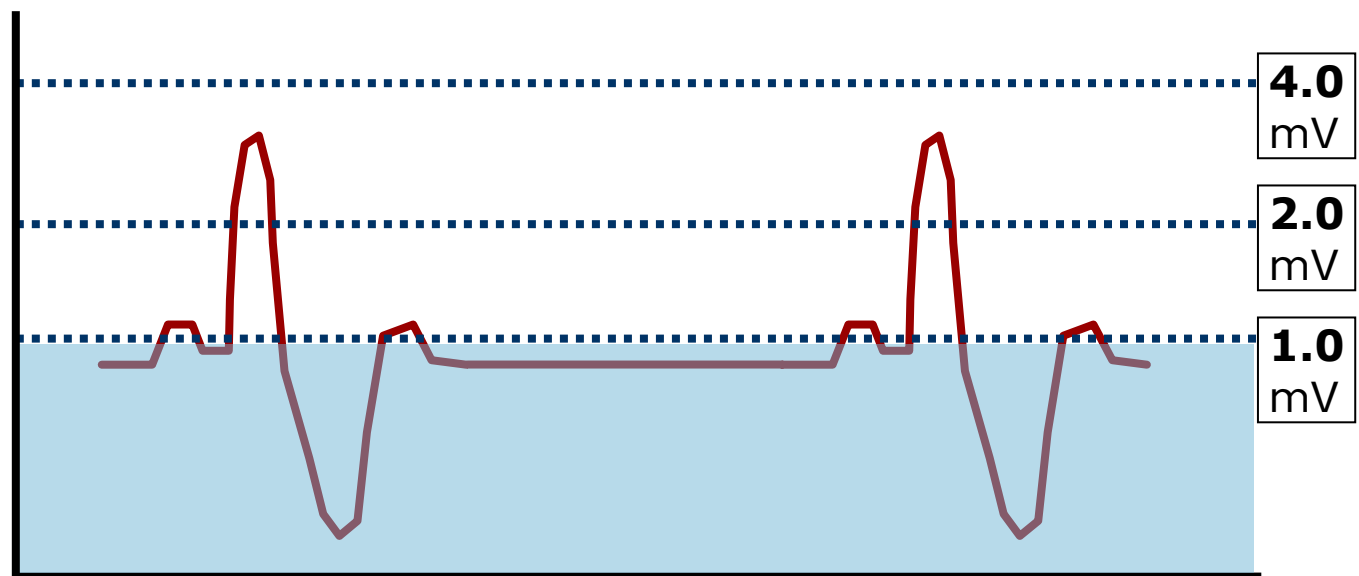
Review of Sensitivity:

Programming a **higher** setting decreases the sensitivity of the device – fewer signals are sensed



Review of Sensitivity:

Programming a **lower** setting increases the sensitivity of the device – more signals are sensed



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Slew Rate:

$$\Delta V / \text{Time} = \text{Slew Rate}$$

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