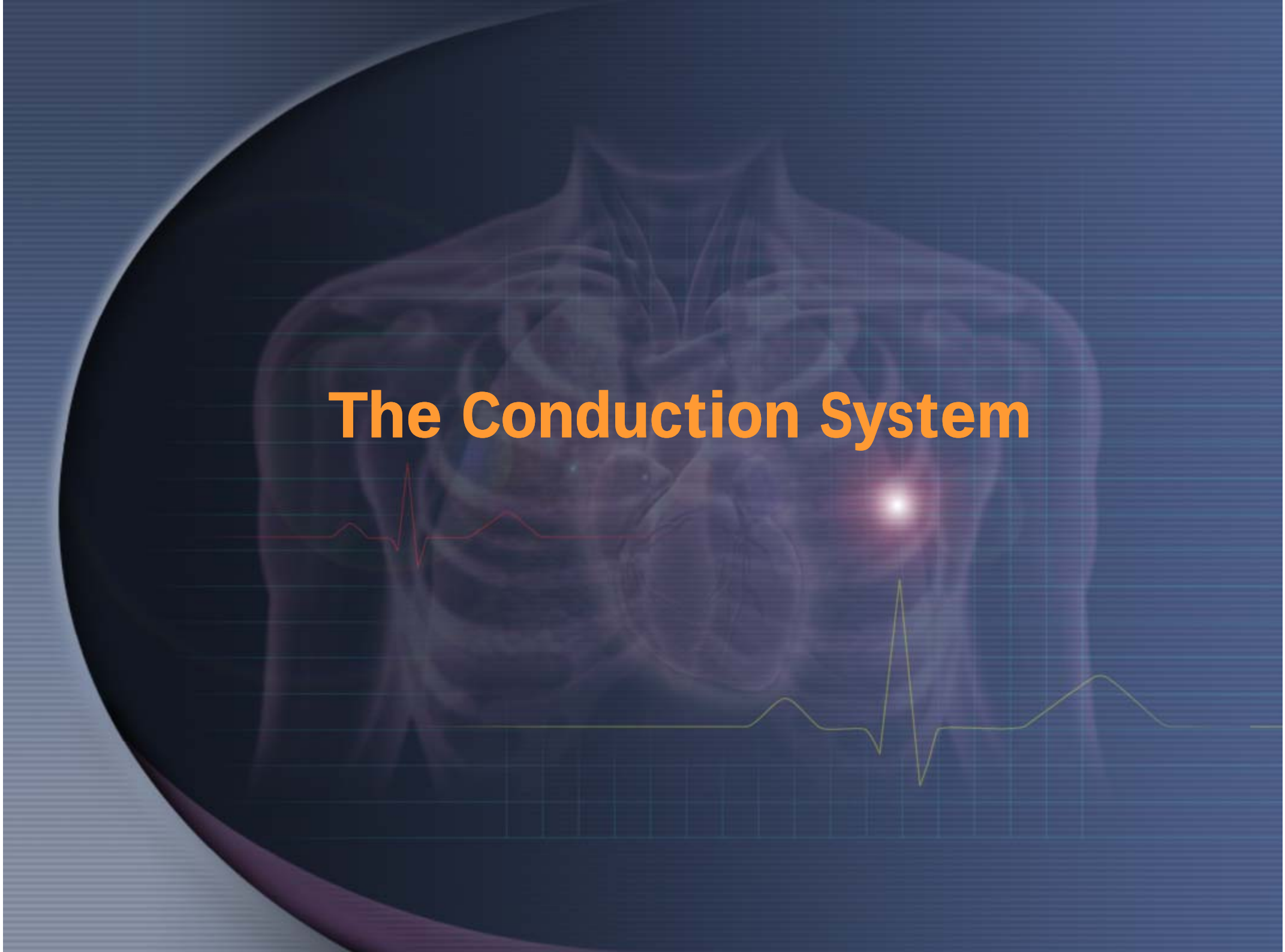
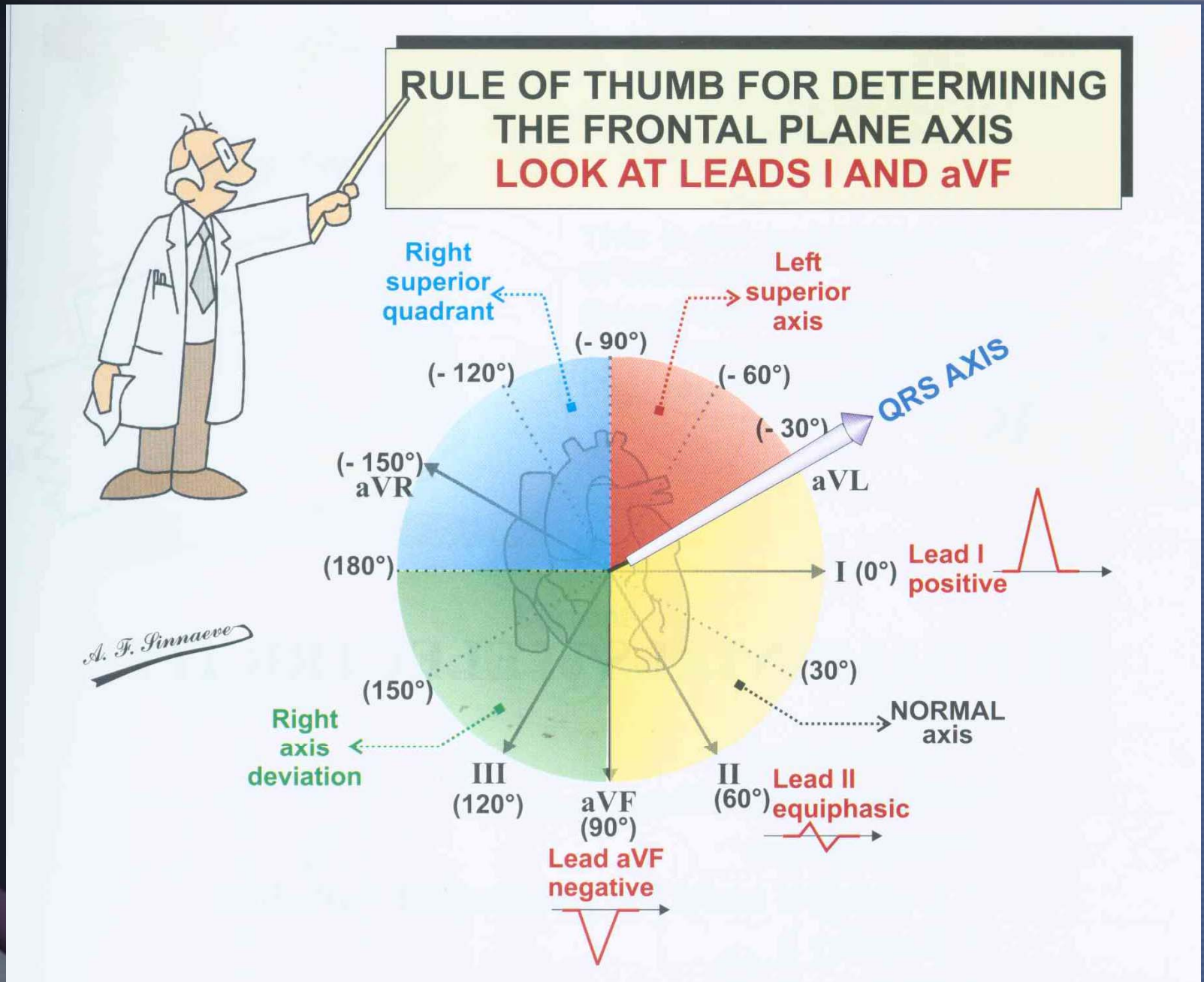
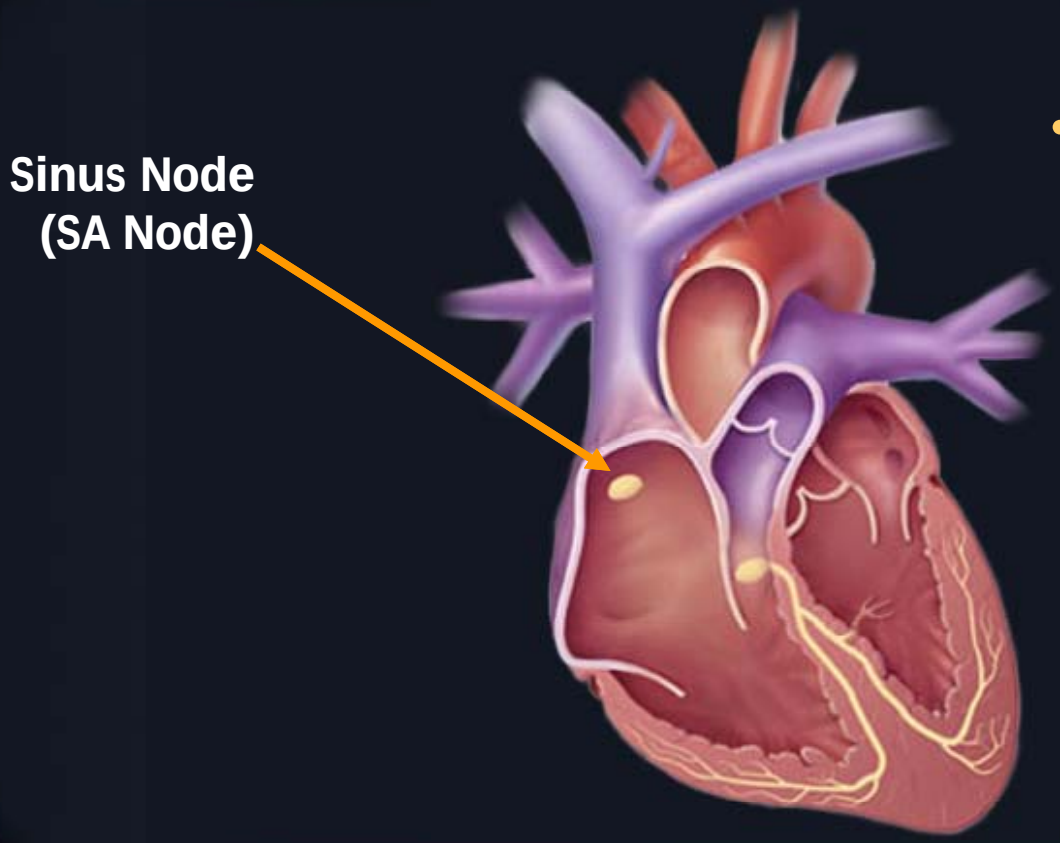

Rhythm Basics


The Conduction System

Heart axis determination



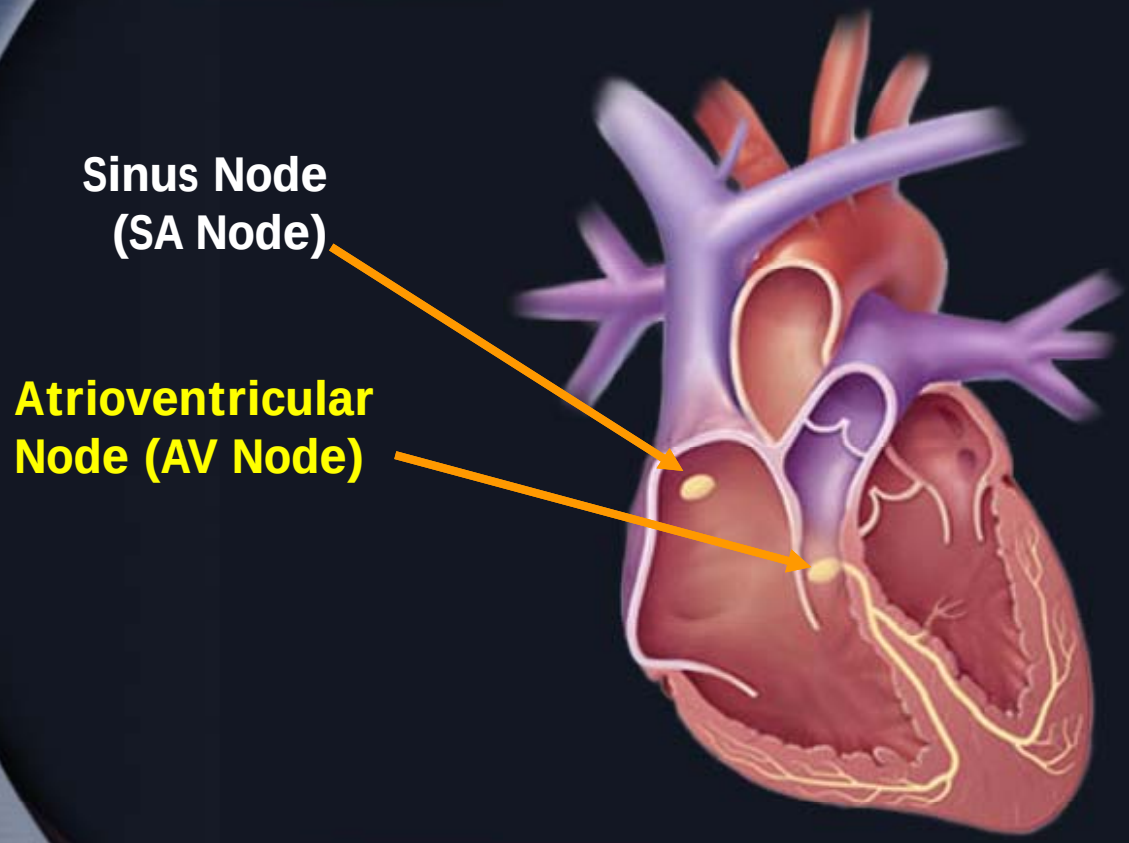
Heart Beat Anatomy



SINUS NODE

- The Heart's 'Natural Pacemaker'
  - 60-100 BPM at rest

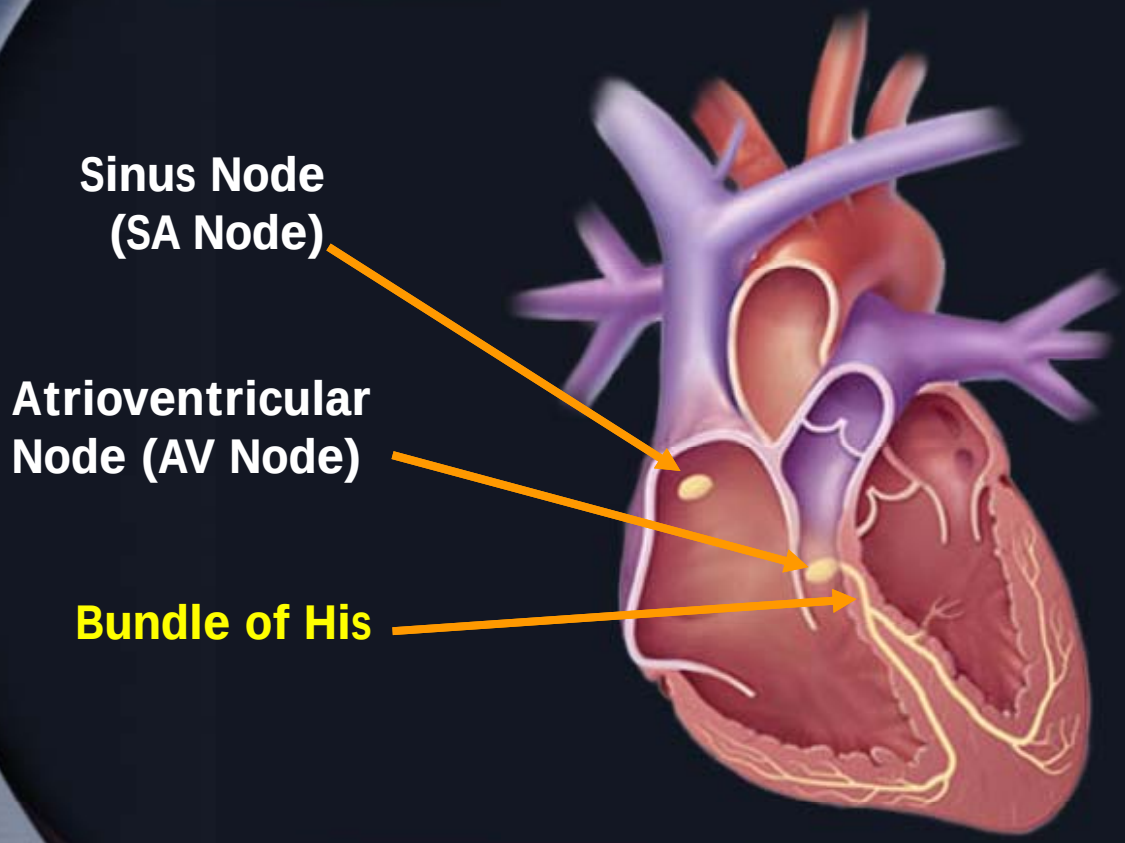
Heart Beat Anatomy



AV NODE

- Receives impulse from SA Node
- Delivers impulse to the His-Purkinje System
- 40-60 BPM if SA Node fails to deliver an impulse

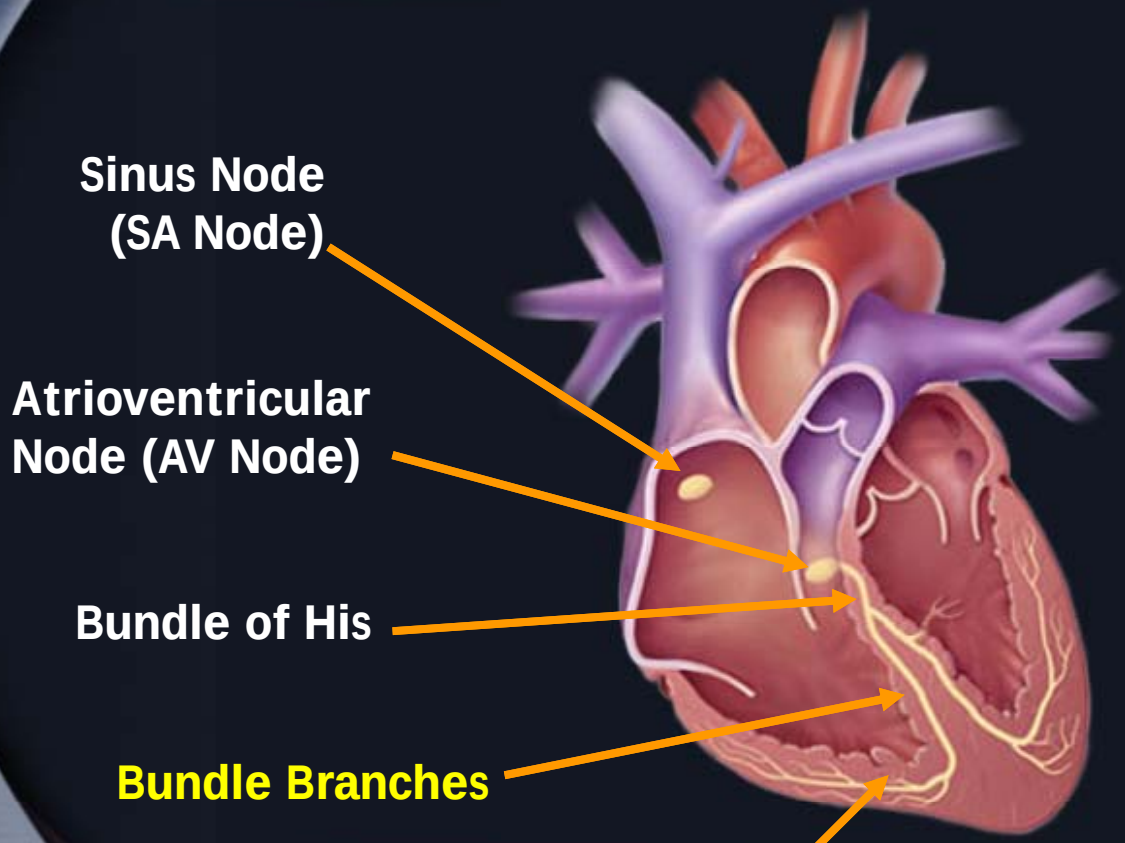
Heart Beat Anatomy



BUNDLE OF HIS

- Begins conduction to the Ventricles
- AV Junctional Tissue: 40-60 BPM

Heart Beat Anatomy



THE PURKINJE NETWORK

- Bundle Branches
- Purkinje Fibers
- Moves the impulse through the ventricles for contraction
- Provides ‘Escape Rhythm’: 20-40 BPM

Normal Sinus Rhythm

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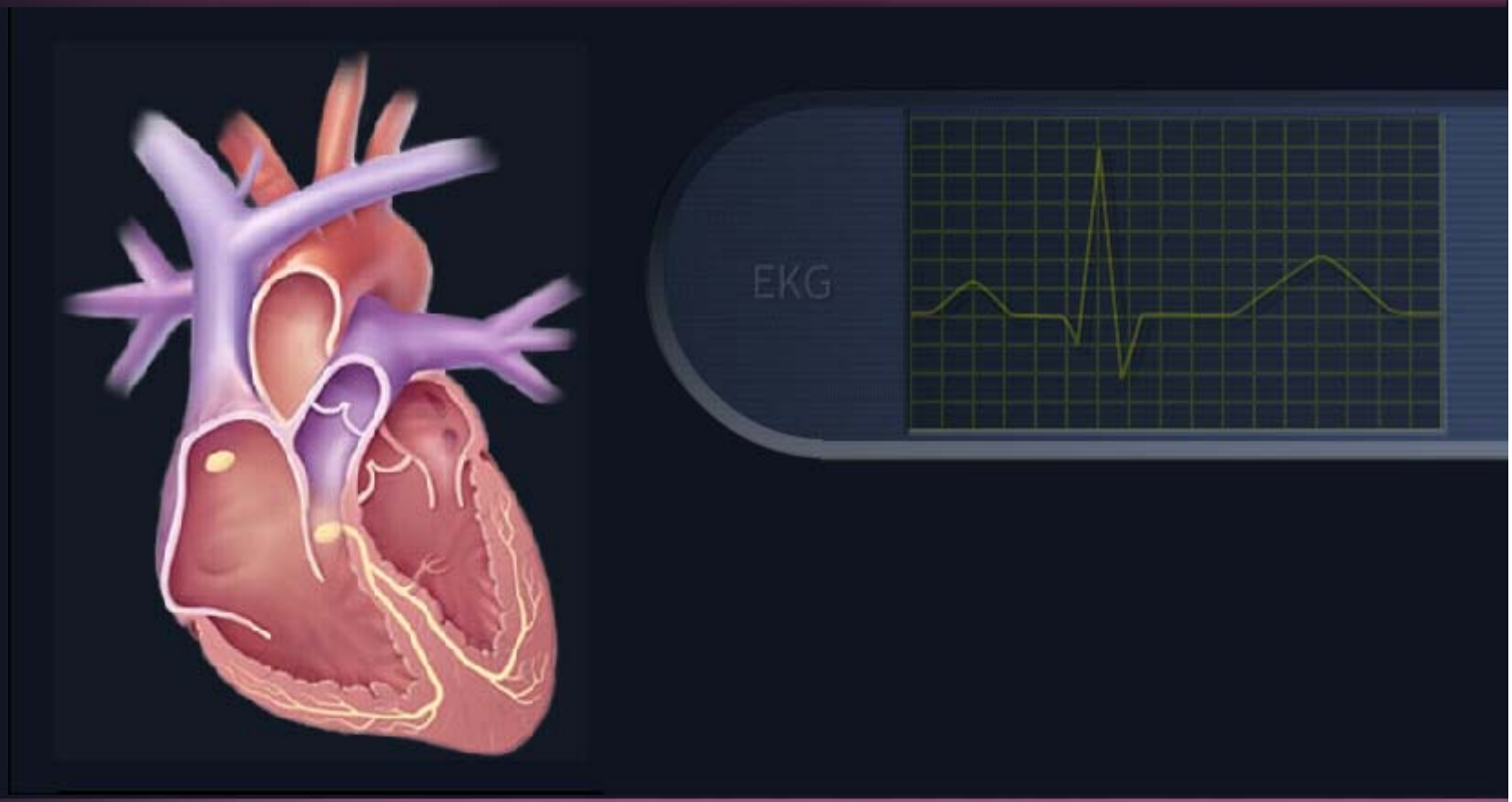
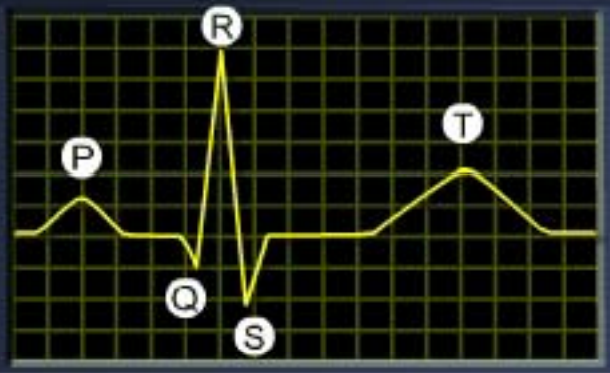
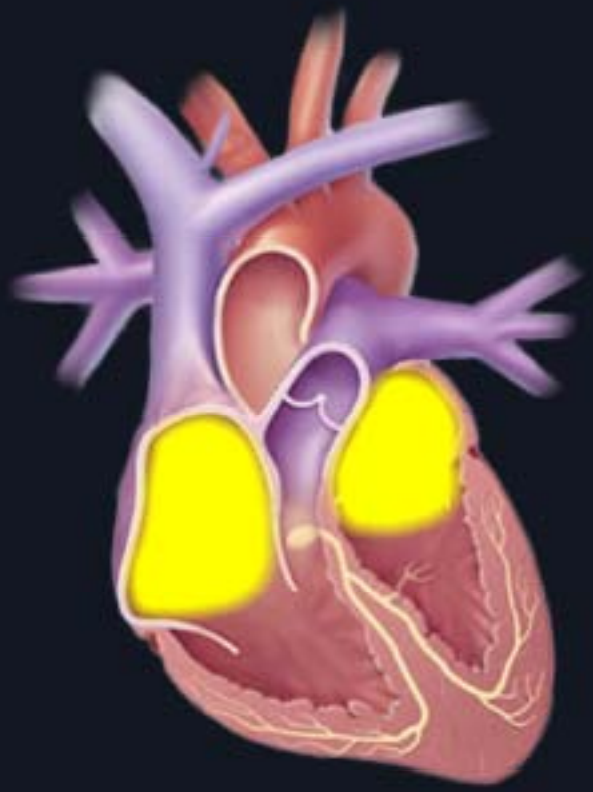


Impulse Formation In SA Node

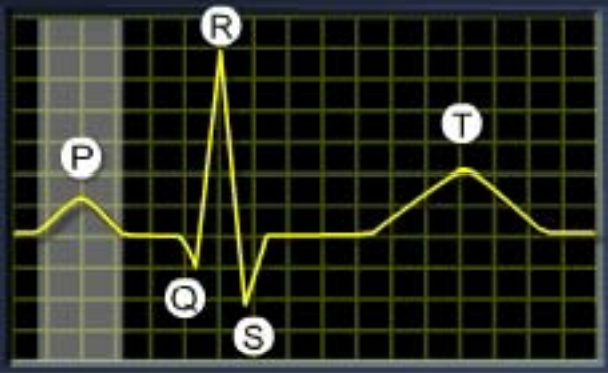
EKG



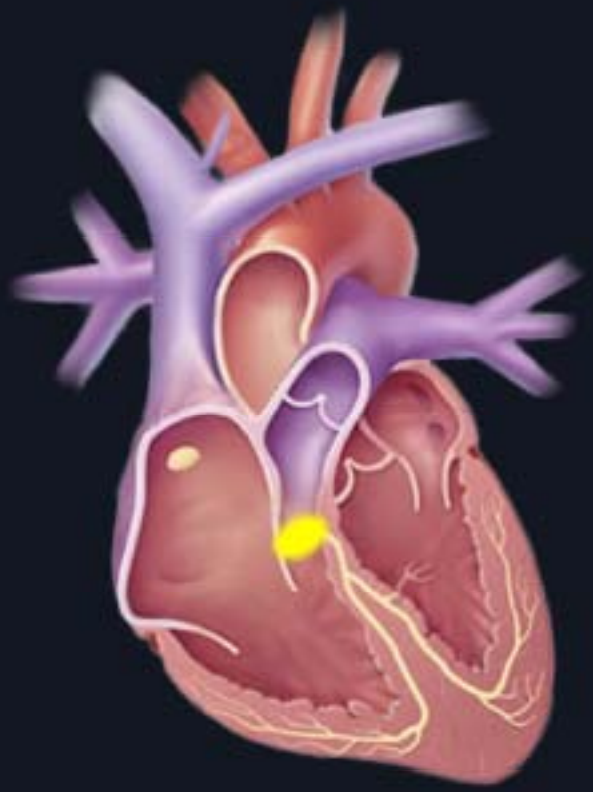
Atrial Depolarization



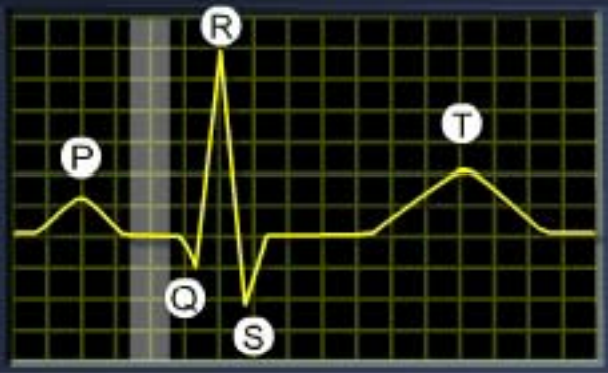
EKG



Delay At AV Node

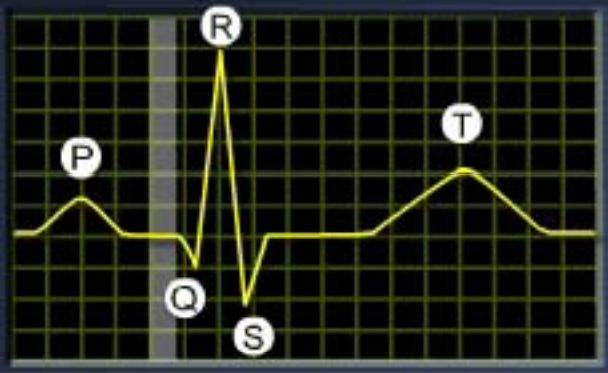


EKG



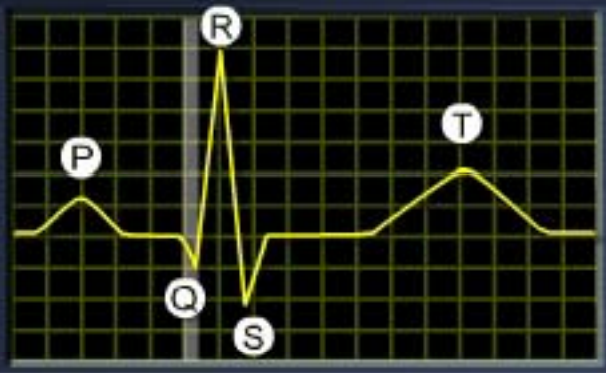
Conduction Through Bundle Branches

EKG

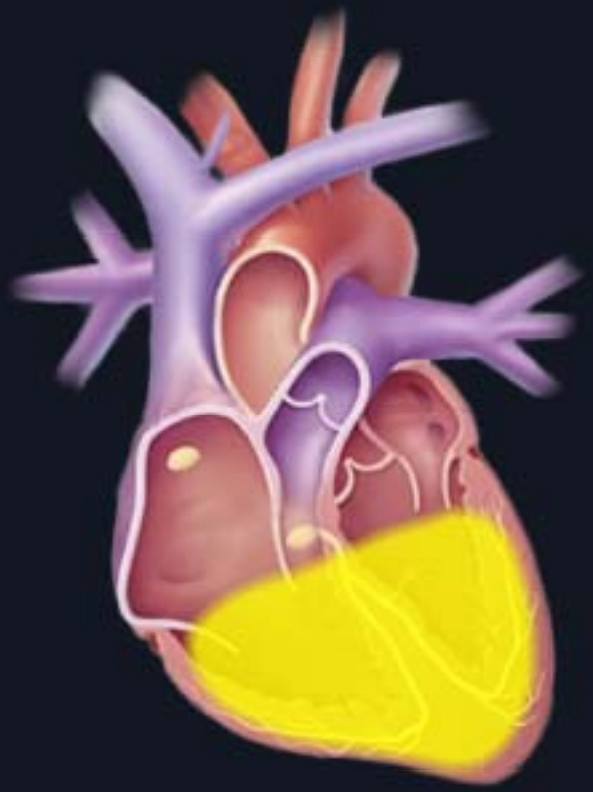


Conduction Through Purkinje Fibers

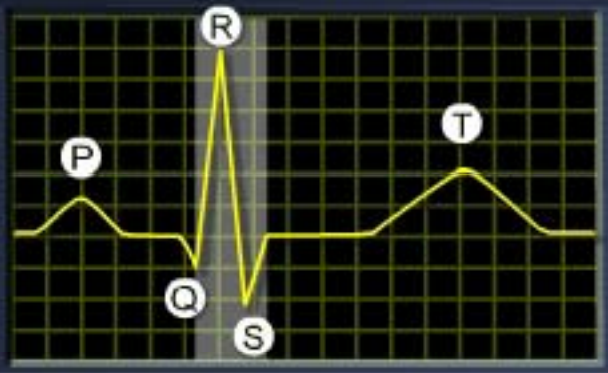
EKG



Ventricular Depolarization

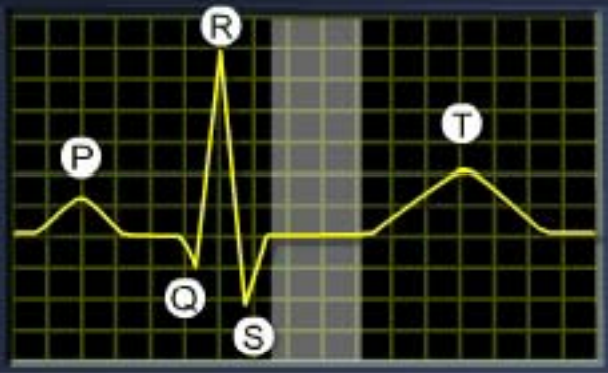


EKG



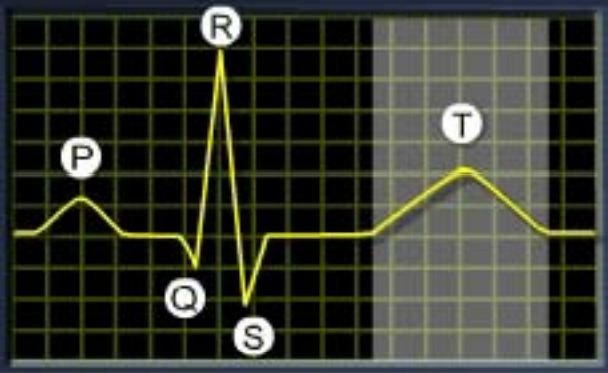
Plateau Phase of Repolarization

EKG

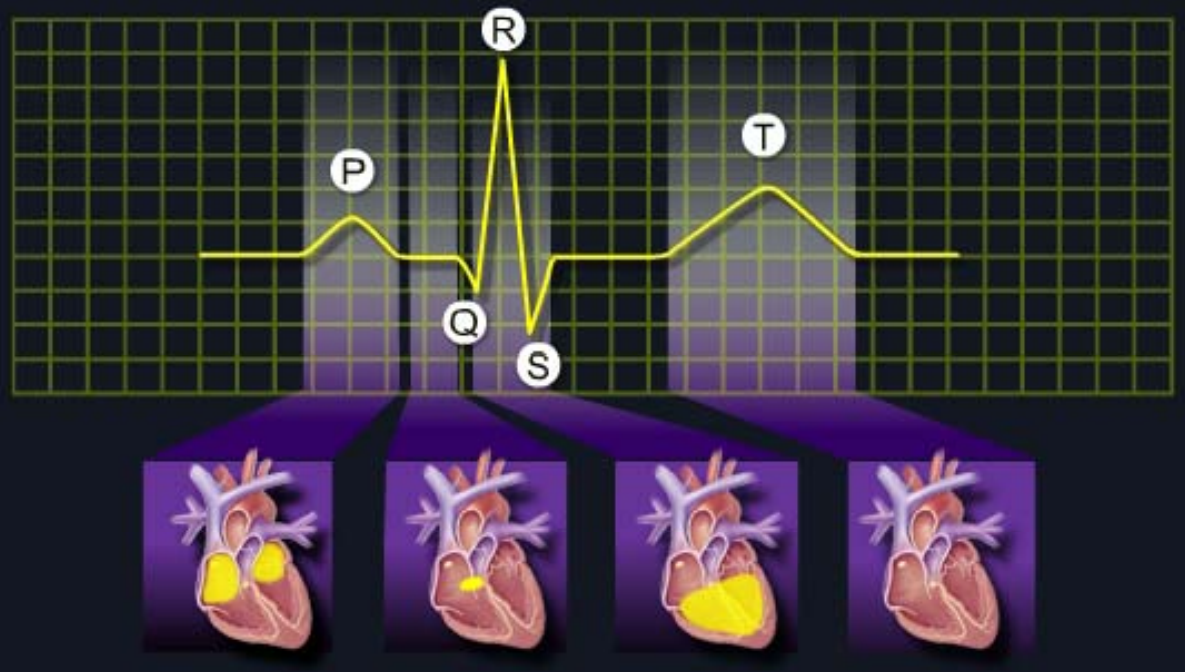


Final Rapid (Phase 3) Repolarization

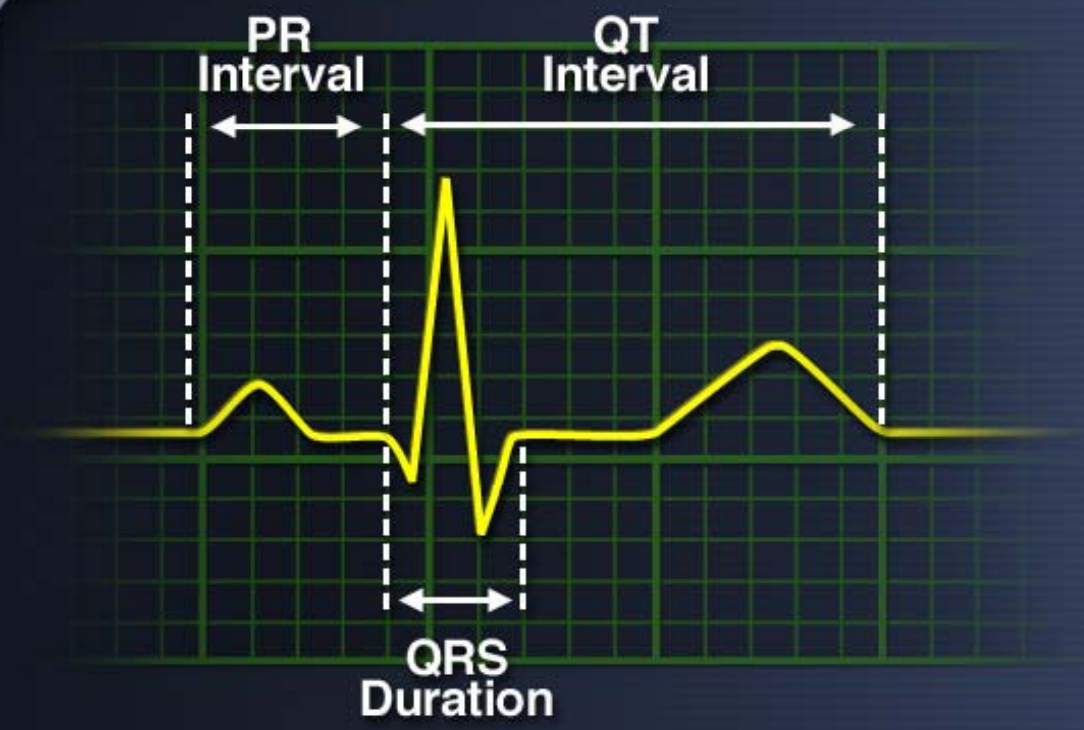
EKG



Normal EKG Activation



Reading EKGs



Intervals and Timing

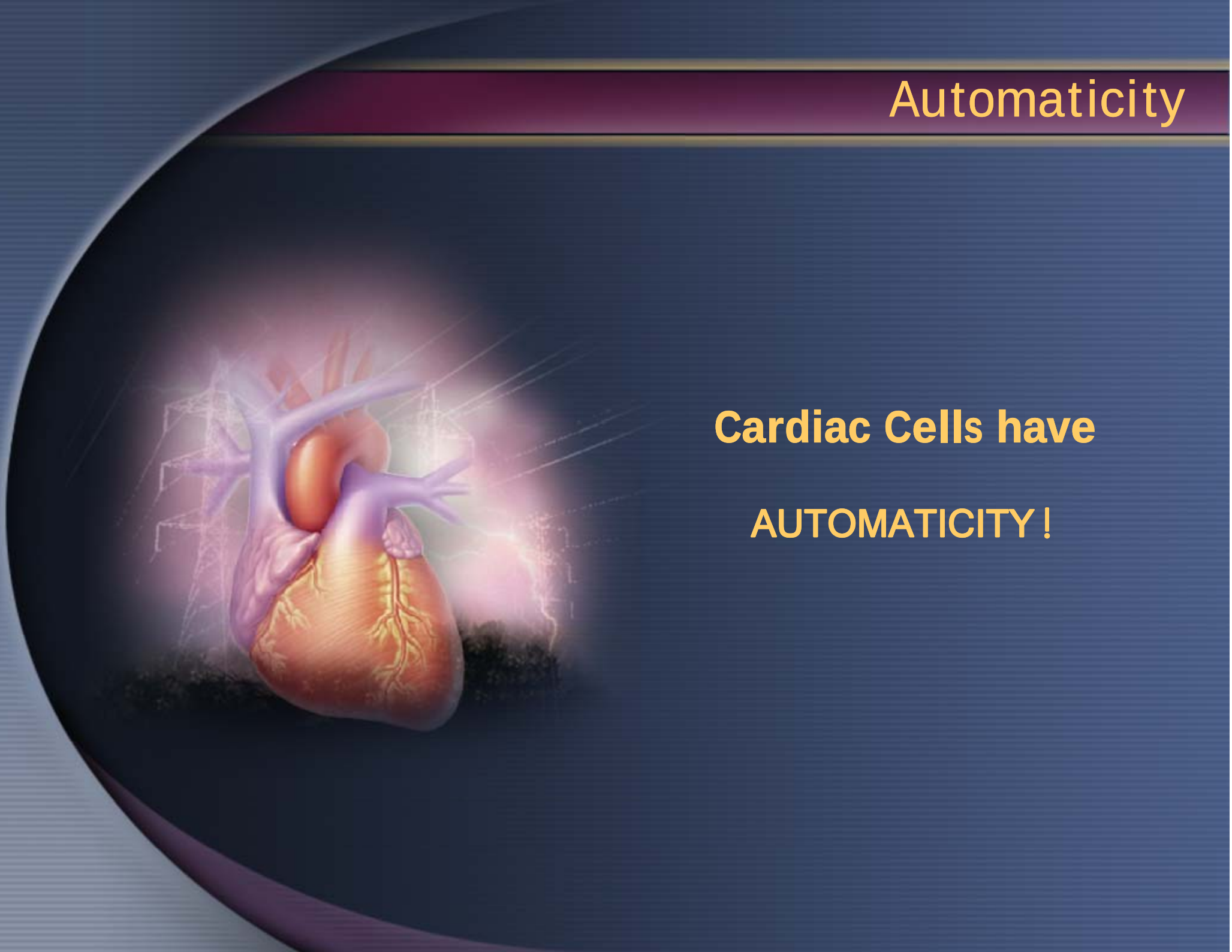
Normal Ranges in Milliseconds:

- PR Interval 120 – 200 ms
- QRS Complex 60 – 100 ms
- QT Interval 360 – 440 ms

Question?

Where does the SA Node get its energy?

Automaticity

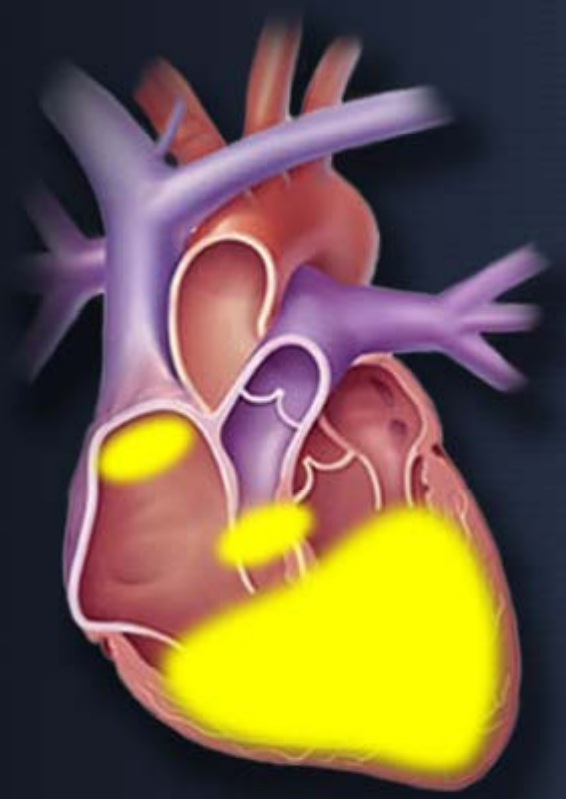


Cardiac Cells have

AUTOMATICITY !

Automaticity

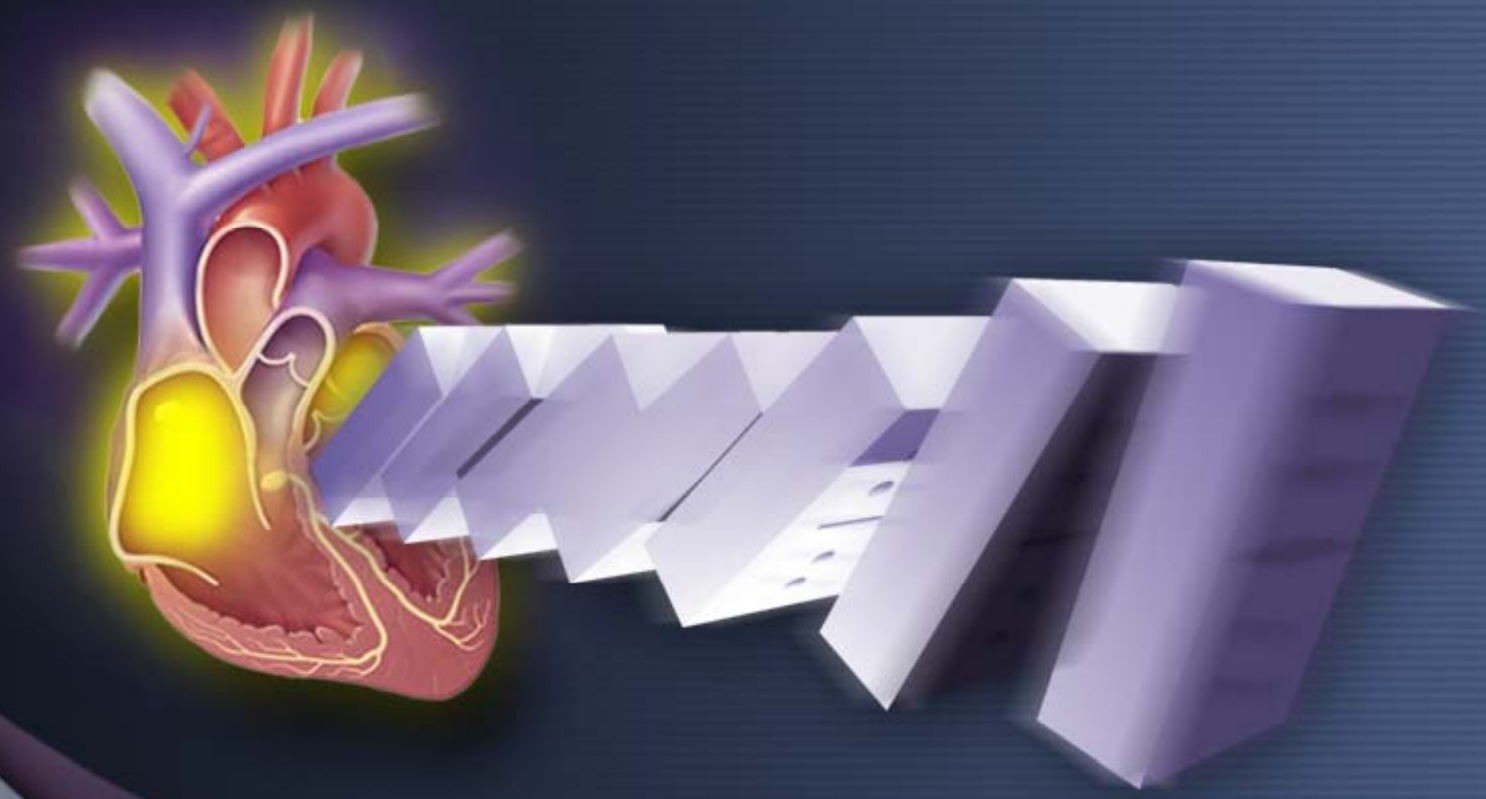
Cardiac Cells



- **Spontaneously depolarize**
- **Generally present in:**
  - **Upper (SA Node)**
    - **60-100 BPM**
  - **Middle (AV Junction)**
    - **40-60 BPM**
  - **Lower (Purkinje Network)**
    - **20–40 BPM**

Automaticity

Once a pacemaker cell initiates an impulse, its neighboring cells follow suit – like dominos!

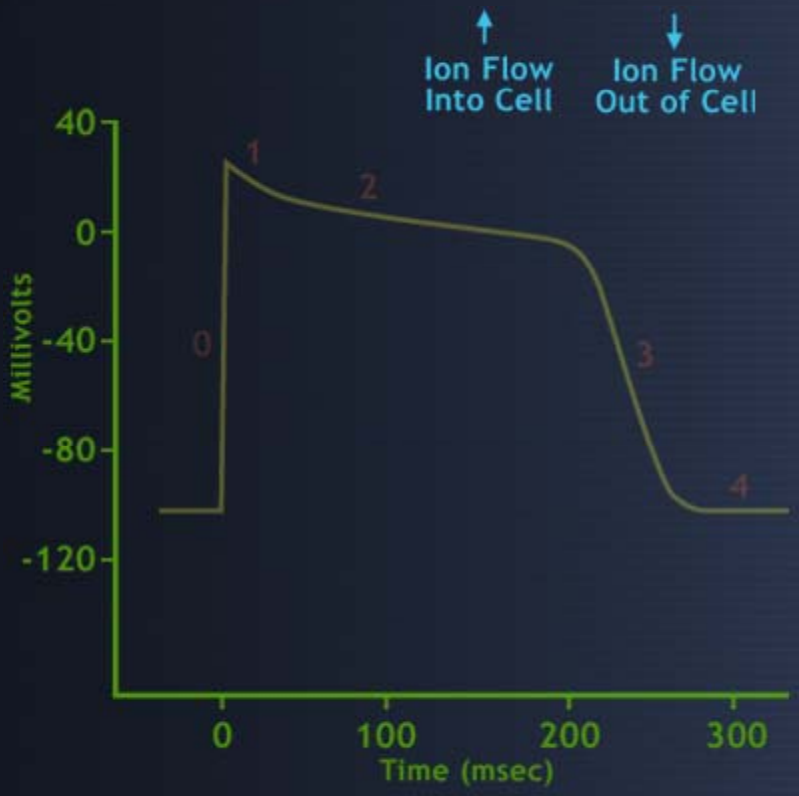


Question?

What Triggers the First Cell?

Action Potential of a Cardiac Cell

5 Phases



Action Potential of a Cardiac Cell

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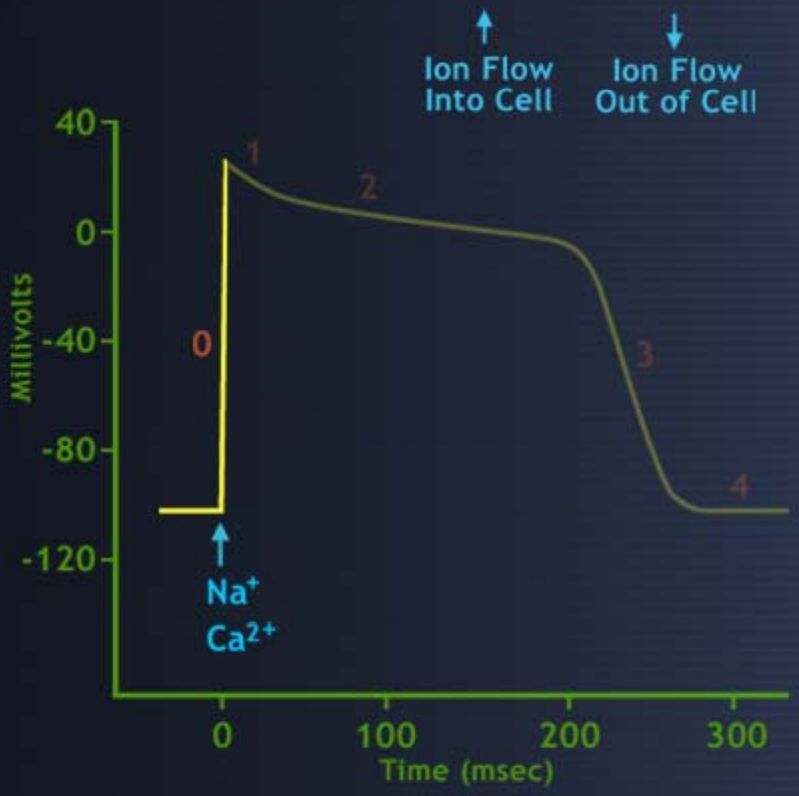
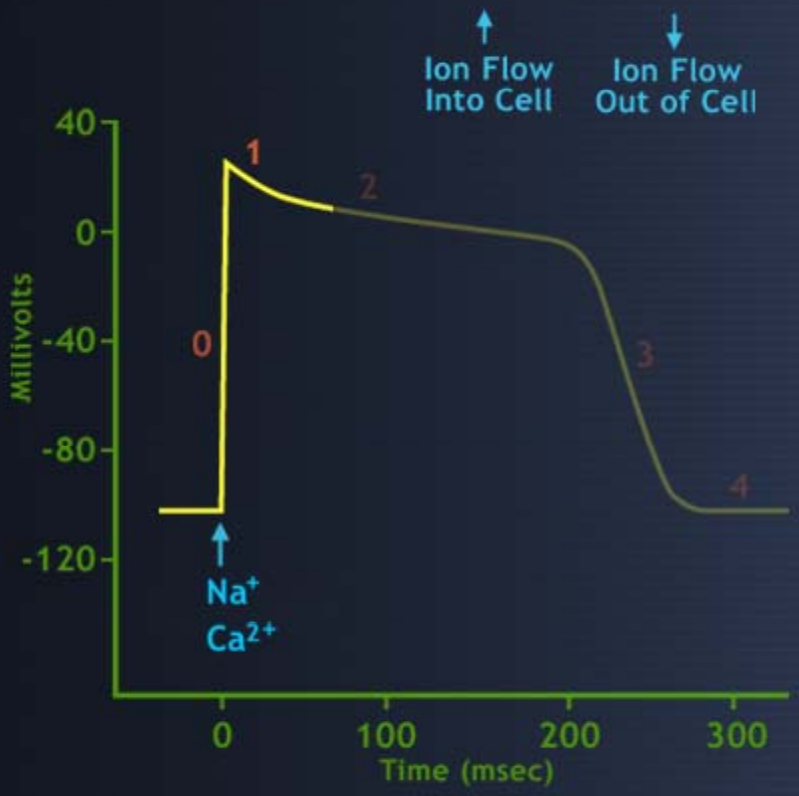


- **Phase 0**
  - Rapid or upstroke depolarization with an influx of sodium ions into the cell

Action Potential of a Cardiac Cell

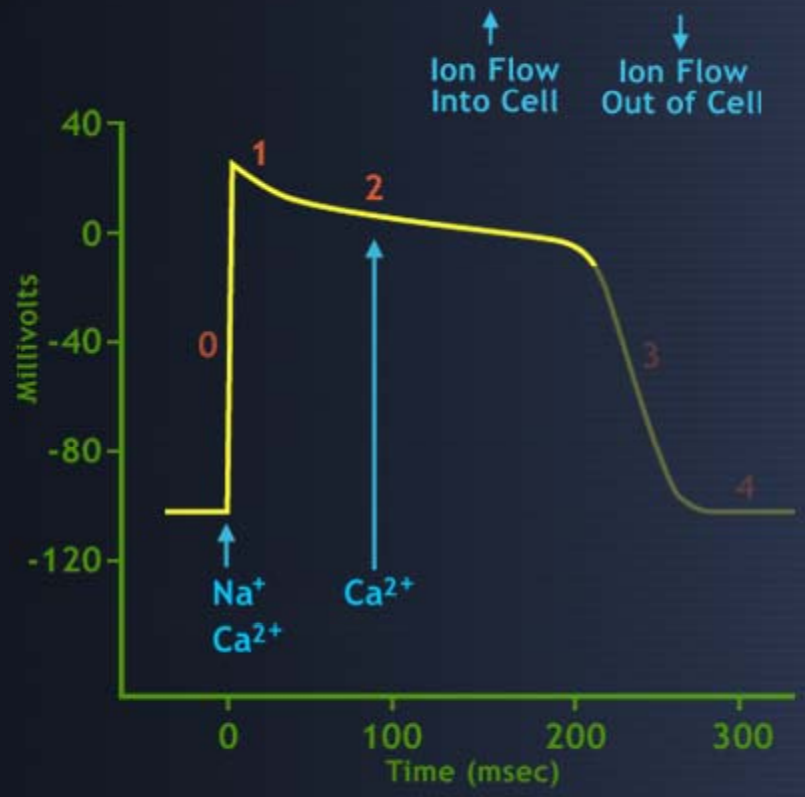
5 Phases



- **Phase 0**
  - Rapid upstroke depolarization with an influx of sodium ions into the cell
- **Phase 1**
  - Early rapid repolarization with transient outward movement of potassium ions

Action Potential of a Cardiac Cell

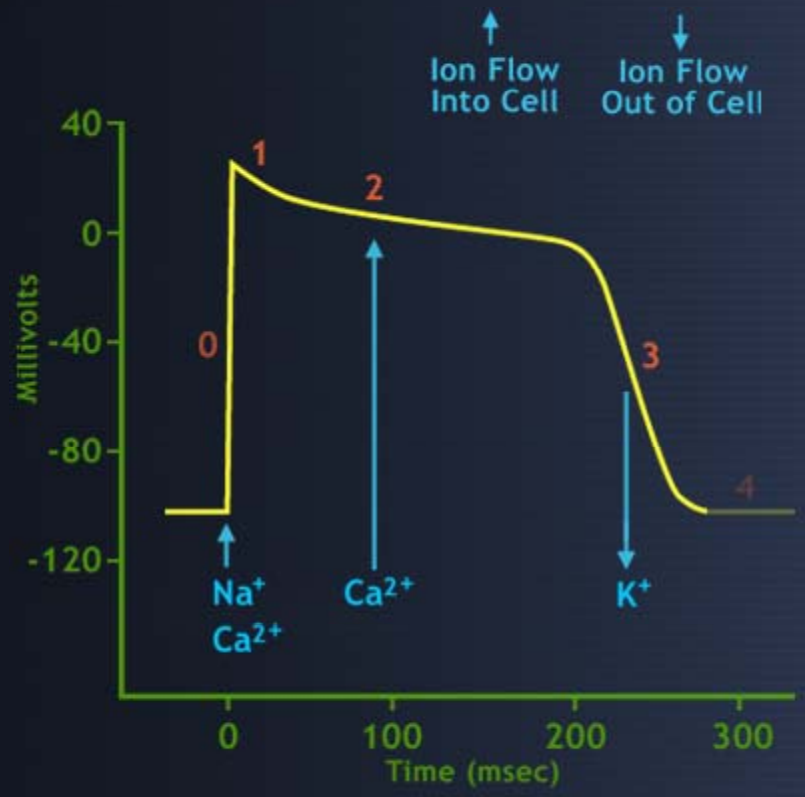
5 Phases



- **Phase 0**
  - Rapid upstroke depolarization with an influx of sodium ions into the cell
- **Phase 1**
  - Early rapid repolarization with transient onward movement of potassium ions
- **Phase 2**
  - Plateau Phase: Continued Influx of Sodium & slow Influx of Calcium

Action Potential of a Cardiac Cell

5 Phases



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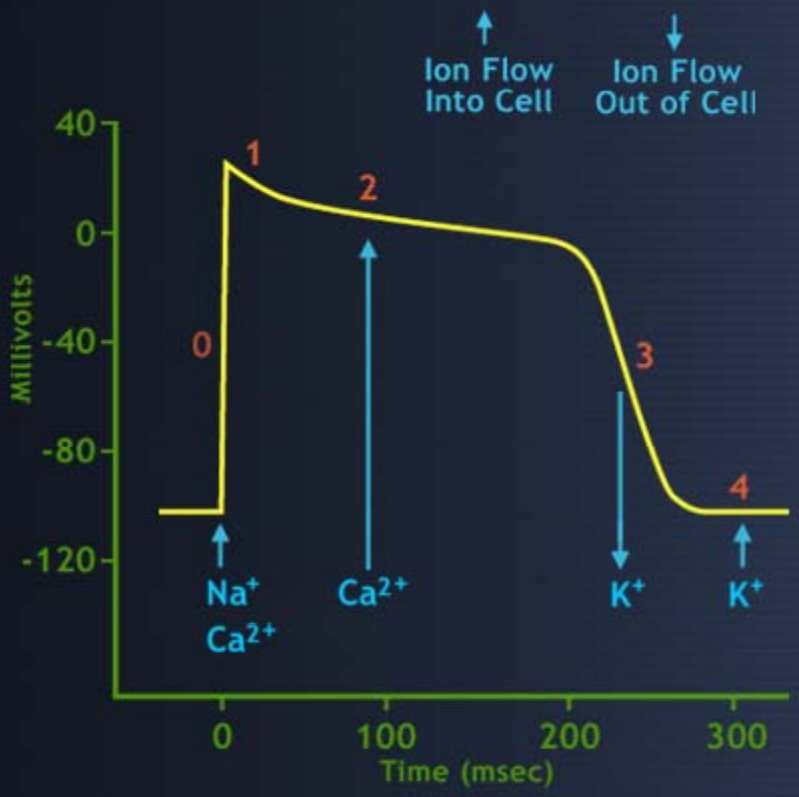
- **Phase 3**
  - Repolarization: Potassium outflow

Action Potential of a Cardiac Cell

5 Phases



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- **Phase 2**
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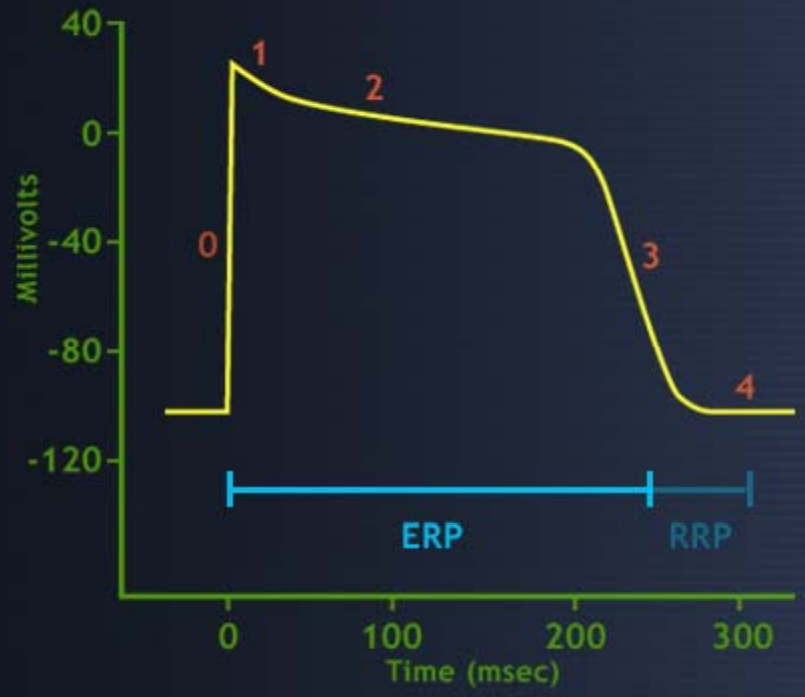
- **Phase 3**
  - Repolarization: Potassium outflow
- **Phase 4**
  - Resting Phase

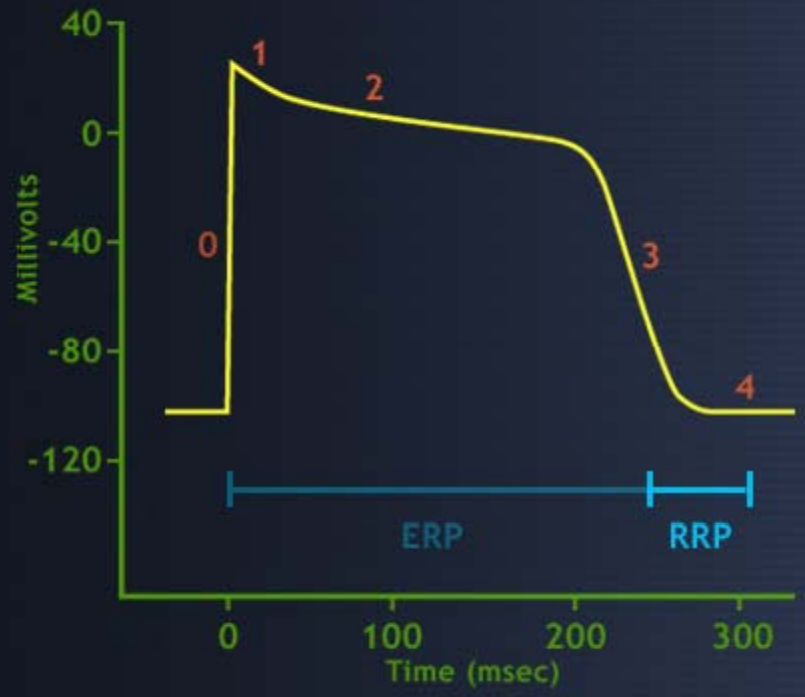
Action Potential of a Cardiac Cell



Refractory Periods

- **ERP - Effective Refractory Period**
  - –Phases 0, 1, 2 and early Phase 3
  - –A depolarization cannot be initiated by an impulse of any strength

Action Potential of a Cardiac Cell

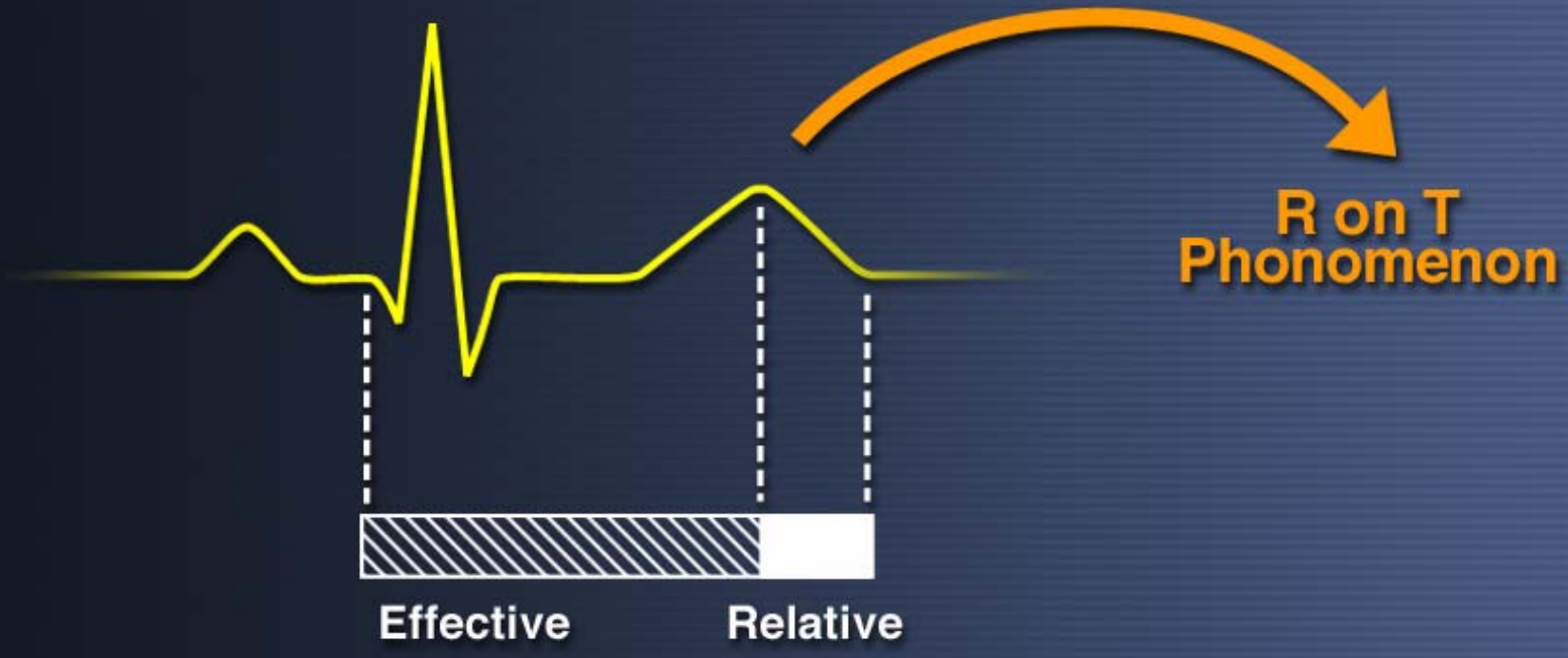


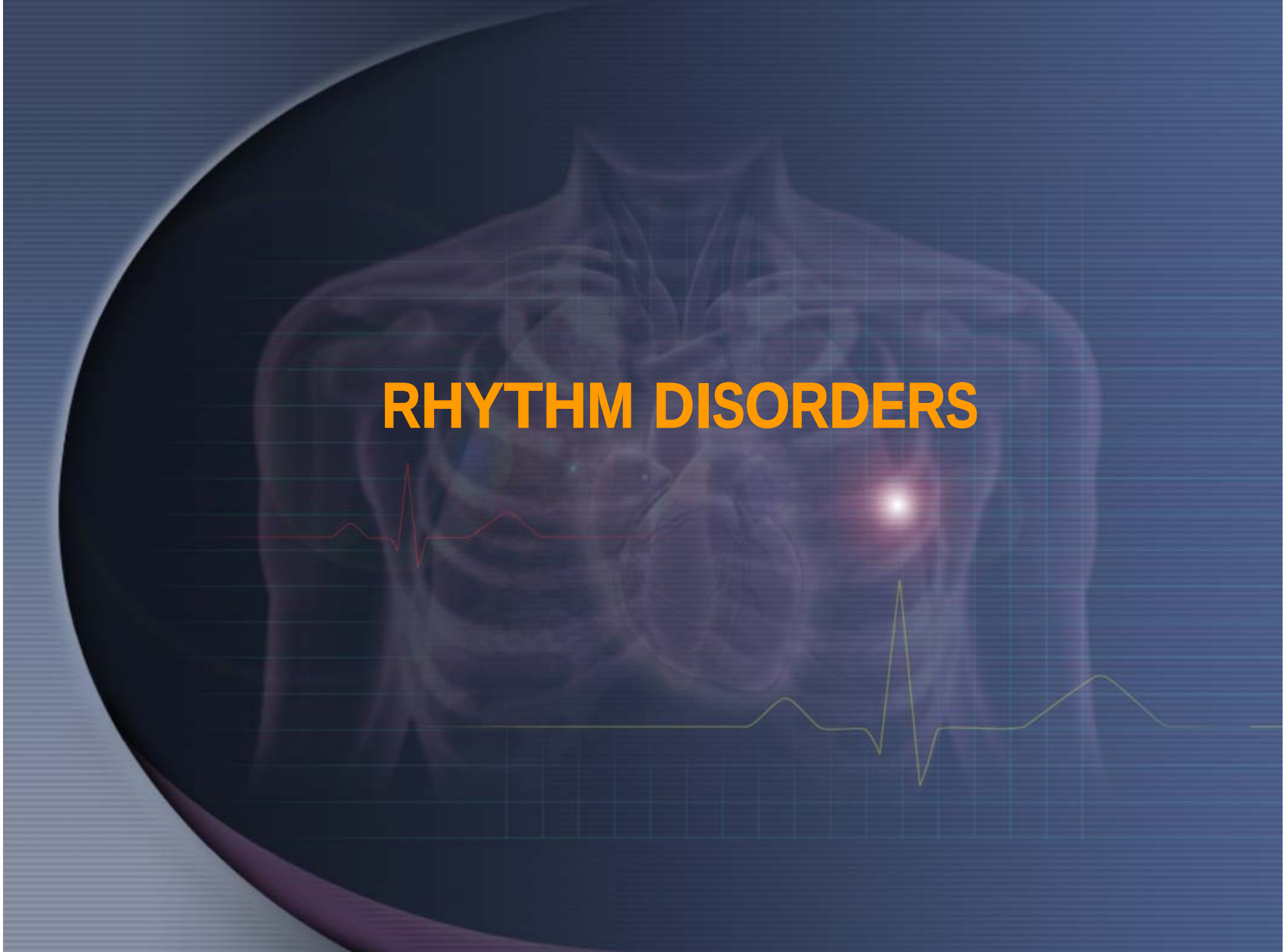
Refractory Periods

- **RRP - Relative Refractory Period**
  - –Late Phase 3 and early Phase 4
  - –A strong impulse can cause depolarization, possibly with aberrancy

Action Potential of a Cardiac Cell

Effective & Relative Refractory Periods




RHYTHM DISORDERS

Rhythm Disorders

2 Categories of Rhythm Disorders

Disorders of →

- Impulse Formation
- Impulse Conduction

Mechanisms of Rhythm Disorders

Underlying Mechanisms

Impulse Formation →

- **Abnormal Automaticity**
- **Triggered Activity**

Impulse Conduction →

- **Slow or Blocked Conduction**
- **Reentry**

Mechanisms of Rhythm Disorders

Abnormal Automaticity

Abnormally Slow = Bradycardia

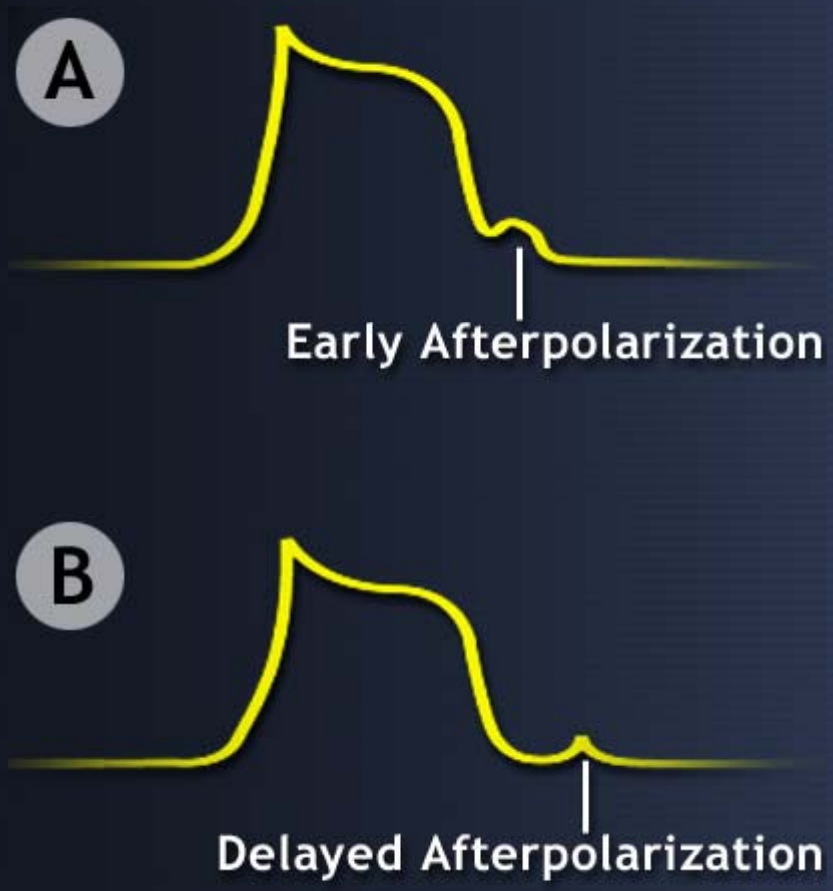
- Failure due to disease

Excessively Rapid = Tachycardia

- Due to sympathetic nervous system

Mechanisms of Rhythm Disorders

Triggered Activity



- Afterpotentials occurring in Phase 3 (early) or 4 (late) of action potential
- Can trigger arrhythmias

Mechanisms of Rhythm Disorders

Triggered Activity

Early Afterdepolarization

- Potential Causes:
  - Low potassium blood levels
  - Slow heart rate
  - Drug toxicity (ex. Quinidine causing Torsades de Pointes)

Late Afterdepolarization

- Potential Causes:
  - Premature beats
  - Increased calcium blood levels
  - Increased adrenaline levels
  - Digitalis toxicity

Mechanisms of Rhythm Disorders

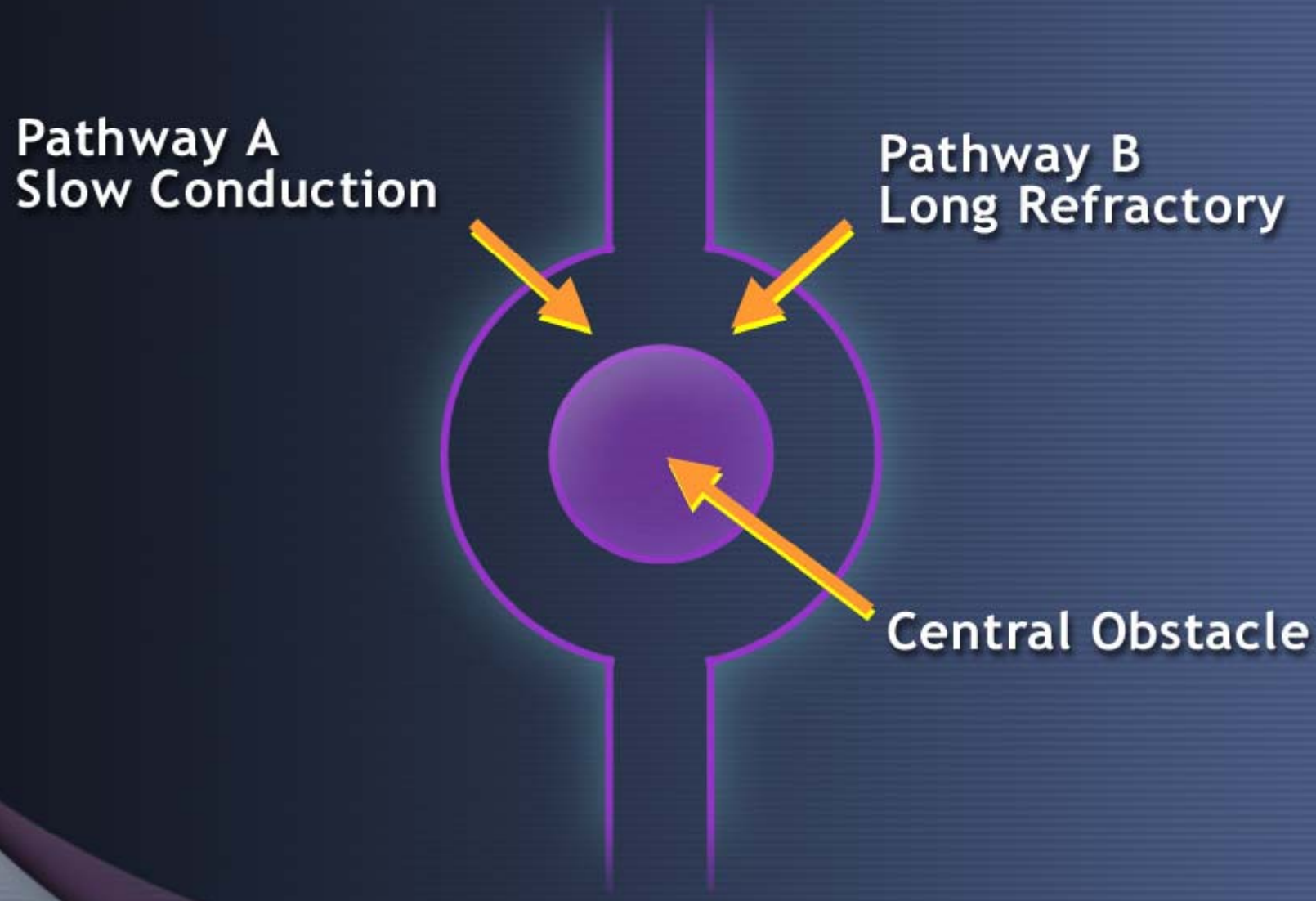
Slowed or Blocked Conduction

- **Impulse generated normally**
- **Impulse slowed or blocked as it makes its way through the conduction system**

Mechanisms of Rhythm Disorders

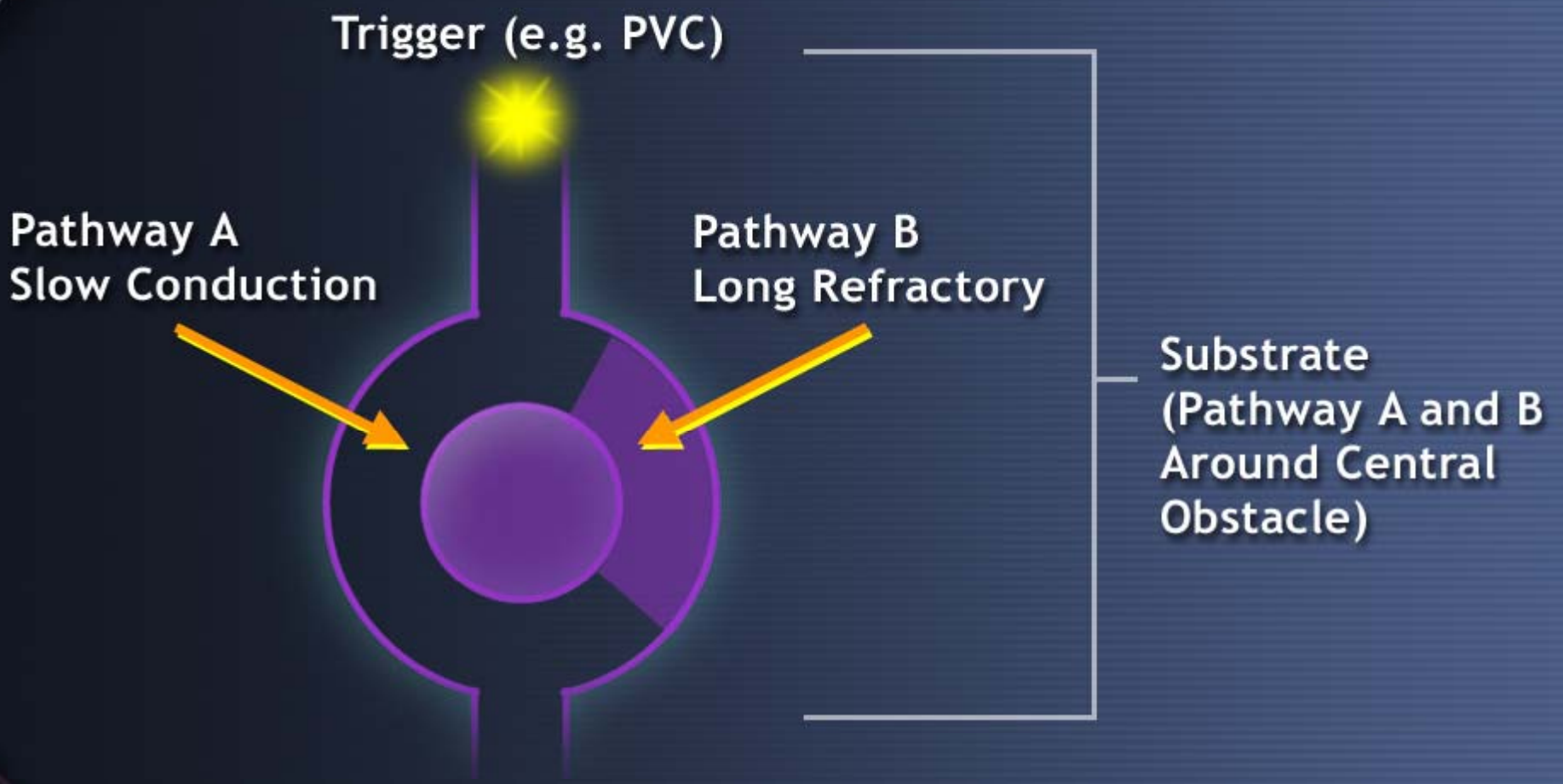
Reentry

Conditions of Reentry



Mechanisms of Rhythm Disorders

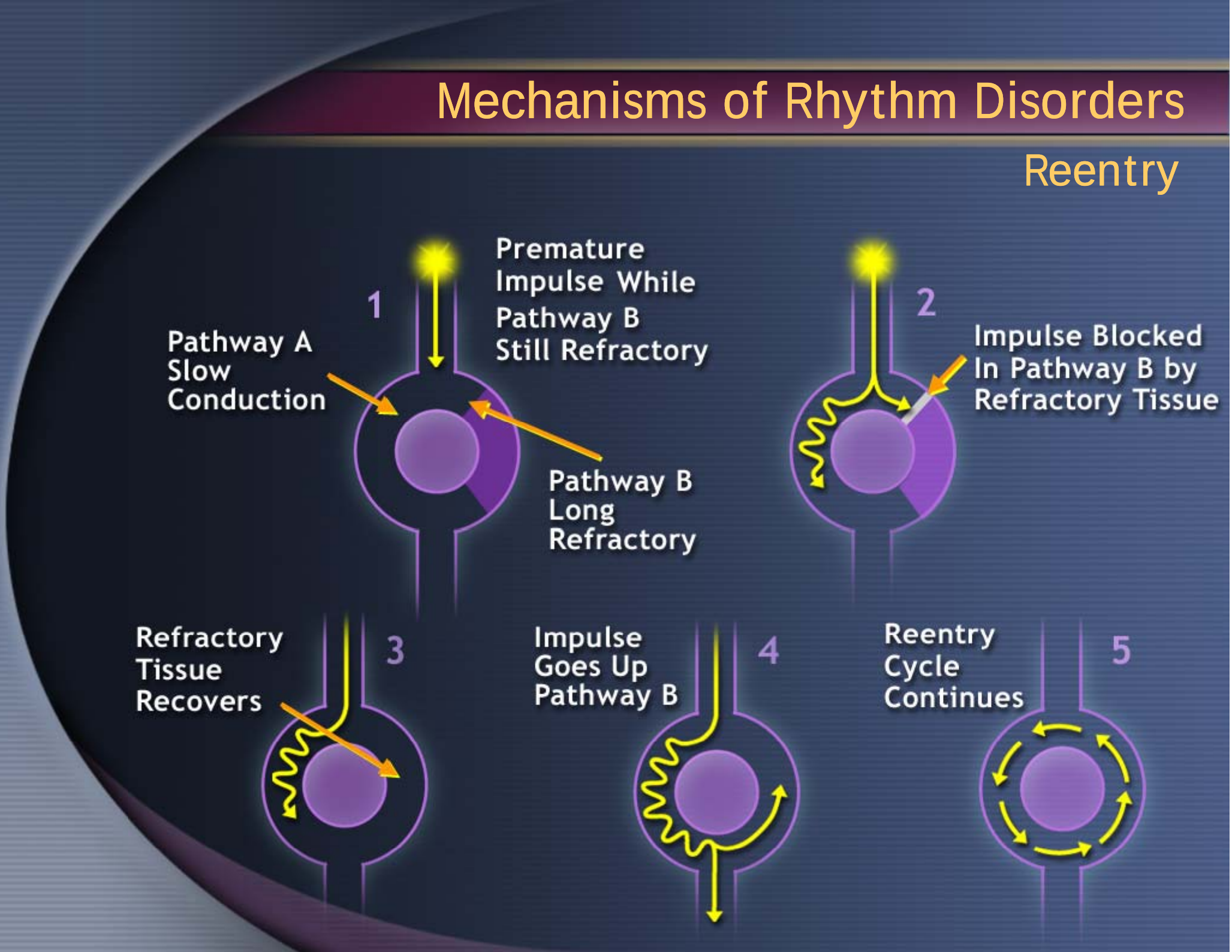
Reentry

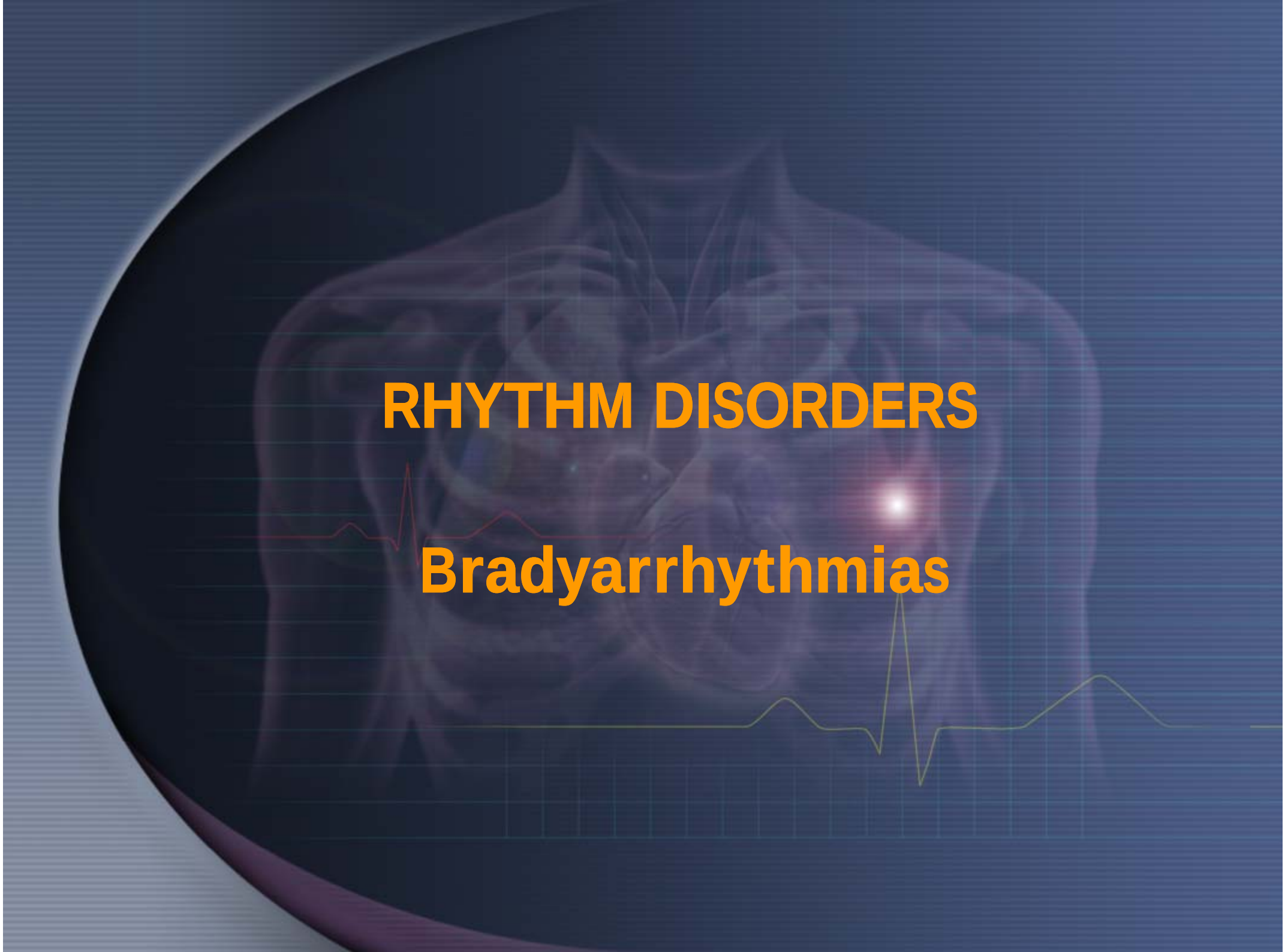


Substrate + Trigger = Reentry

Mechanisms of Rhythm Disorders

Reentry




RHYTHM DISORDERS
Bradyarrhythmias

Bradyarrhythmia Classifications

Classification Based on Disorder

Bradycardias

- Impulse Formation Disorders
- Impulse Conduction Disorders

Bradyarrhythmia Classifications

Classification Based on Disorder

Impulse Formation Disorders

- **Sinus Arrest**
- **Sinus Bradycardia**
- **Brady/Tachy Syndrome**

Impulse Conduction Disorders

Sinus Arrest

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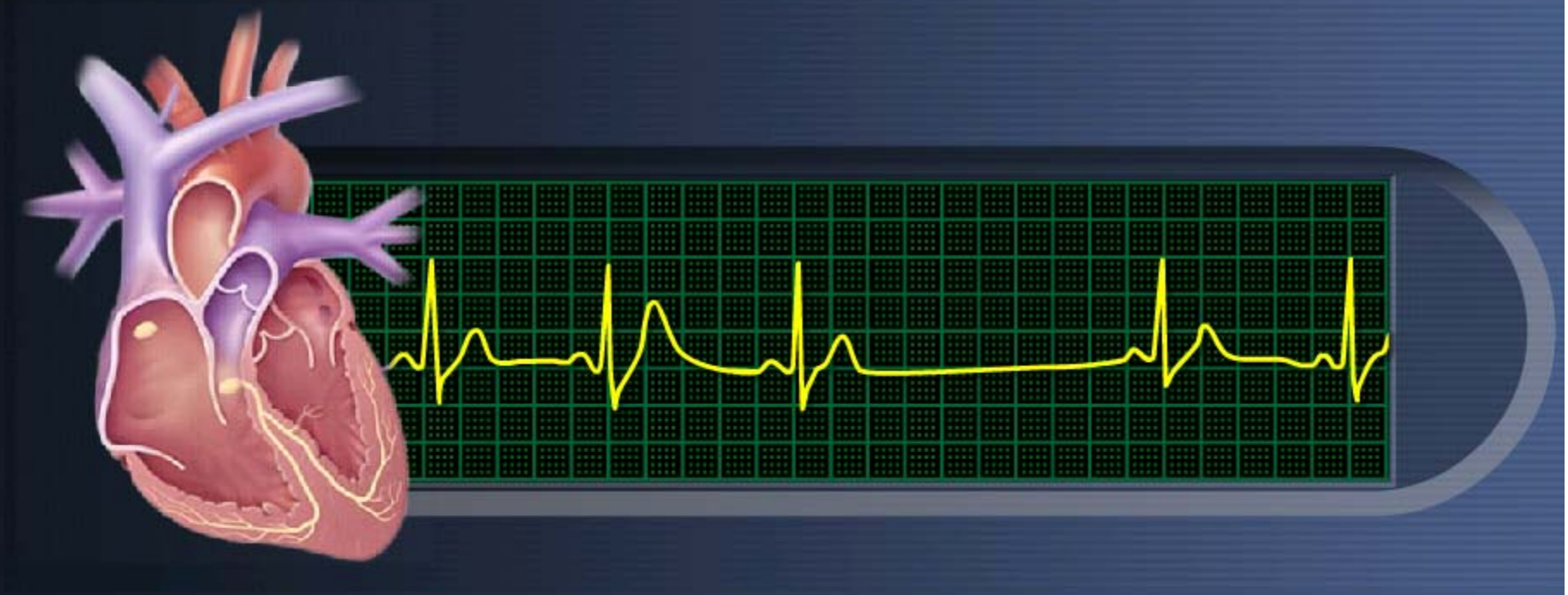


- **Failure of sinus node discharge**
- **Absence of atrial depolarization**
- **Periods of asystole**

Sinus Bradycardia

- **Sinus Node emits energy very slowly**

Brady/Tachy Syndrome

- **Intermittent episodes of slow and fast rates from the SA node or atria**
- **Brady <60 BPM**
- **Tachy >100 BPM**

Bradyarrhythmia Classifications

Classification Based on Disorder

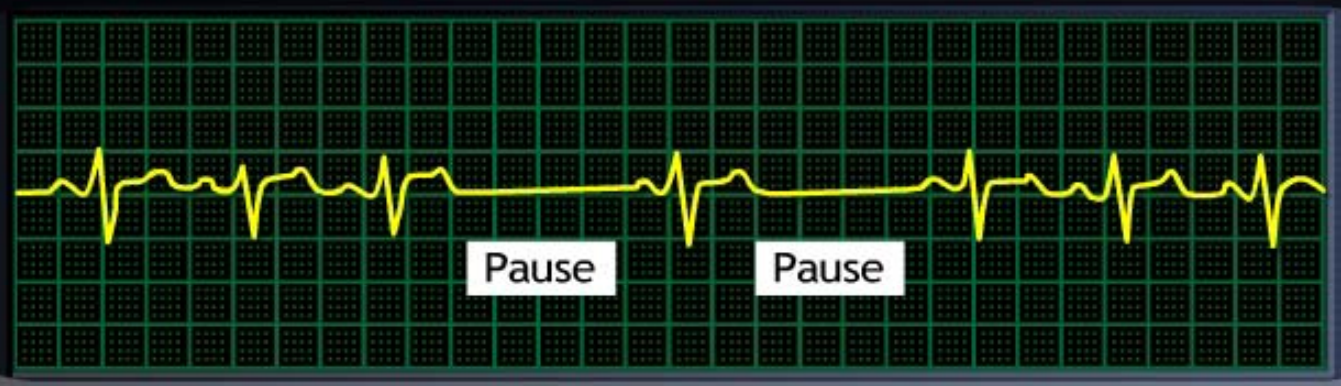
Impulse Formation Disorders

- **Sinus Arrest**
- **Sinus Bradycardia**
- **Brady/Tachy Syndrome**

Impulse Conduction Disorders

- **Exit Block**
- **1st Degree AV Block**
- **2nd Degree AV Block**
- **3rd Degree AV Block**
- **Bi/Trifascicular Block**

Exit Block



- **Transient block of impulses from the SA node**
- **Identified by P-P interval relationship**

First-Degree AV Block

- **PR interval > 200 ms**
- **Delayed conduction through the AV Node**
  - **Example shows PR Interval = 320 ms**

Second-Degree AV Block - Mobitz I

Known as Wenckebach Block

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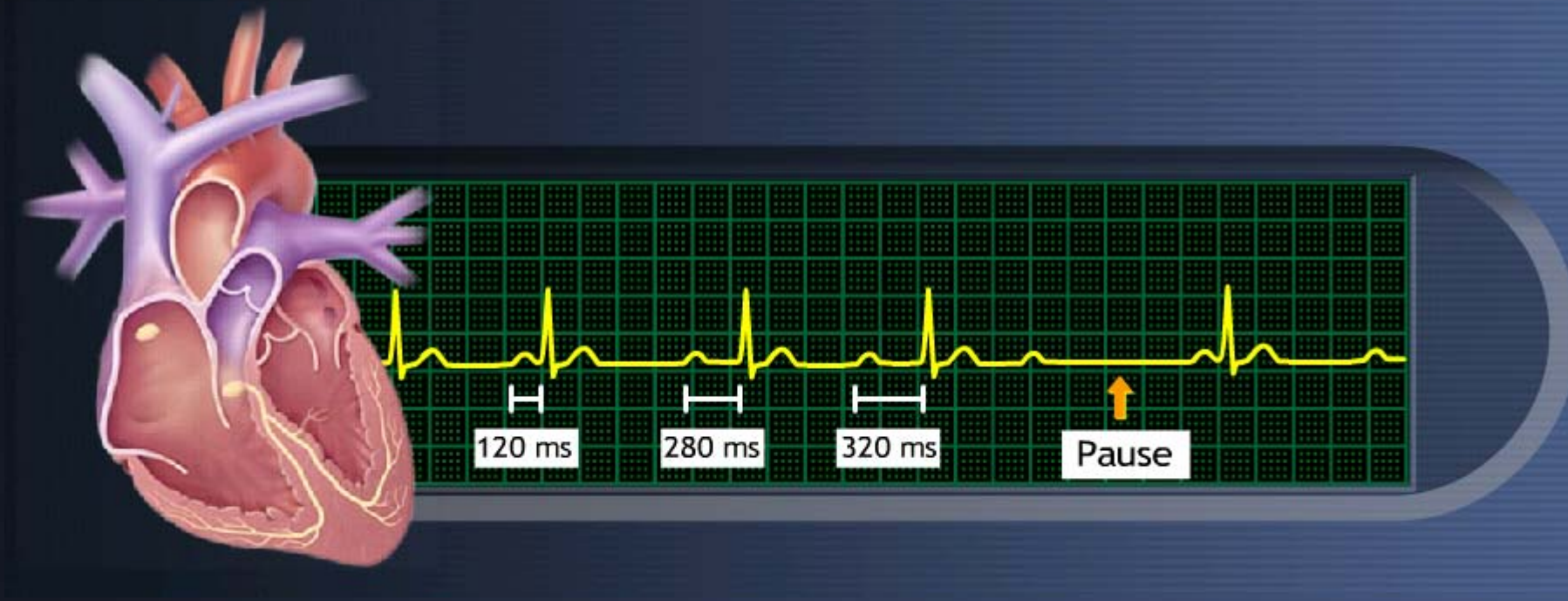


- **Progressive prolongation of the PR interval until there is failure to conduct and a ventricular beat is dropped**

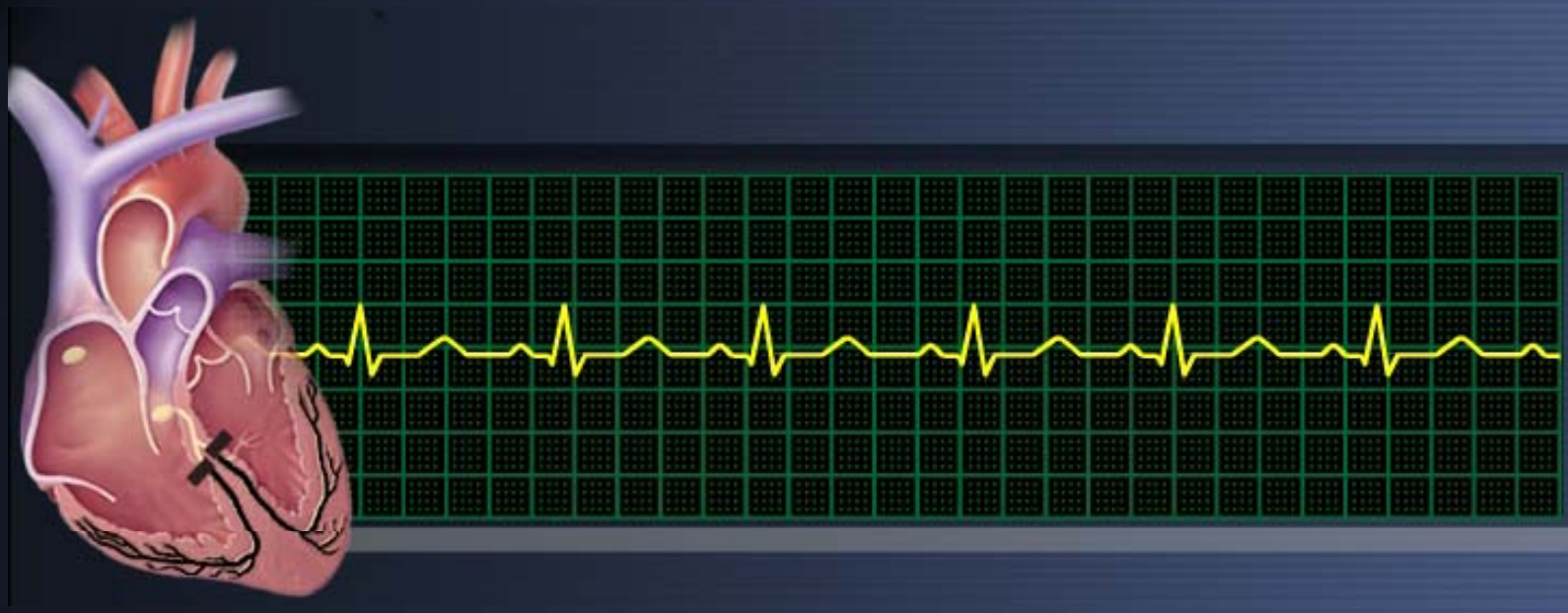
Second-Degree AV Block – Mobitz II

- **Regularly dropped ventricular beats**
  - **Ex: 2:1 block (2 P-waves to 1 QRS complex)**
  - **Atrial rate = 75 BPM**
  - **Ventricular rate = 42 BPM**

Third-Degree AV Block

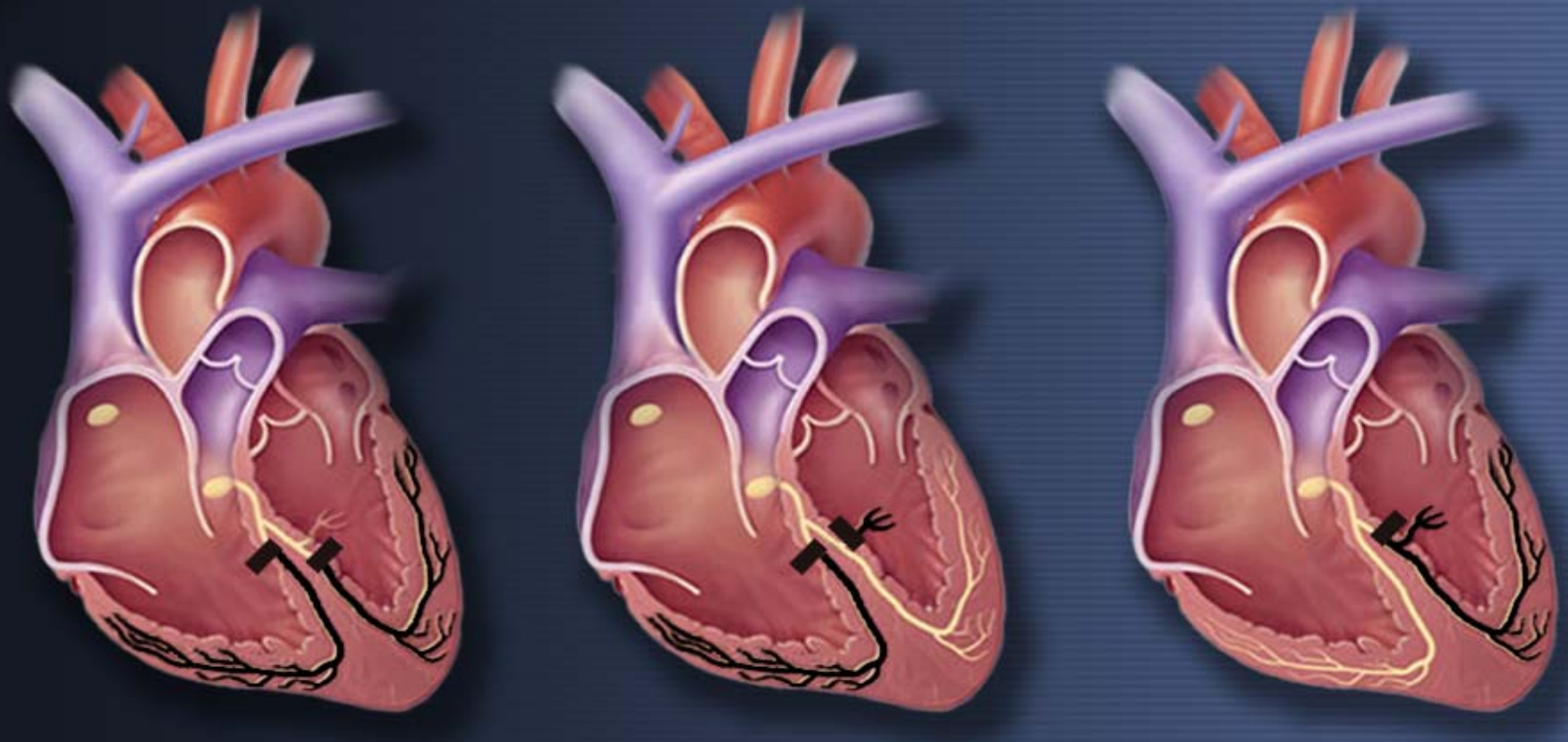
- No impulse conduction from the atria to the ventricles
  - Ventricular rate = 37 BPM
  - Atrial rate = 130 BPM
  - PR interval = variable

Bifascicular Block



- **A complete or incomplete block in at least two conduction system pathways below the AV Node**
- **Marked by a widened QRS**

Bifascicular Block

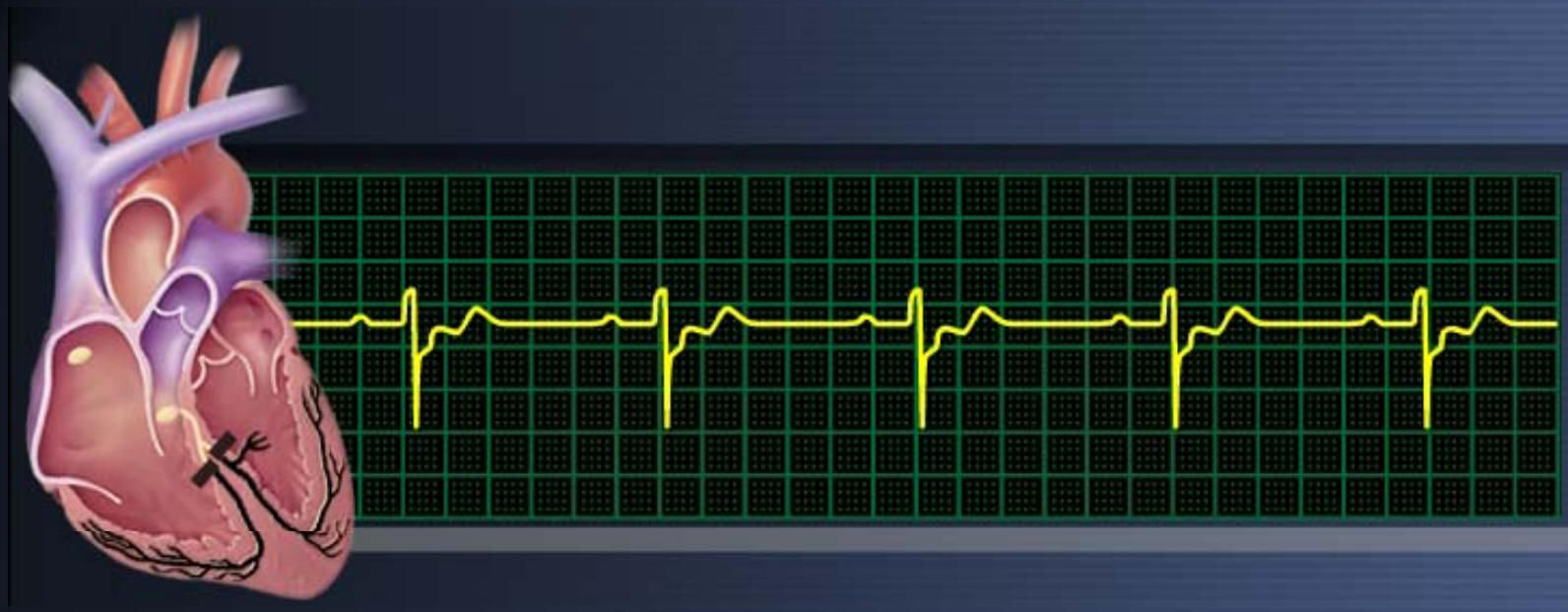


Right bundle branch block and left anterior hemiblock

Right bundle branch block and left posterior hemiblock

Complete left bundle branch block

Trifascicular Block



- **Complete block in the right bundle branch, and**
- **Complete or incomplete block in both divisions of the left bundle branch**
- **Identified by EP Study**

Bradyarrhythmia Classifications

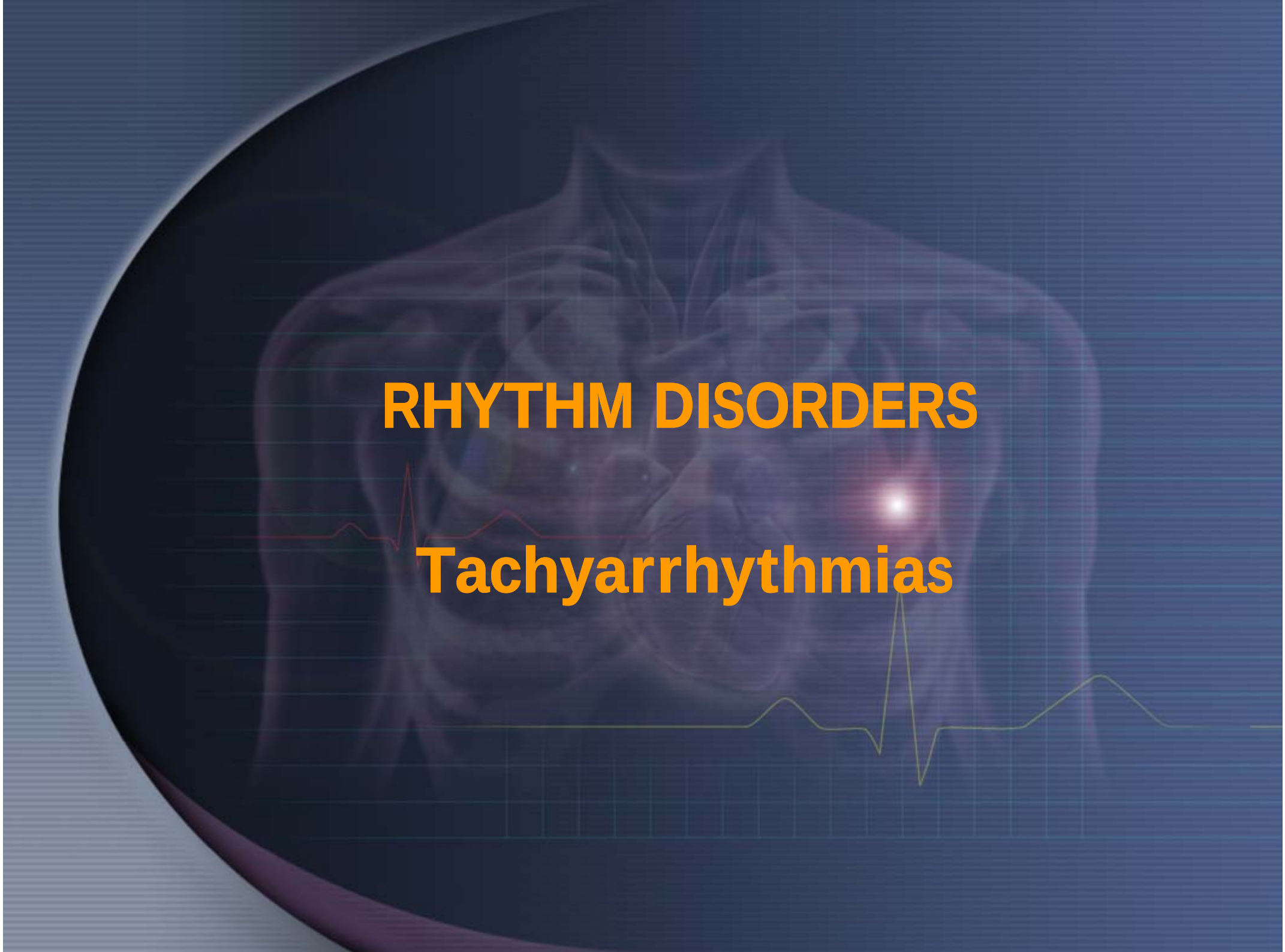
Summary

Impulse Formation Disorders

- Sinus Arrest
- Sinus Bradycardia
- Brady/Tachy Syndrome

Impulse Conduction Disorders

- Exit Block
- 1st Degree AV Block
- 2nd Degree AV Block
  - -Mobitz I (Wenckebach Block)
  - -Mobitz II
- 3rd Degree AV Block
- Bi/Trifascicular Block


RHYTHM DISORDERS
Tachyarrhythmias

Terms Describing Tachycardias

- **Paroxysmal**
  - Ectopic focus, sudden onset, abrupt cessation
- **Sustained**
  - Duration of > 30 seconds
  - Requires intervention to terminate
- **Non-Sustained**
  - At least 6 beats or < 30 seconds
  - Spontaneously terminates
- **Recurrent**
  - Occurs periodically
  - Periods of no tachycardia are longer than periods of tachycardia

Terms Describing Tachycardias

- **Incessant**
  - Long periods of tachy, short periods of NSR
- **Monomorphic**
  - Single focus
  - Complexes are similar with equal intervals
- **Polymorphic**
  - Multiple foci
  - Complexes appear different with varied intervals

Tachyarrhythmia Classifications

Classification Based on Disorder

Tachycardias

- Impulse Formation Disorders
- Impulse Conduction Disorders

Tachyarrhythmia Classifications

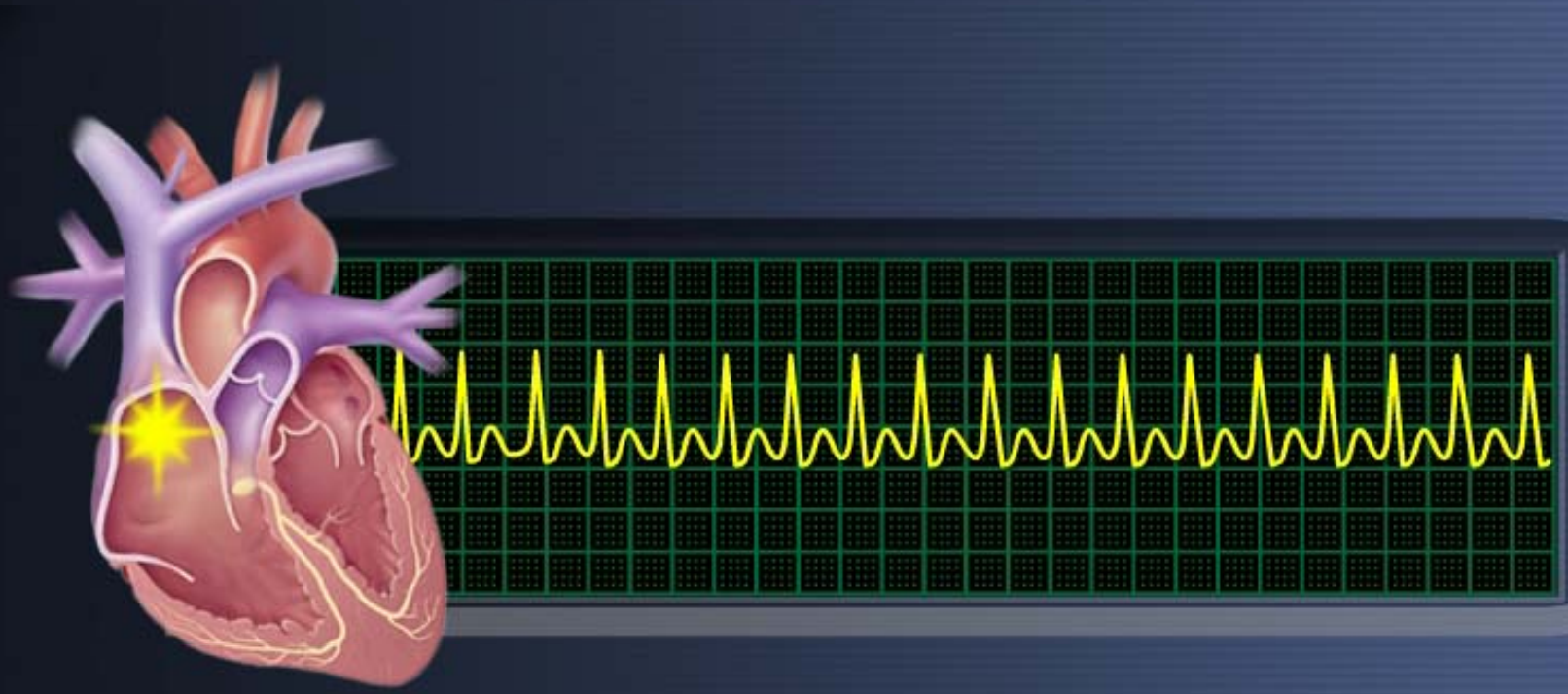
Classification Based on Disorder

Impulse Formation Disorders

- **Sinus Tachycardia**
- **Atrial Tachycardia**
- **Premature Contractions**
- **Accelerated Idio-Junctional Rhythm**
- **Accelerated Idioventricular Rhythm (AIVR)**

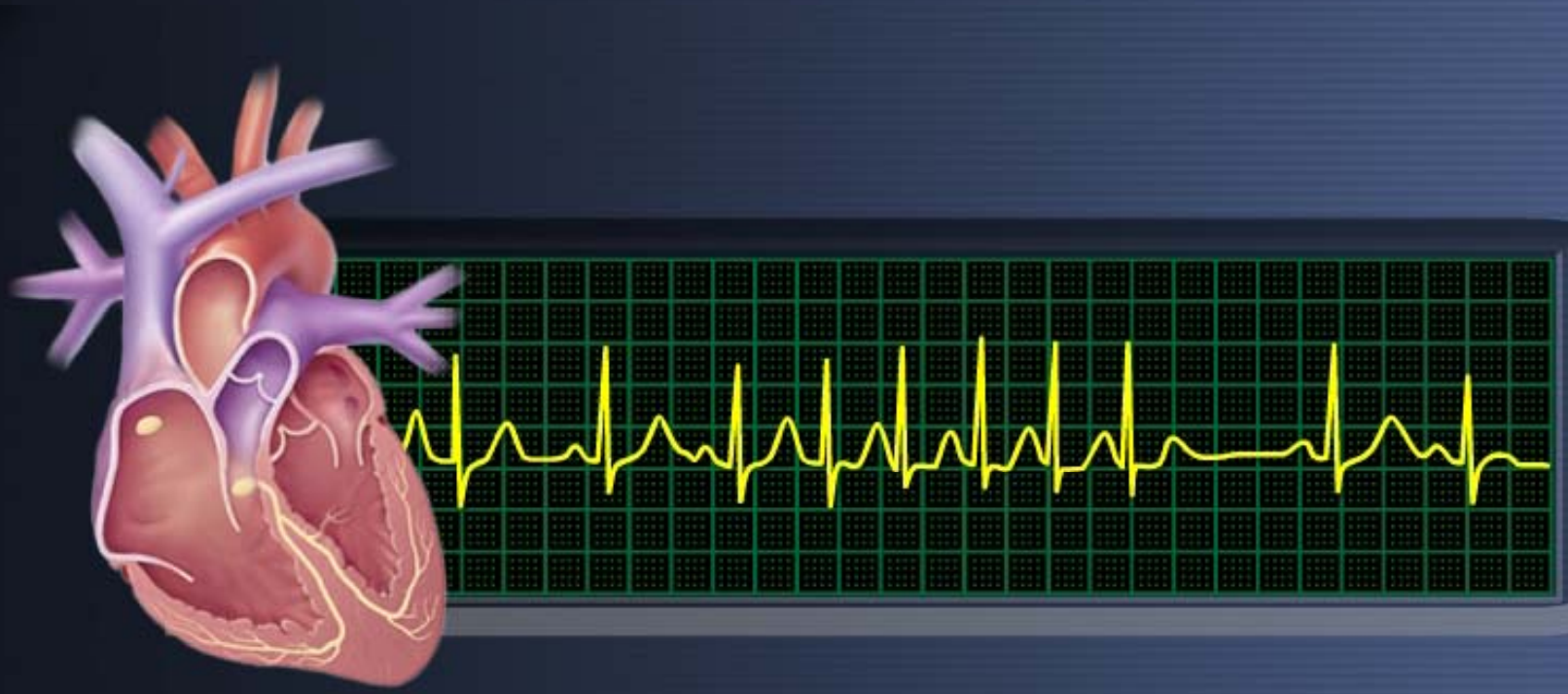
Impulse Conduction Disorders

Sinus Tachycardia



- **Origin:** Sinus Node
- **Rate:** 100-180 BPM
- **Mechanism:** Abnormal (Hyper) Automaticity

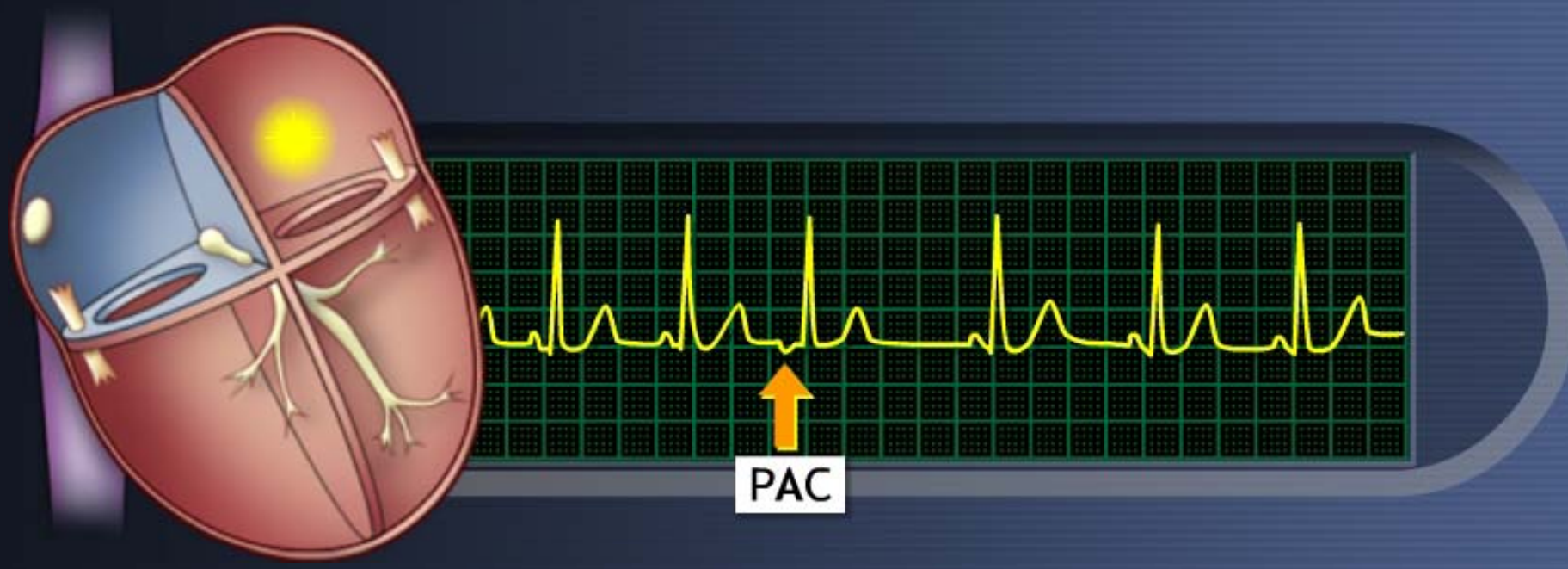
Atrial Tachycardia



- **Origin:** Atrium - Ectopic Focus
- **Rate:** >100 BPM
- **Mechanism:** Abnormal Automaticity

Premature Beats

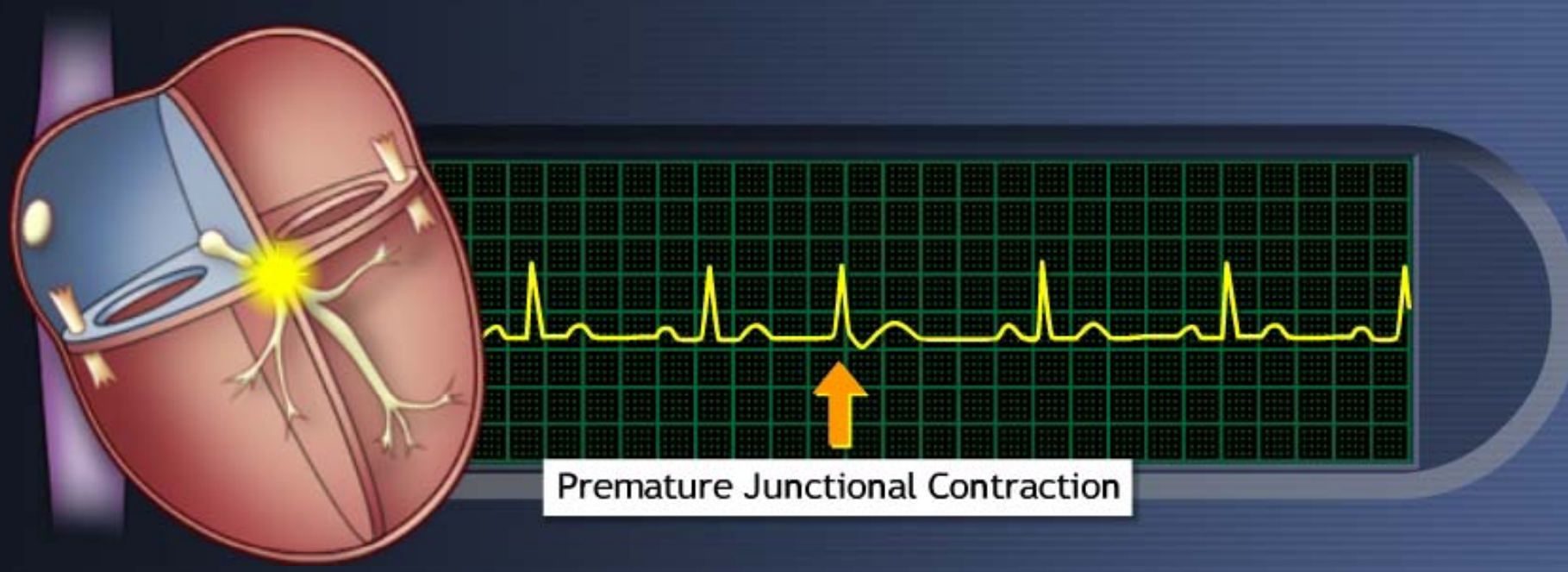
Premature Atrial Contraction (PAC)



- **Origin:** Atrium (outside the Sinus Node)
- **Mechanism:** Abnormal Automaticity
- **Characteristics:** An abnormal P-wave occurring earlier than expected, followed by compensatory pause

Premature Beats

Premature Junctional Contraction



- **Origin:** AV Node Junction
- **Mechanism:** Abnormal Automaticity
- **Characteristics:** A normally conducted complex with an absent p-wave, followed by a compensatory pause

Premature Beats

Premature Ventricular Contractions (PVCs)

- **Origin:** Ventricles
- **Mechanism:** Abnormal Automaticity
- **Characteristics:** A broad complex occurring earlier than expected, followed by a compensatory pause

PVC Patterns

- **Bigeminy**
  - Every other beat
- **Trigeminy**
  - Every third beat
- **Quadrigeminy**
  - Every fourth beat

Multifocal PVC

- **Origin:** Varies within the Ventricle
- **Mechanism:** Abnormal Automaticity
- **Characteristics:** Each premature beat changes axis; implies a different focus origin for each beat

Accelerated Idio-Junctional Rhythm

- **Origin:** AV Node or Junctional Tissue
- **Mechanism:** Abnormal Automaticity
- **Characteristics:** Occurs when cells depolarize at a rate faster than the Sinus Node

Accelerated Idioventricular Rhythm

- **Origin:** Ventricle
- **Mechanism:** Abnormal Automaticity
- **Rate:** Ventricular rate >sinus rate, but <VT
- **Characteristic:** Dominates and takes over the rhythm

Accelerated Idioventricular Rhythm

Sinus Rhythm being taken over by an Idioventricular Rhythm

Tachyarrhythmia Classifications

Classification Based on Disorder

Impulse Formation Disorders

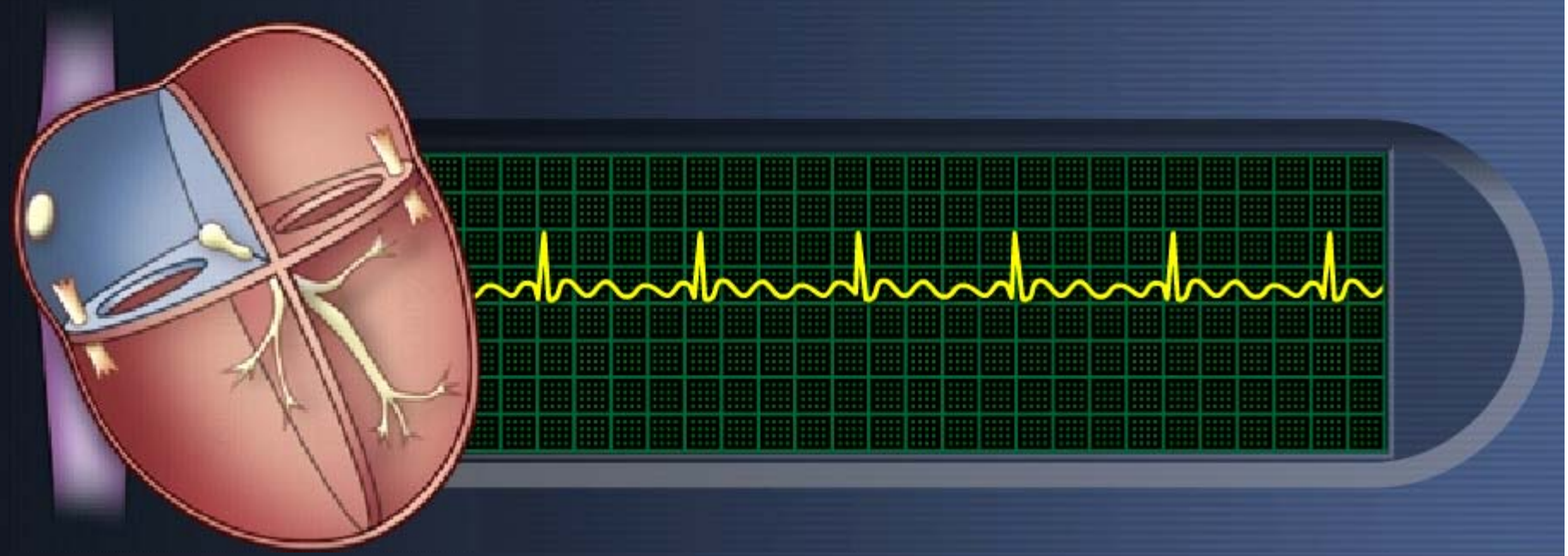
- **Sinus Tachycardia**
- **Atrial Tachycardia**
- **Premature Contractions**
- **Accelerated Idio-Junctional Rhythm**
- **Accelerated Idioventricular Rhythm (AIVR)**

Impulse Conduction Disorders

- **Atrial Flutter**
- **Atrial Fibrillation**
- **AVRT**
- **AVNRT**
- **Ventricular Tachycardia**
- **Ventricular Fibrillation**

Atrial Flutter

*



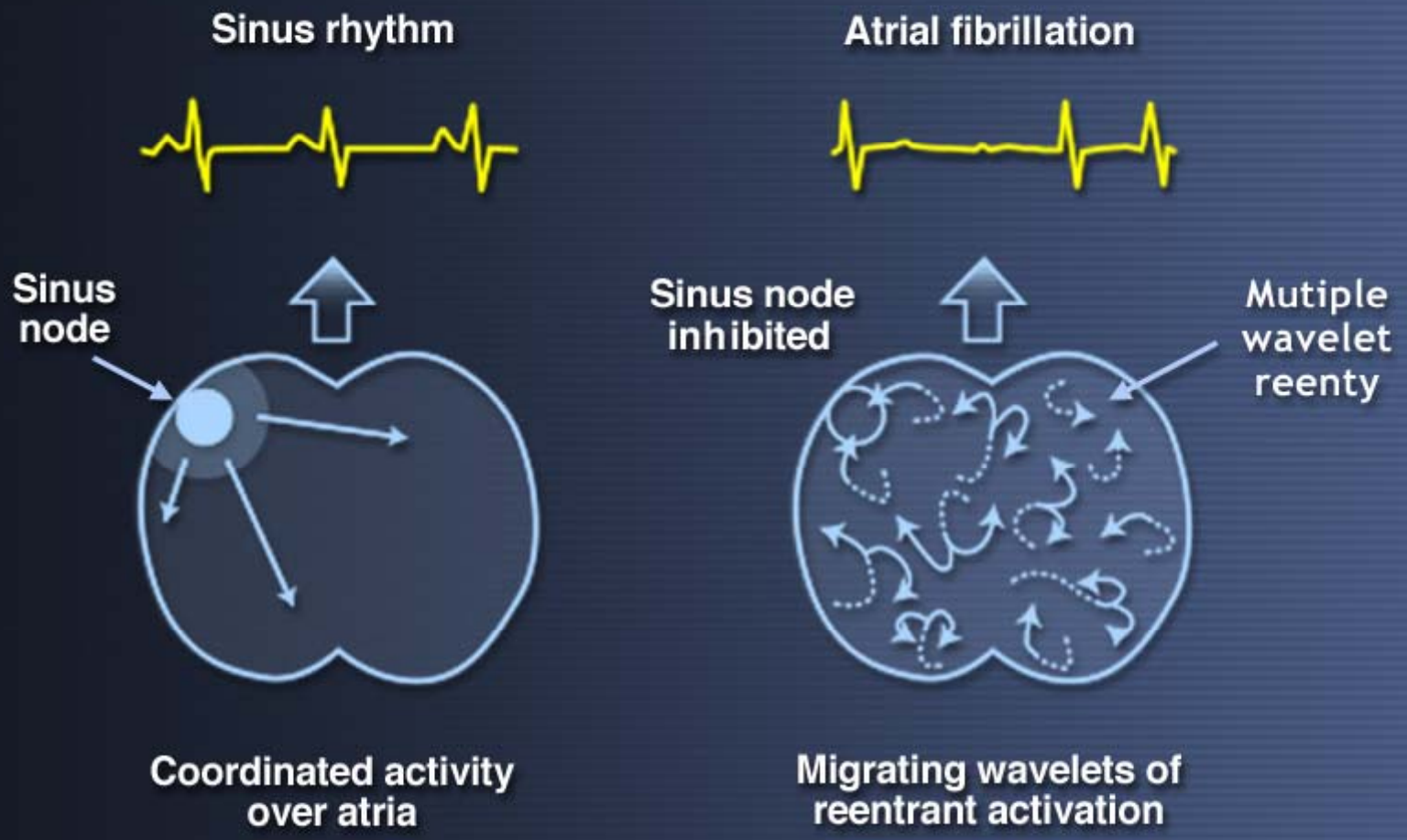
- **Origin:** Right & Left Atrium
- **Mechanism:** Reentry
- **Characteristics:** Rapid, regular p-waves

Atrial Fibrillation (AF)

*

- **Origin:** Right and/or left atrium
- **Mechanism:** Multiple wavelets of reentry
- **Rate** 400 BPM
- **Characteristics:** Random, chaotic rhythm; atria quiver; associated with irregular ventricular rhythm

Atrial Fibrillation (AF)



Atrial Flutter vs. Atrial Fibrillation

Summary of Disease Characteristics

	Atrial Flutter	Atrial Fibrillation
Atrial Rate	• 250 to 400 BPM	• 400 BPM
Ventricular Rate	• Varies w/conduction	• Varies w/conduction
Rhythm	• Usually regular	• Grossly Irregular
Pattern	• Saw tooth baseline	• Wavy baseline
Underlying Mechanism	• Reentry via macro reentrant circuit	• Multiple wavelet reentry • Multiple/single focus firing

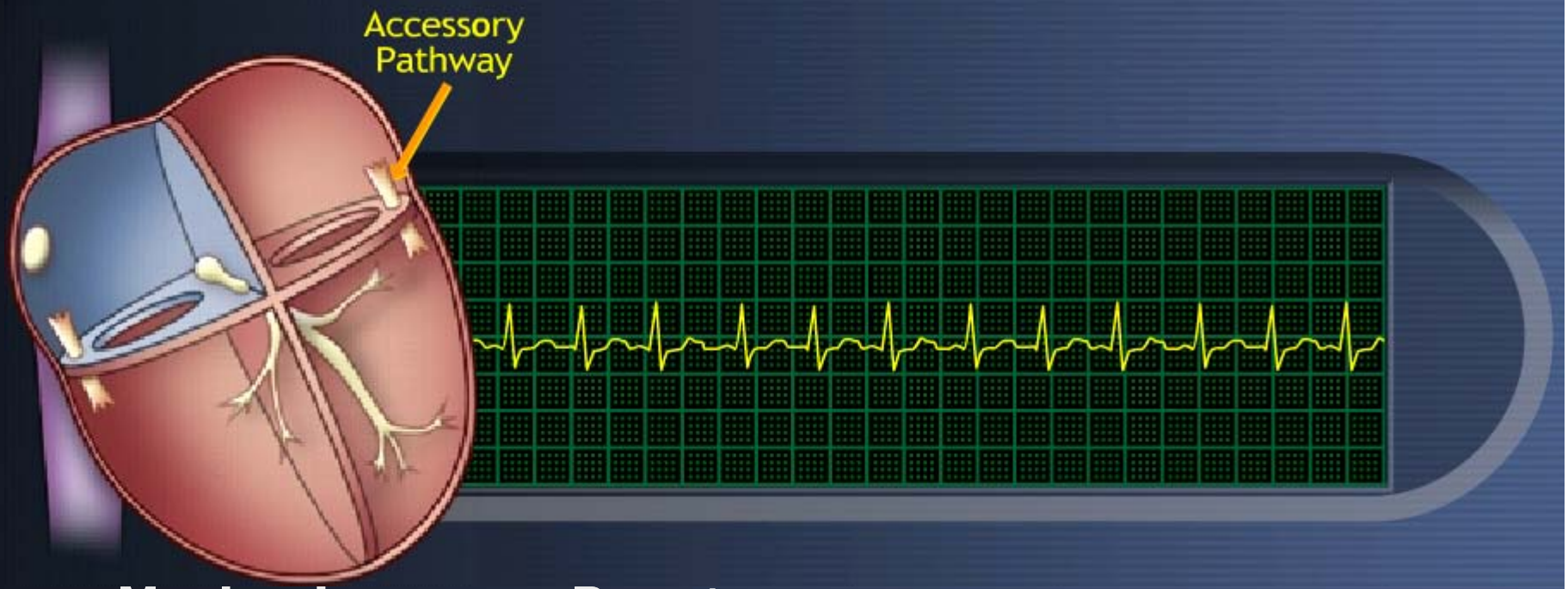
AVRT

- An SVT caused by the existence of an extra pathway from the atria to the ventricles
- Extra pathway + AV Node = reentry
- 2 Types
  - Orthodromic
    - A to V through node, then enters accessory pathway to loop
    - Produces narrow complex SVT
  - Antidromic
    - A to V through accessory pathway, then enters node to loop
    - Produces wide-complex SVT

AVRT

Orthodromic

*Animation

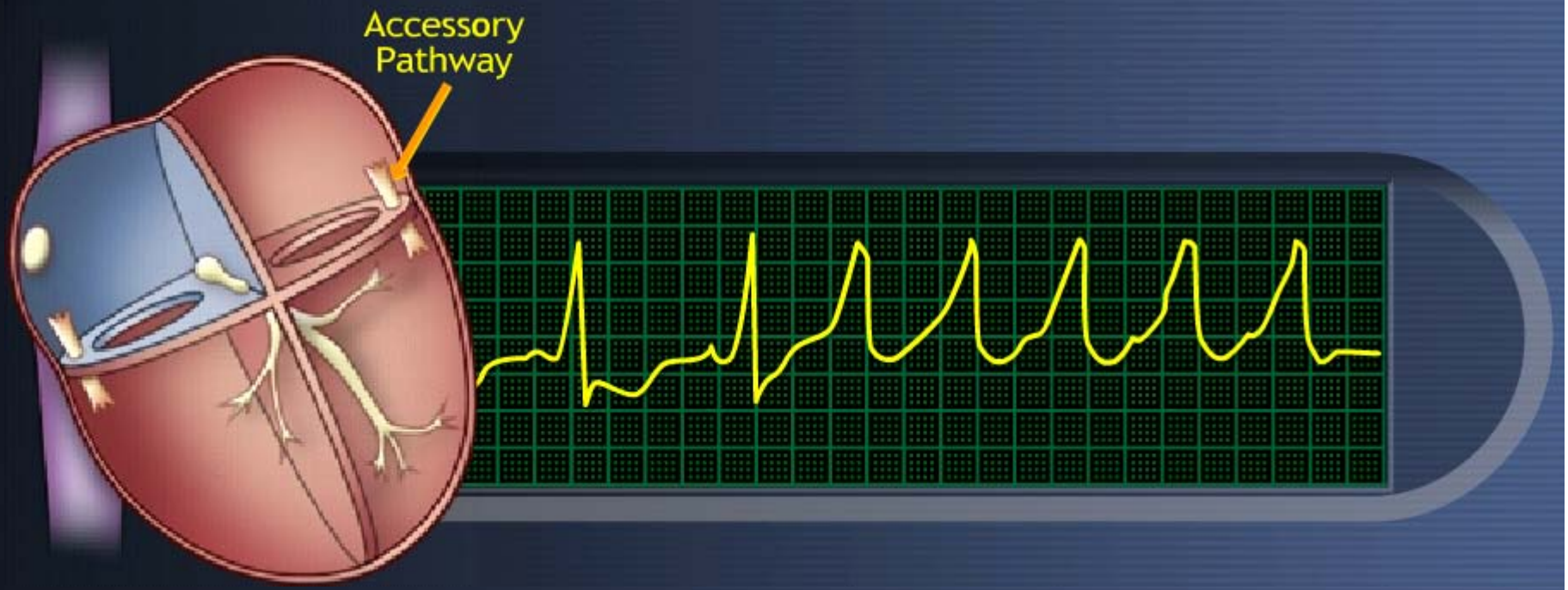


- **Mechanism:** Reentry
- **Rate:** 180 - 260 BPM, sometimes faster
- **Characteristics:** Extra electrical pathway to ventricles
  Wolf-Parkinson-White (WPW)
  Syndrome is most common

AVRT

Antidromic

*Animation

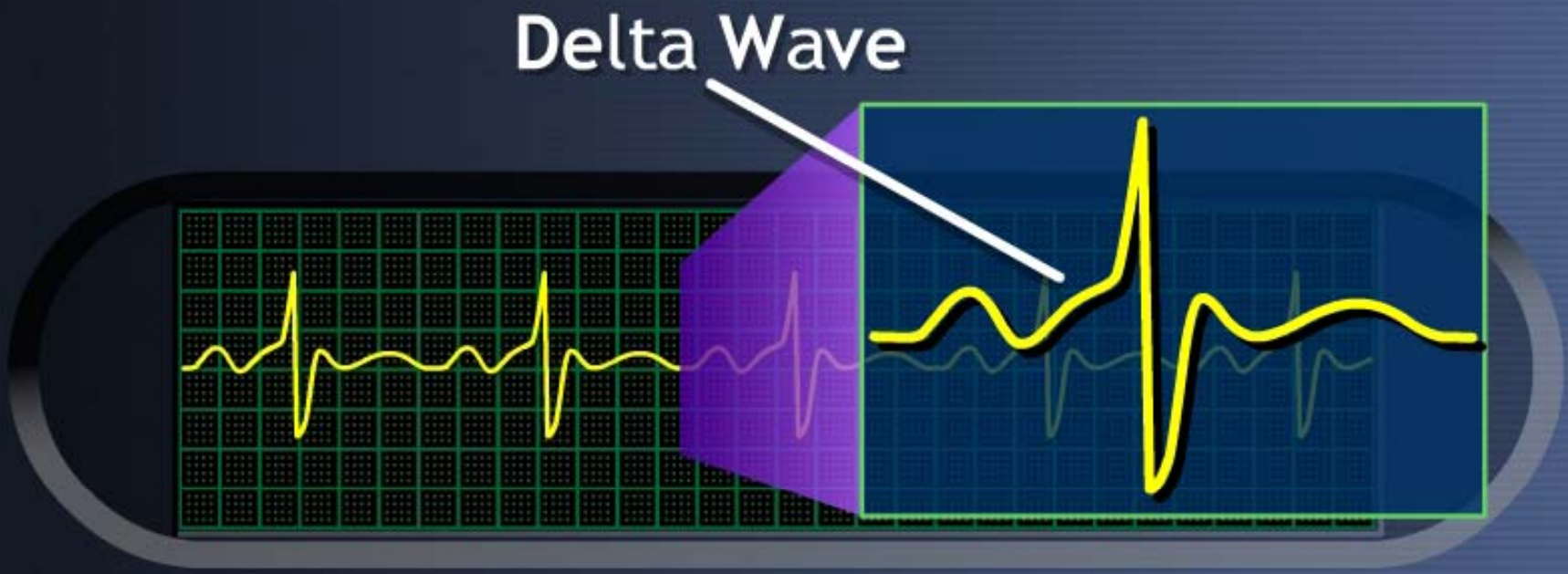


- **Mechanism:** Reentry
- **Rate:** 180 - 260 BPM, sometimes faster
- **Characteristics:** Extra electrical pathway to ventricles; produces wide complex tachycardia

Wolff-Parkinson-White

- **Accessory Pathway = Bundle of Kent**
- **Orthodromic - 90%**
  - **AV node – antegrade conduction;**
  - **Extra pathway – retrograde conduction**
- **Antidromic – 10%**
  - **Extra pathway – antegrade conduction**
  - **AV node – retrograde conduction**

Wolff-Parkinson-White



- **Origin:** Outside the AV Node
- **Mechanism:** Reentry
- **Rate:** 180-260 BPM – can be faster
- **Characteristics:** Short PR Interval (≤ 120 ms),wide QRS (≥ 110 ms), obvious delta wave

AVNRT

- **Origin:** AV Node
- **Mechanism:** Reentry
- **Rate:** 150 - 230 BPM, faster in teenagers
- **Characteristics:** Normal QRS with absent P-waves; most common SVT in adults

AVRT vs. AVNRT

AVRT

- 180 – 260 BPM
- Narrow QRS if orthodromic
- Wide QRS if antidromic
- Delta wave + in SR
- PR < 120 ms
- 1:1 Conduction

AVNRT

- 150 – 230 BPM
- Narrow QRS
- Short RP interval
- No delta waves
- Initiating PR long
- P-waves buried in QRS
- Conduction 1:1, or 2:1 when distal block present

Ventricular Tachycardia

Classification Based on Morphology

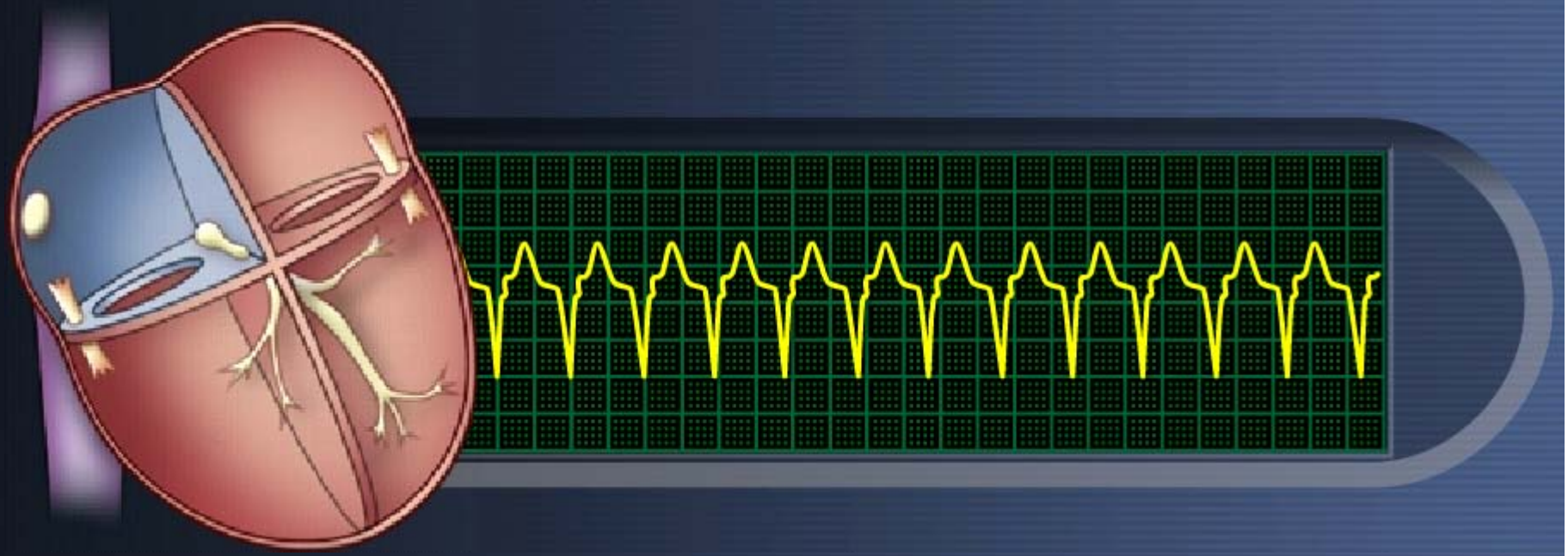
Ventricular Tachycardia (VT)

- **Monomorphic**

Monomorphic VT

EKG Characteristics

*



- **Origin:** Ventricles (Single Focus)
- **Mechanism:** Reentry Initiated by abnormal Automaticity or Triggered activity
- **Characteristics:** Rapid, wide, and regular QRS

Ventricular Arrhythmias

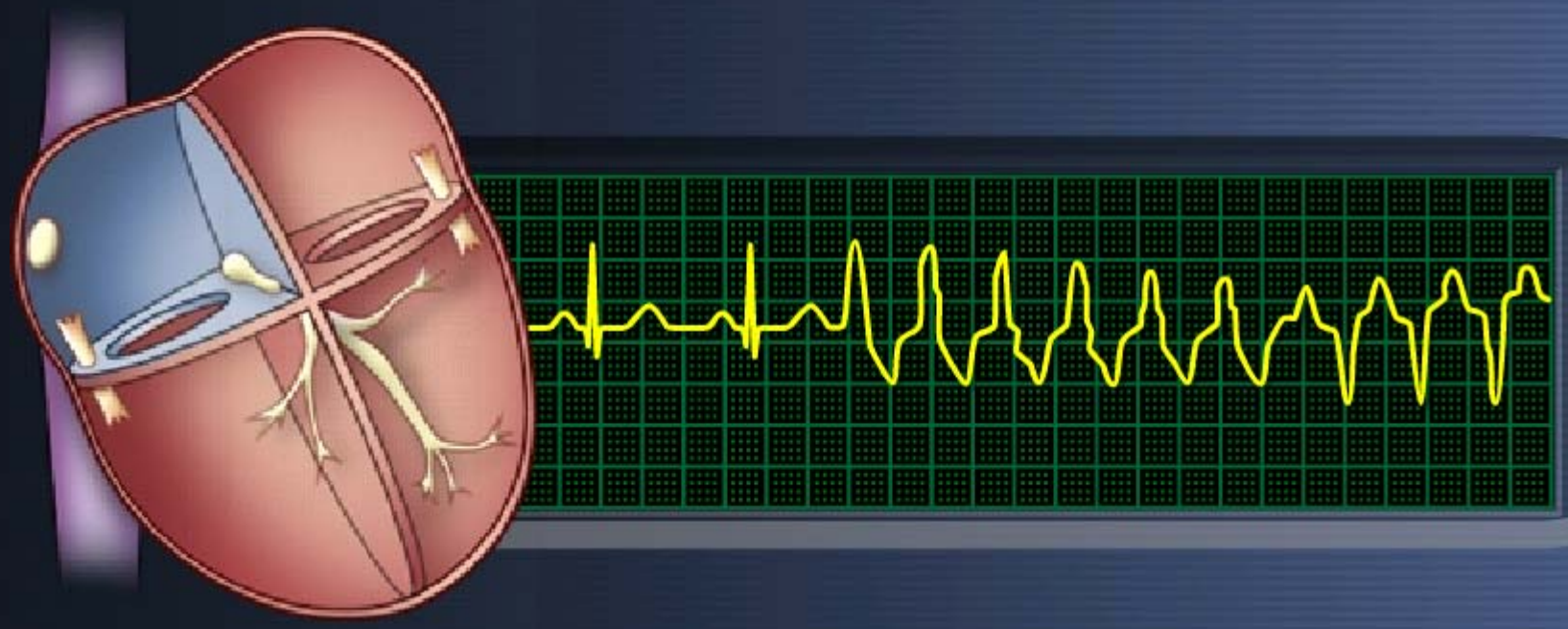
Classification Based on Morphology

Ventricular Tachycardia (VT) →

- **Monomorphic**
- **Polymorphic**

Polymorphic VT

*



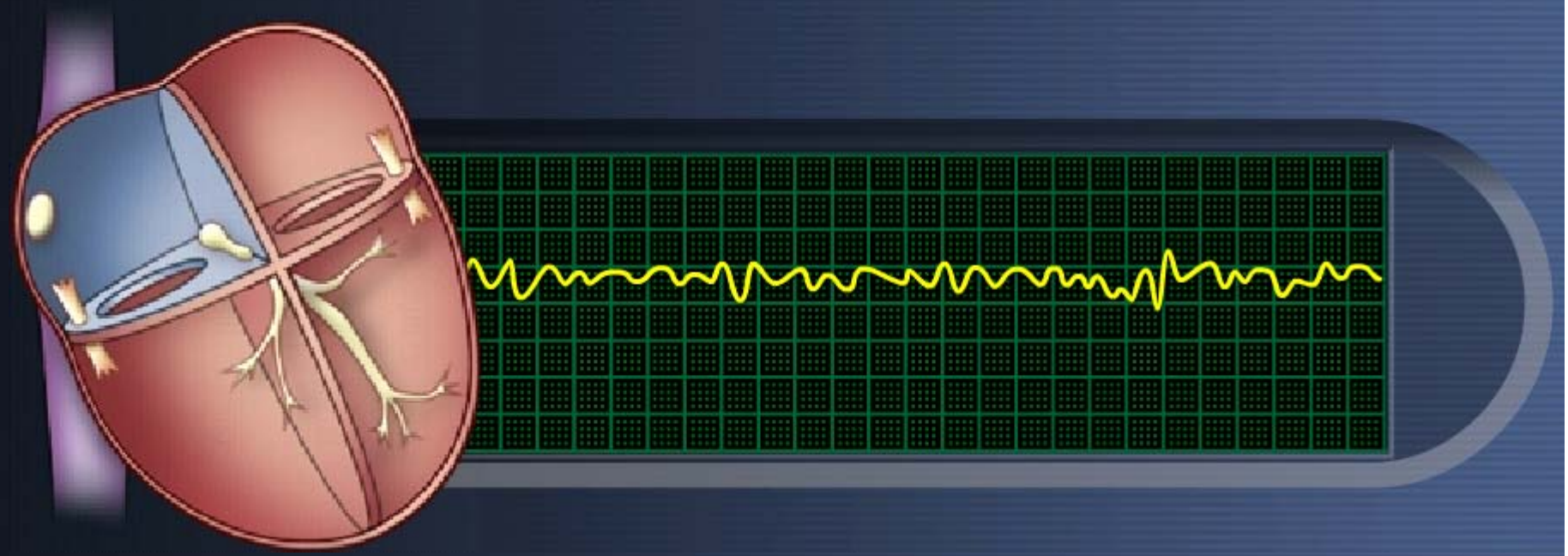
- **Origin:** Ventricles (Wandering Single Focus)
- **Mechanism:** Reentry with movement in the circuit Initiated by Abnormal Automaticity or Triggered activity
- **Characteristics:** Wide and irregular QRS Complex that changes in axis

Torsades de Pointes

- **Origin:** Ventricle
- **Mechanism:** Reentry (movement in focus)
- **Rate:** 200 – 250 BPM
- **Characteristics:** Associated with Long QT interval; QRS changes axis & morphology with alternating positive/negative complexes

Ventricular Fibrillation (VF)

*



- **Origin:** Ventricle
- **Mechanism:** Multiple Wavelets of reentry
- **Characteristics:** Irregular with no discrete QRS

Tachyarrhythmia Classifications

Summary

Impulse Formation Disorders

- Sinus Tachycardia
- Atrial Tachycardia
- Premature Contractions
- Accelerated Idio-Junctional Rhythm
- Accelerated Idioventricular Rhythm (AIVR)

Impulse Conduction Disorders

- Atrial Flutter
- Atrial Fibrillation
- AVRT
- AVNRT
- Ventricular Tachycardia
- Ventricular Fibrillation

What is SVT?

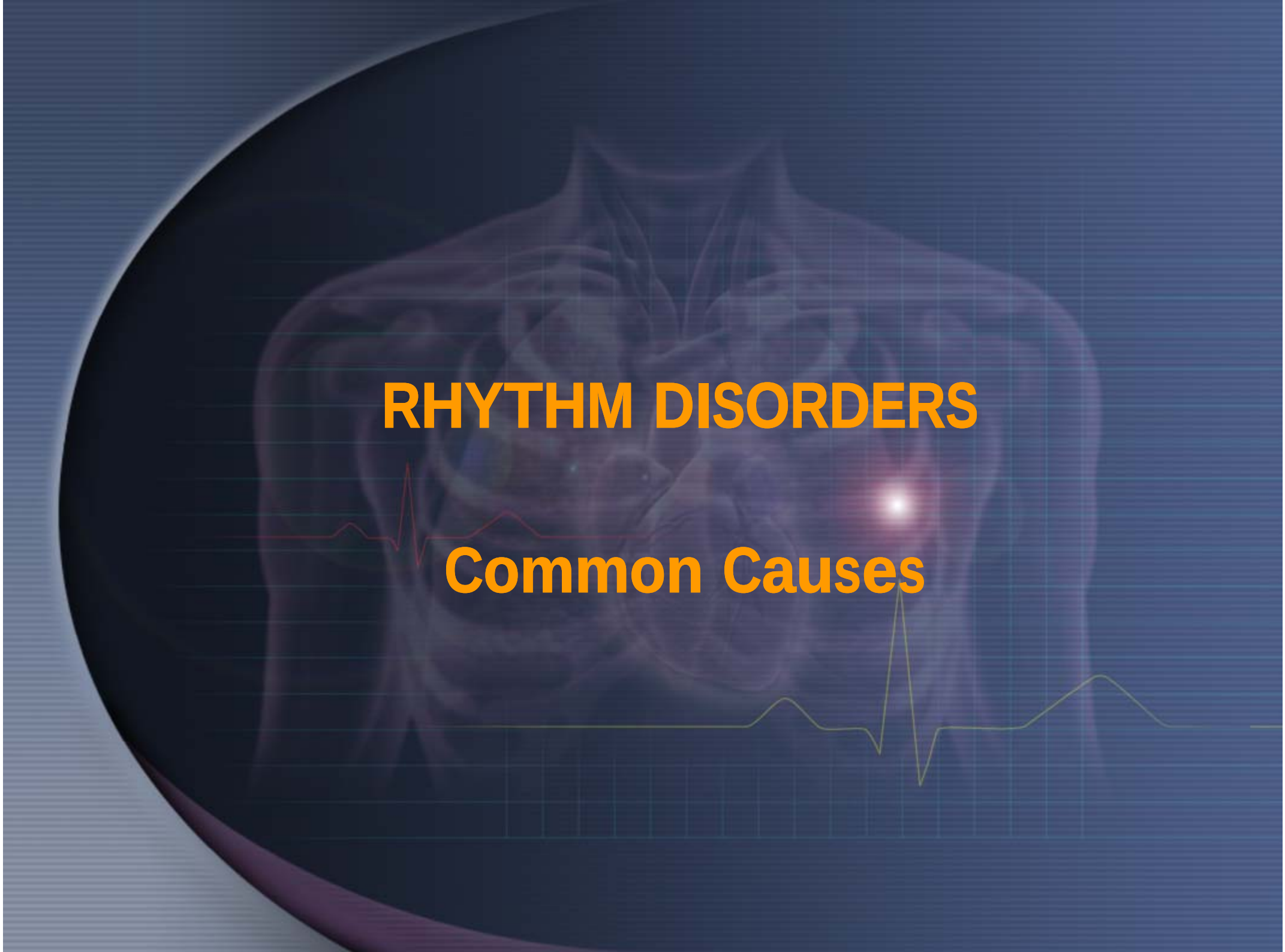
Supraventricular Tachycardia

Tachyarrhythmia Classifications

Based on origin

- Sinus Tachycardia
- Atrial Tachycardia
- Accelerated Idio-Junctional Rhythm
- Atrial Flutter
- Atrial Fibrillation
- AVRT
- AVNRT

- Accelerated Idioventricular Rhythm (AIVR)
- Ventricular Tachycardia (VT)
- Ventricular Fibrillation (VF)


RHYTHM DISORDERS
Common Causes

Causes of Rhythm Disorders

Congenital

- Present at birth due to genetics, environment

Heart Disease

- Myocardial Infarction, Cardiomyopathy, High Blood Pressure

Chemically Induced

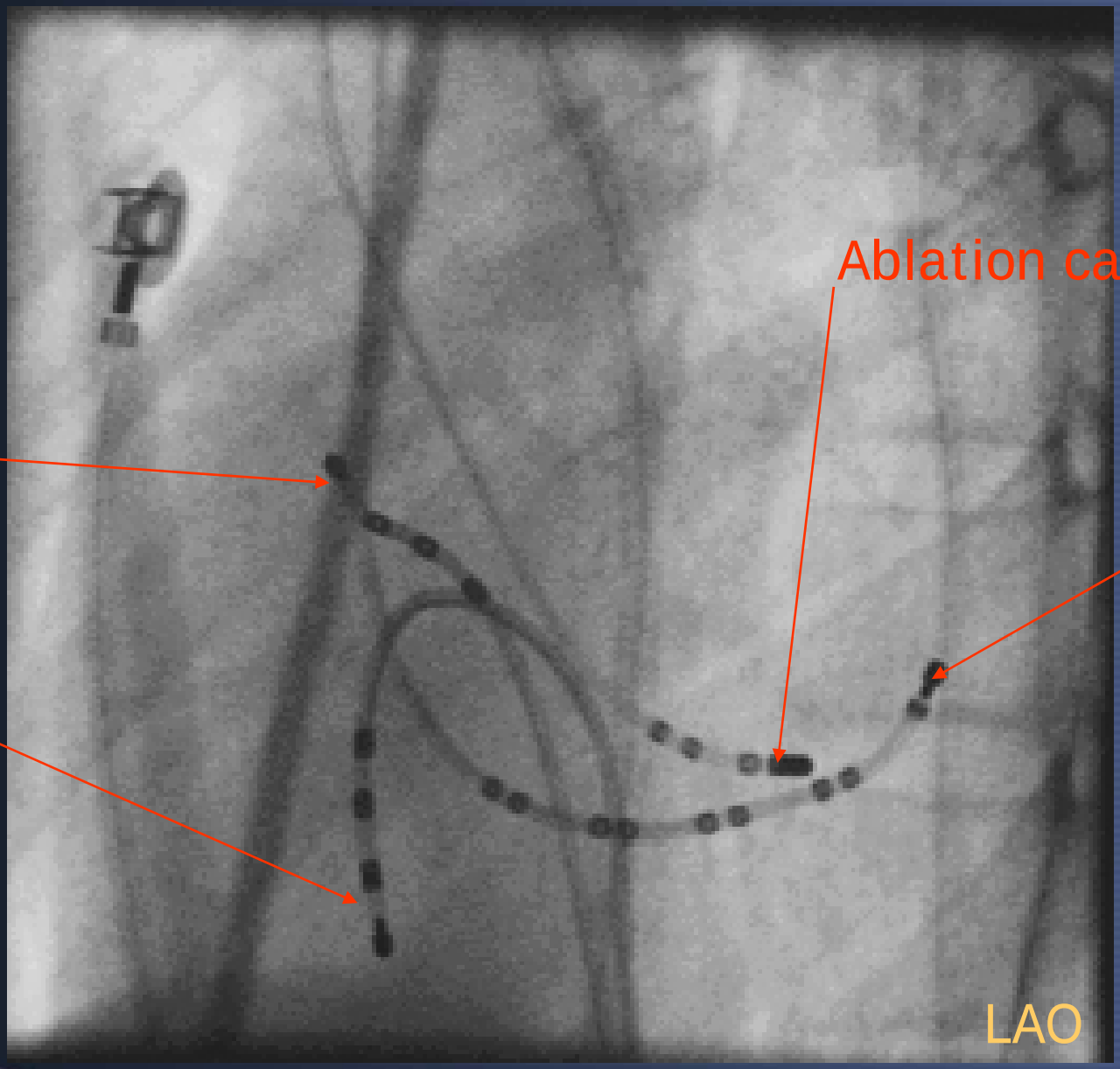
- Diet Pills, Cold Medicine, Illegal Drugs, Caffeine, Tobacco, Alcohol

Causes of Rhythm Disorders

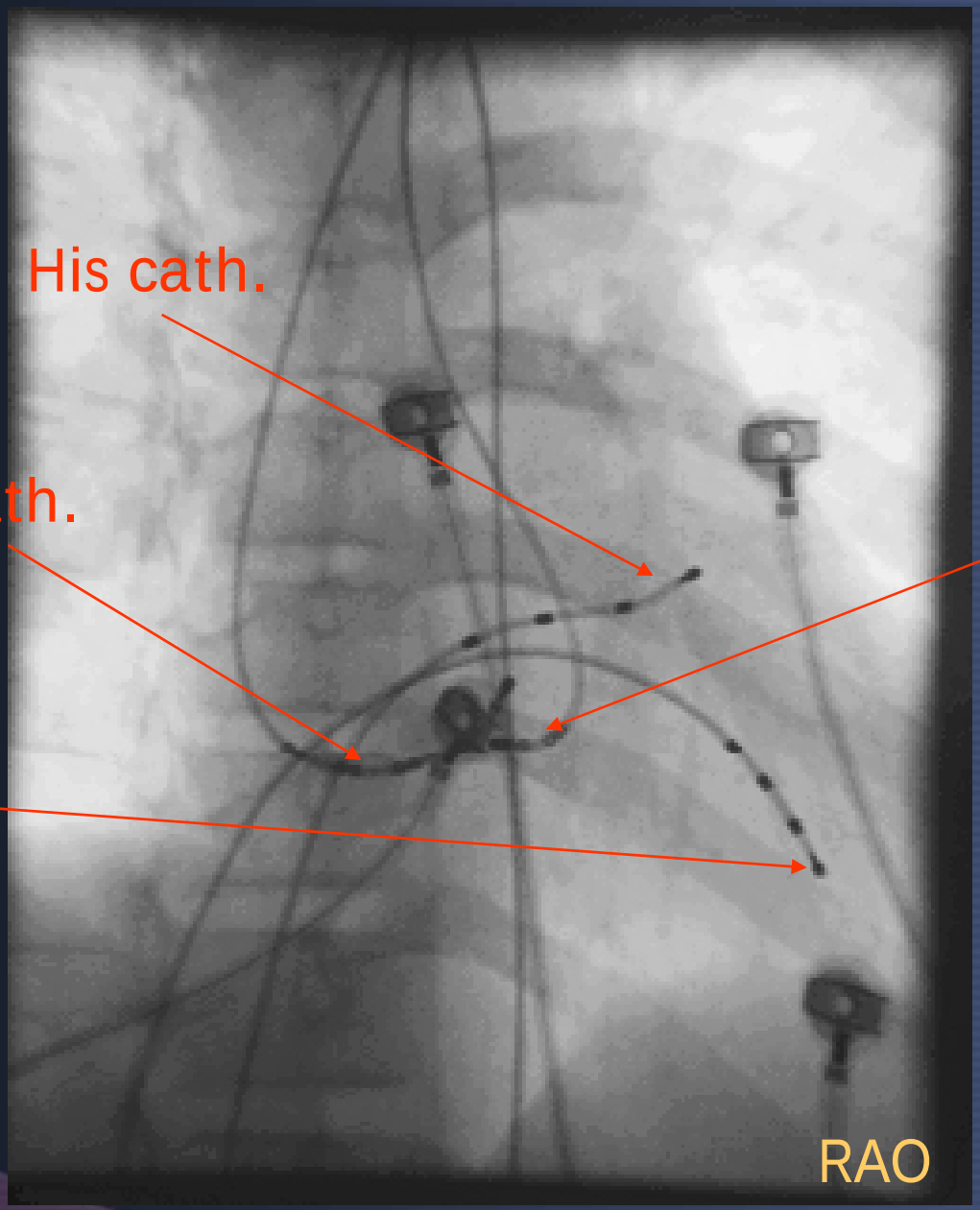
Secondary to other conditions

- Hyper-Thyroid
- Neurocardiogenic Syncope
  - Hypersensitive Carotid Sinus Syndrome (CSS)
  - Vasovagal Syncope (VS)

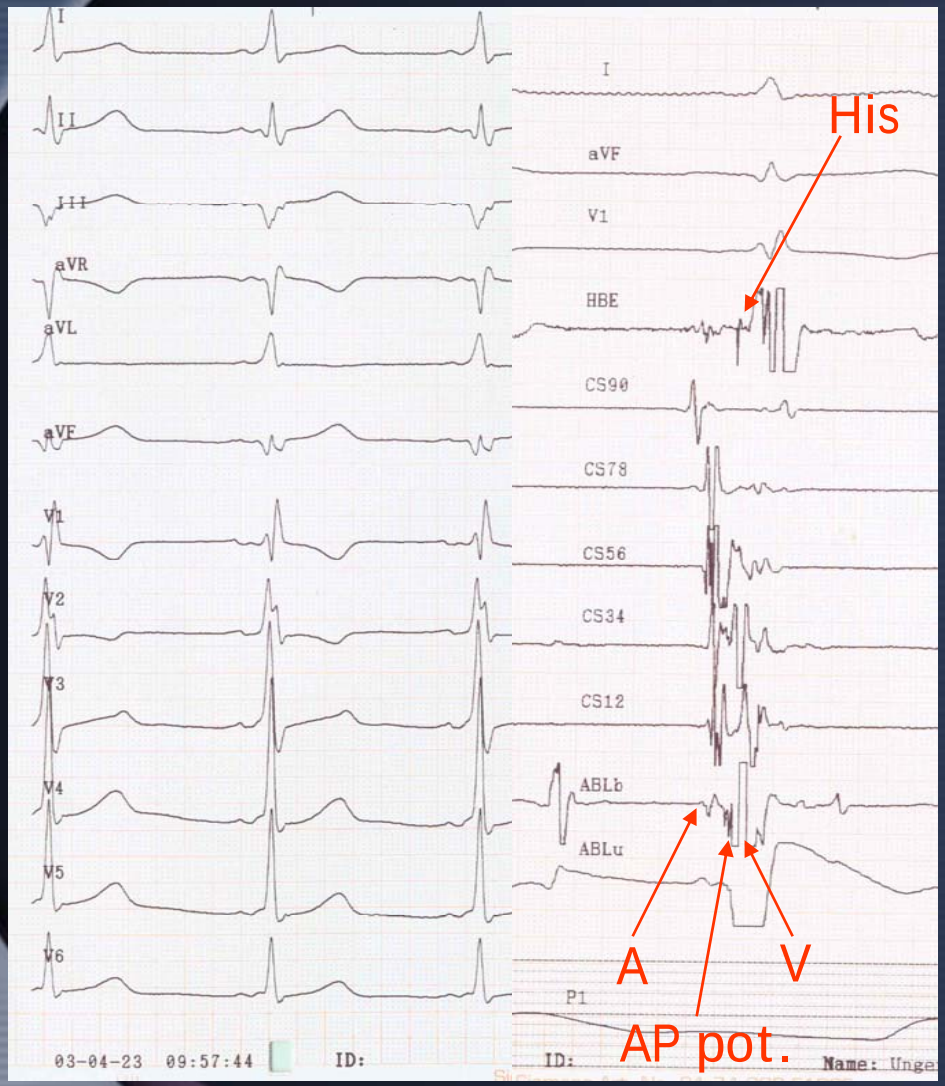
Catheter RF Ablation (left posterior AP)



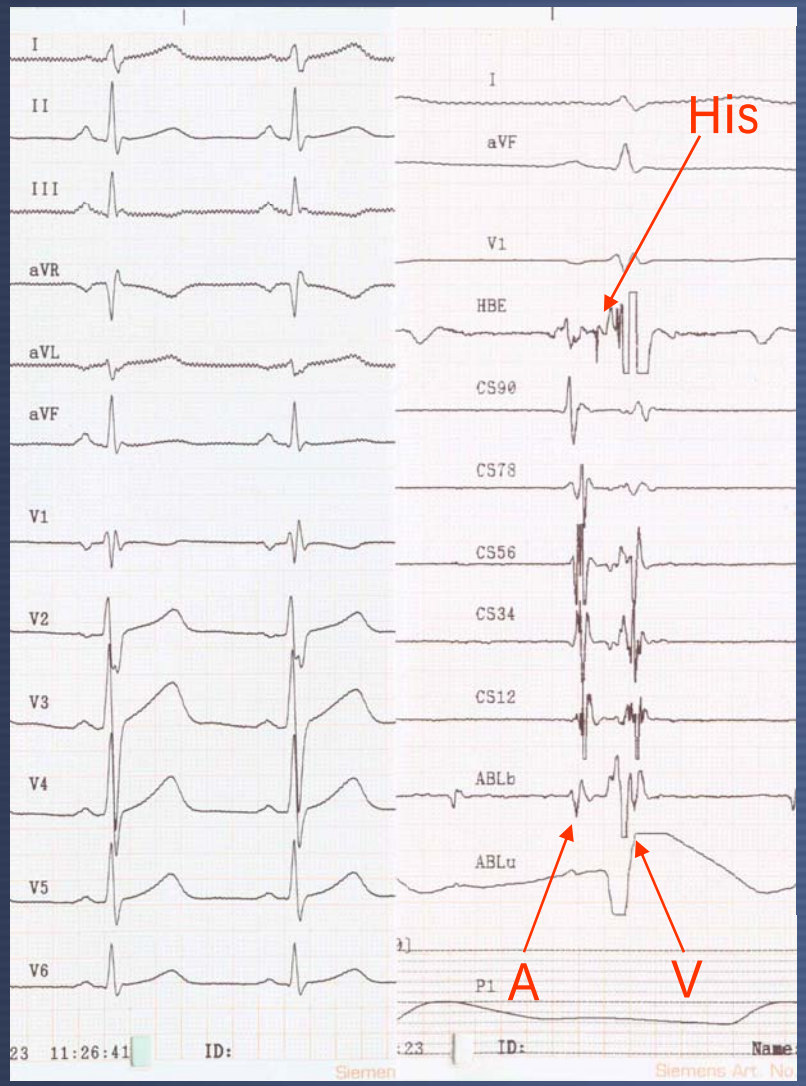
Catheter RF Ablation (left posterior AP)



Catheter RF Ablation (left posterior AP)



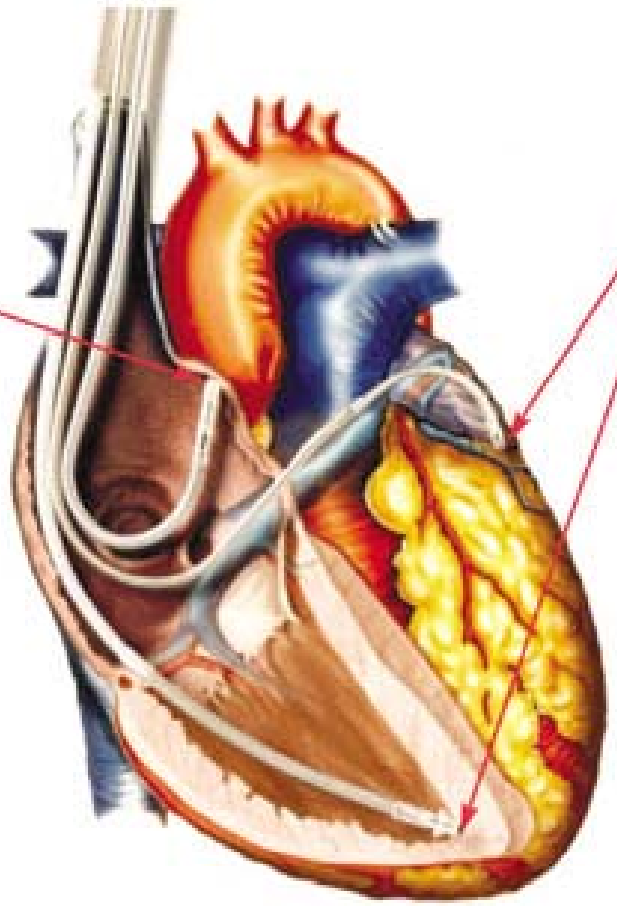
before



after

ICD's and pacemaker's

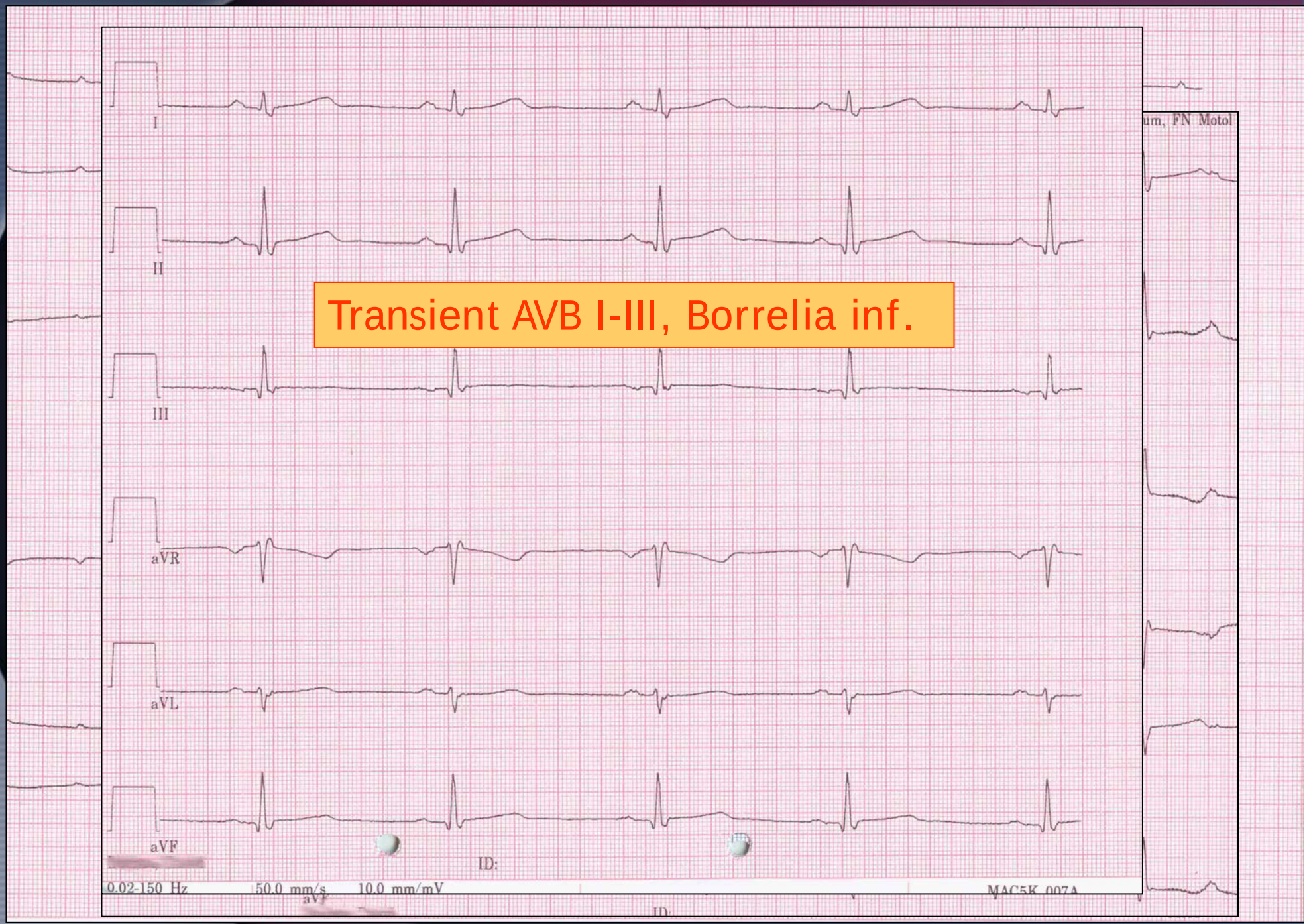
Therapies Provided by Today's Dual Chamber ICDs



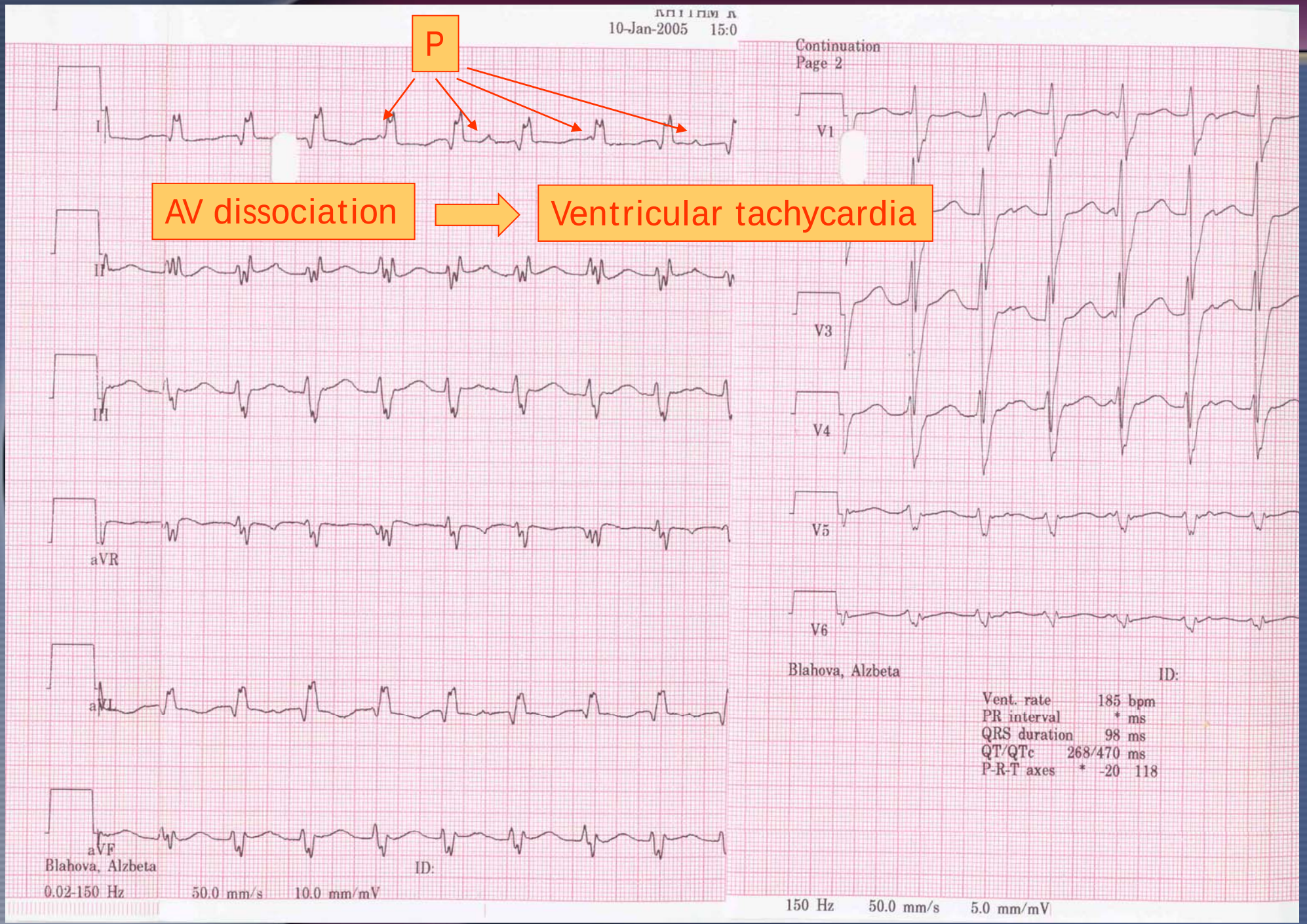
Atrium
- Bradycardia pacing/sensing
- Rate Response
- Antitachycardia pacing
- Cardioversion

Ventricle
- Ventricular arrhythmia therapies
- Antitachycardia pacing
- Cardioversion and defibrillation
- Bradycardia pacing/sensing
- Cardiac resynchronization for heart failure

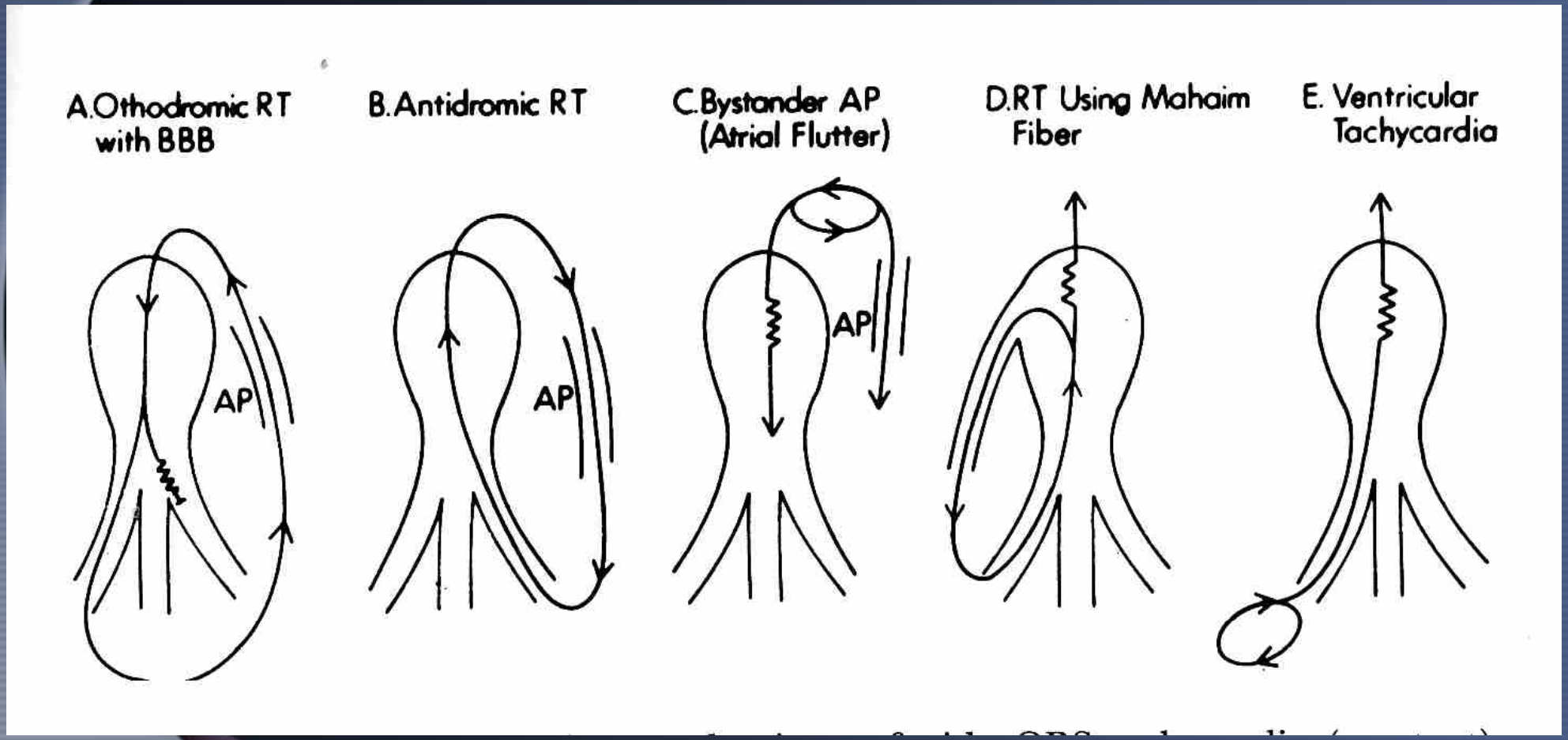
ECG's


I
II
III
aVR
aVL
aVF
ID:
0.02-150 Hz
50.0 mm/s
10.0 mm/mV
MAC5K 007A
Transient AVB I-III, Borrelia inf.

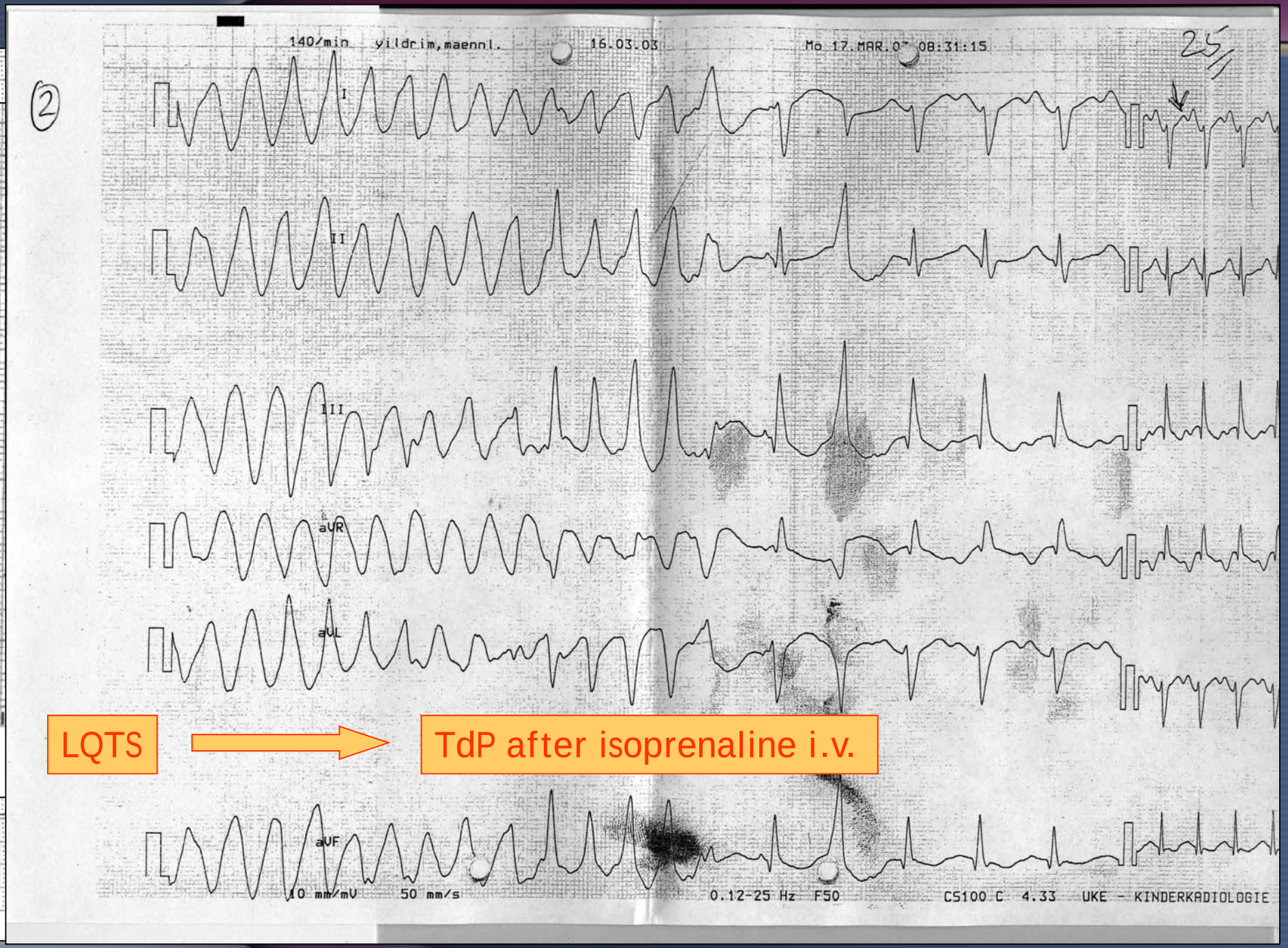
ECG's


10-Jan-2005 15:0
P
AV dissociation
Ventricular tachycardia
Continuation
Page 2
I
II
III
aVR
aVL
aVF
V1
V3
V4
V5
V6
Blahova, Alzbeta
ID:
Vent. rate 185 bpm
PR interval * ms
QRS duration 98 ms
QT/QTc 268/470 ms
P-R-T axes * -20 118
0.02-150 Hz 50.0 mm/s 10.0 mm/mV
150 Hz 50.0 mm/s 5.0 mm/mV

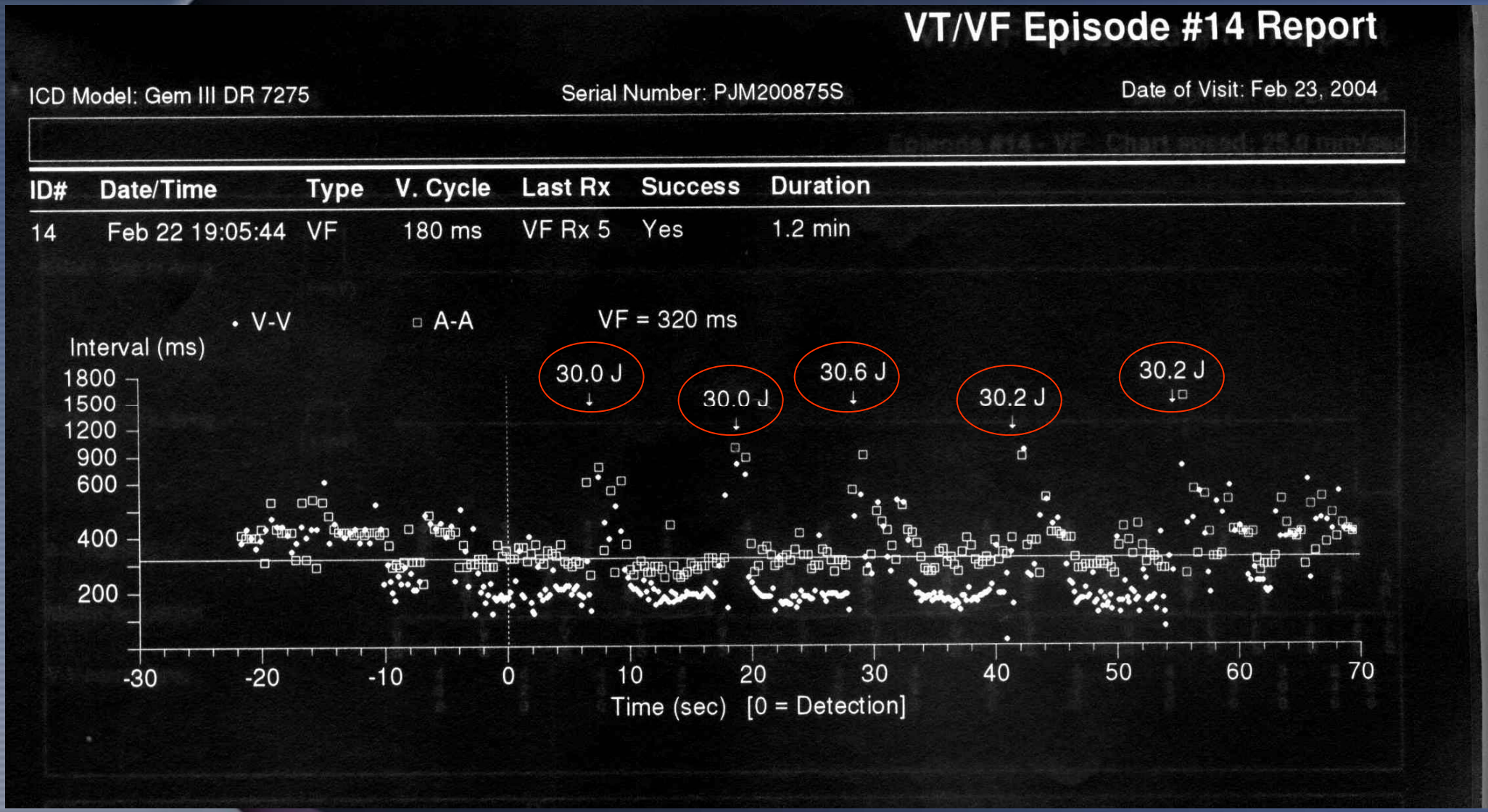
Mechanism of wide QRS complex tachycardia



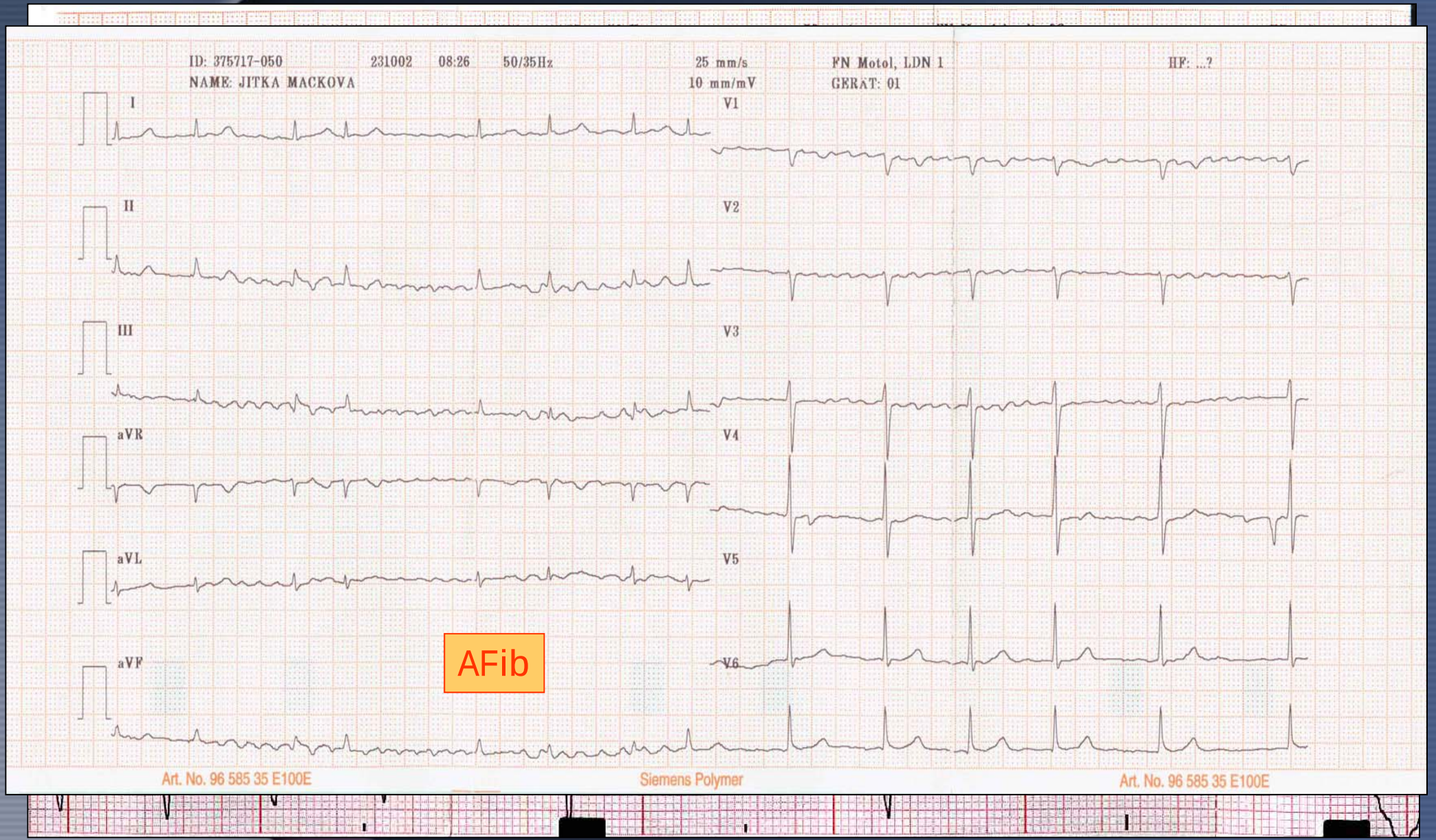
ECG's


140/min yildrim,maennl. 16.03.03 Mo 17.MAR.07 08:31:15
2
I
II
III
aVR
aVL
aVF
LQTS
TdP after isoprenaline i.v.
10 mm/mV 50 mm/s 0.12-25 Hz F50 CS100 C 4.33 UKE - KINDERKARDIOLOGIE

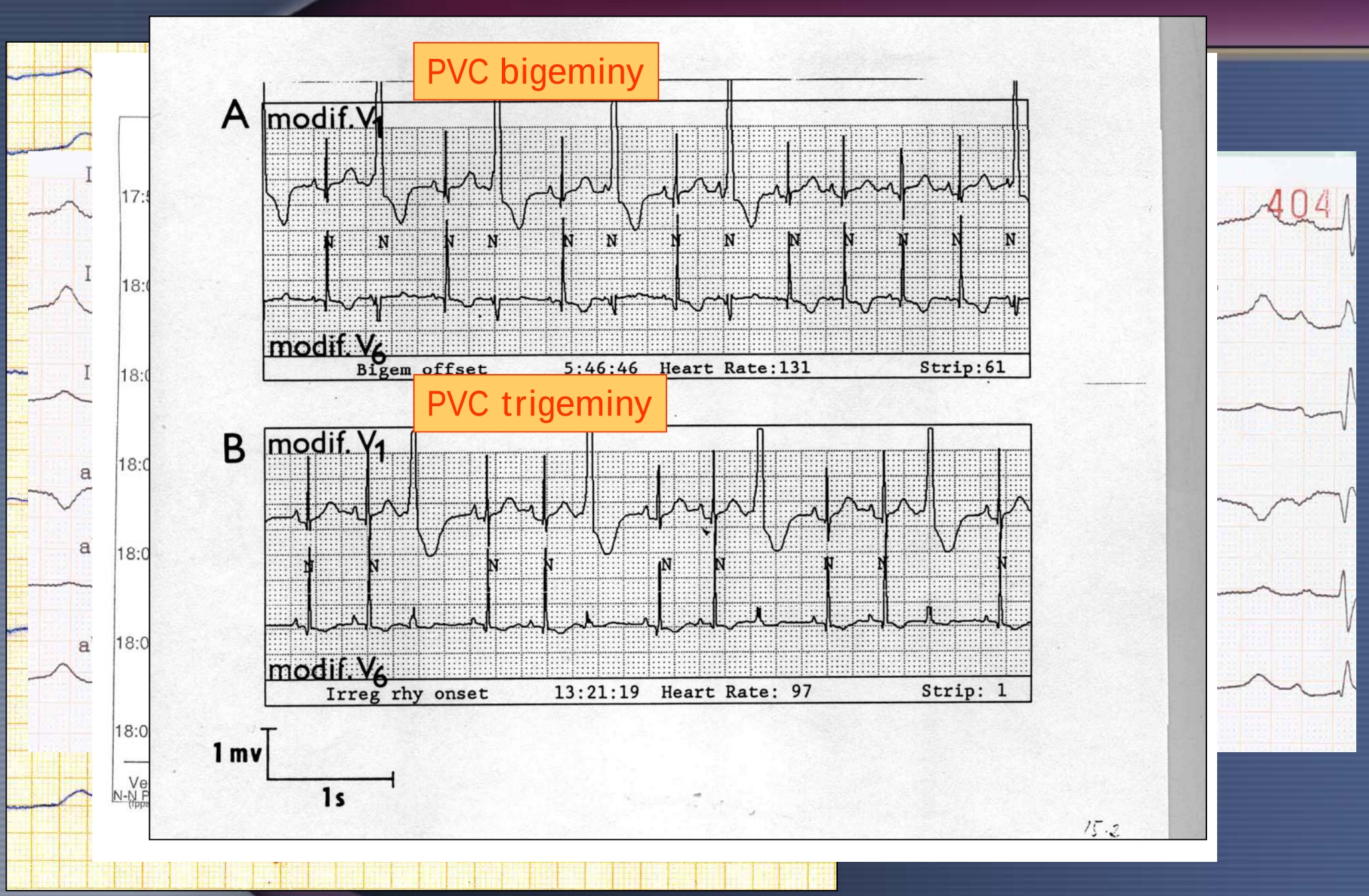
ICD


VT/VF Episode #14 Report
ICD Model: Gem III DR 7275
Serial Number: PJM200875S
Date of Visit: Feb 23, 2004
ID# Date/Time Type V. Cycle Last Rx Success Duration
14 Feb 22 19:05:44 VF 180 ms VF Rx 5 Yes 1.2 min
• V-V
□ A-A
VF = 320 ms
Interval (ms)
1800
1500
1200
900
600
400
200
30.0 J
30.0 J
30.6 J
30.2 J
30.2 J
-30
-20
-10
0
10
20
30
40
50
60
70
Time (sec) [0 = Detection]

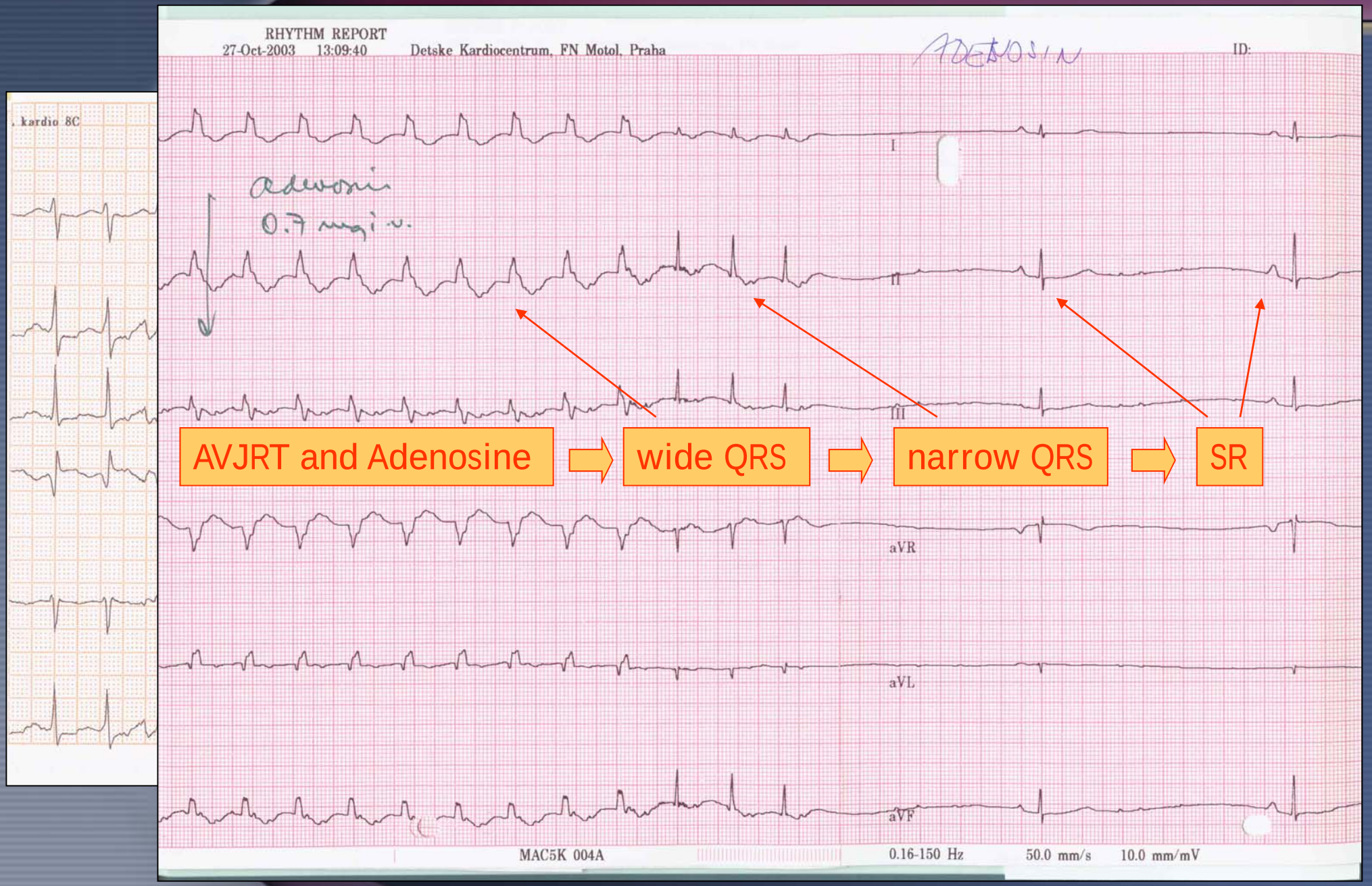
ECG's


ID: 375717-050
231002
08:26
50/35Hz
25 mm/s
10 mm/mV
FN Motol, LDN 1
GERÄT: 01
HF: ...?
NAME: JITKA MACKOVA
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
AFib
Art. No. 96 585 35 E100E
Siemens Polymer
Art. No. 96 585 35 E100E

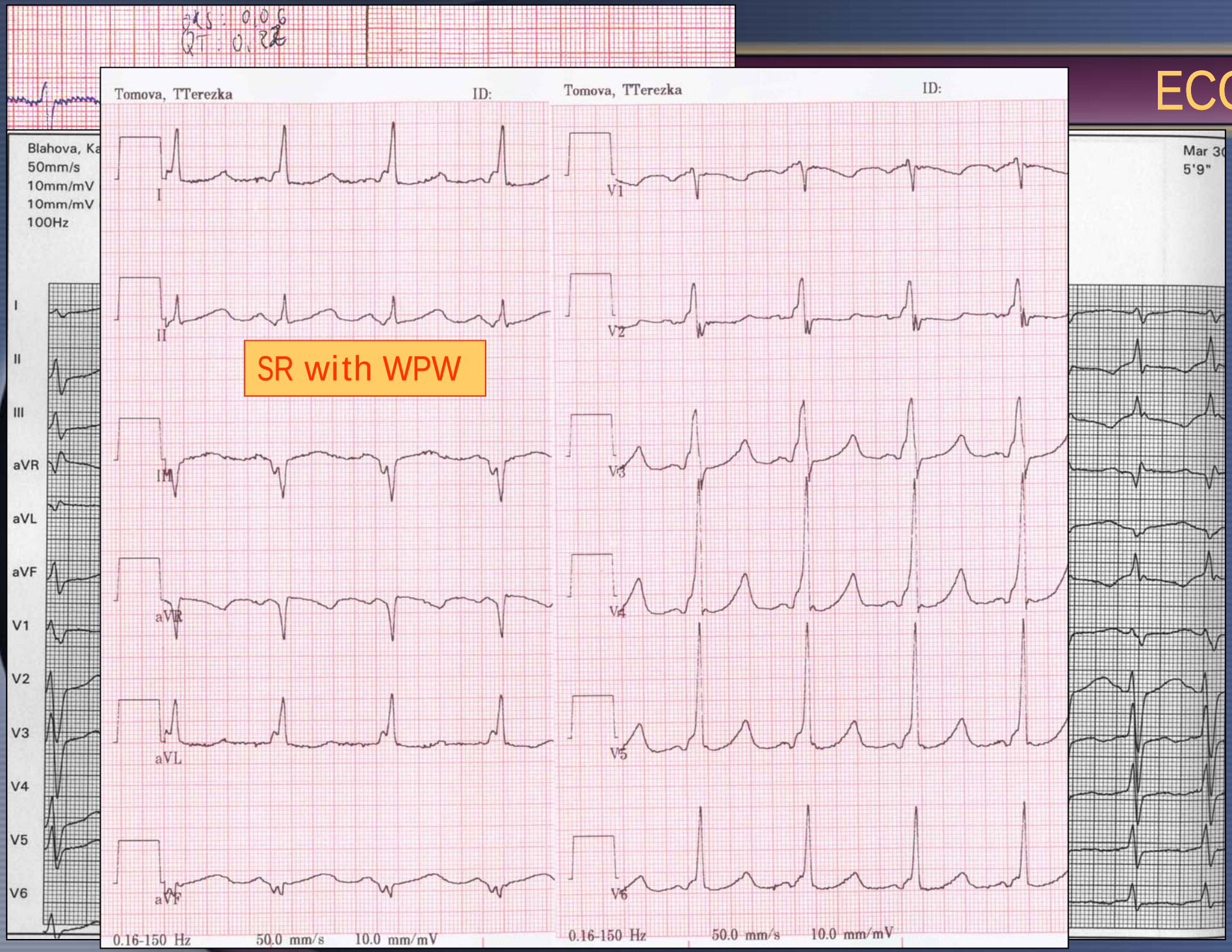
ECG's

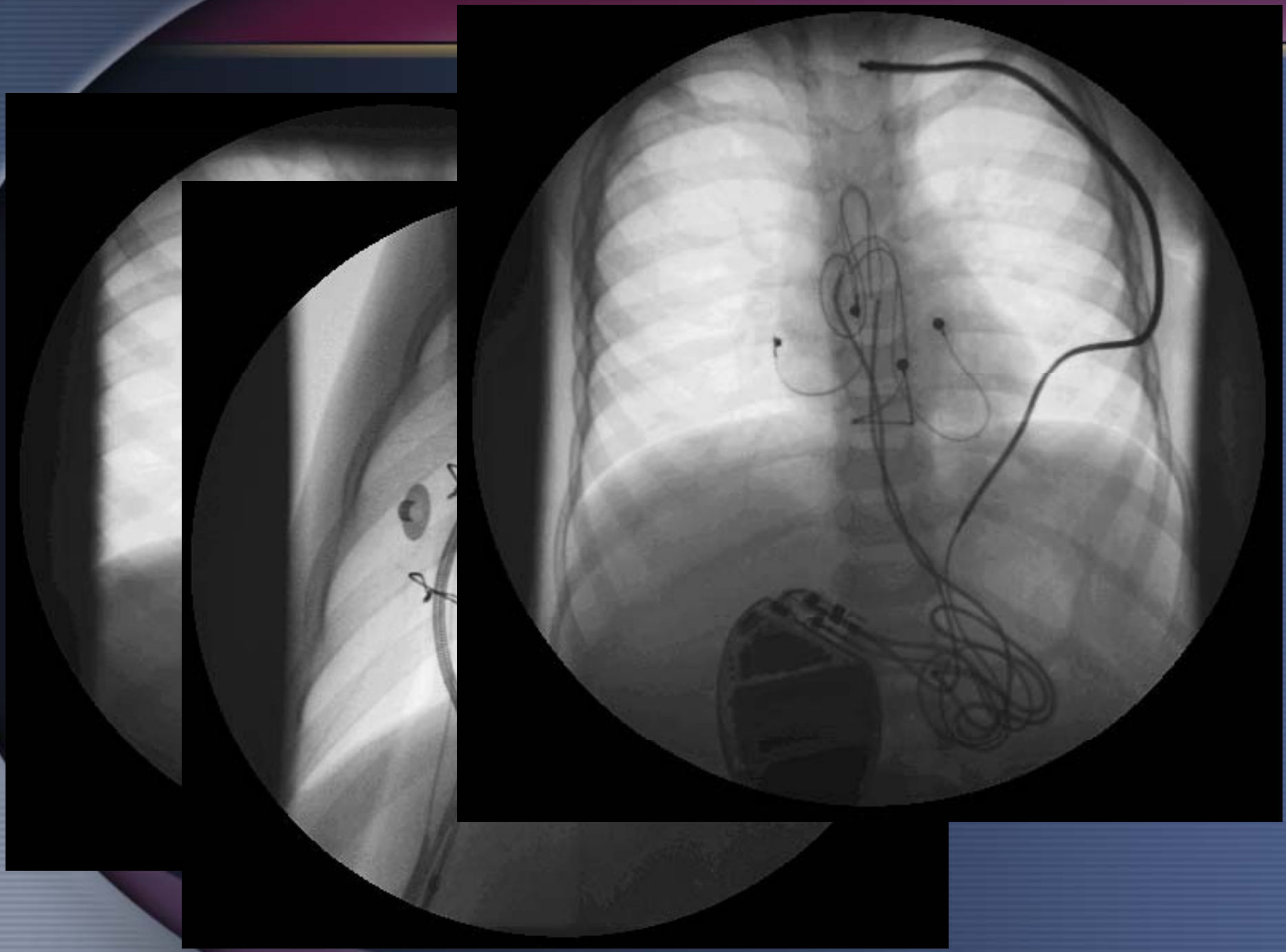

PVC bigeminy
A
modif. V1
N N N N N N N N N N N N N
modif. V6
Bigem offset 5:46:46 Heart Rate:131 Strip:61
PVC trigeminy
B
modif. V1
N N N N N N N N N
modif. V6
Irreg rhy onset 13:21:19 Heart Rate: 97 Strip: 1
1 mv
1s

ECG's


RHYTHM REPORT
27-Oct-2003 13:09:40
Detske Kardiocentrum, FN Motol, Praha
ID:
kardio 8C
Adenosin
0.7 mg i.v.
I
II
III
aVR
aVL
aVF
AVJRT and Adenosine
wide QRS
narrow QRS
SR
MAC5K 004A
0.16-150 Hz
50.0 mm/s
10.0 mm/mV

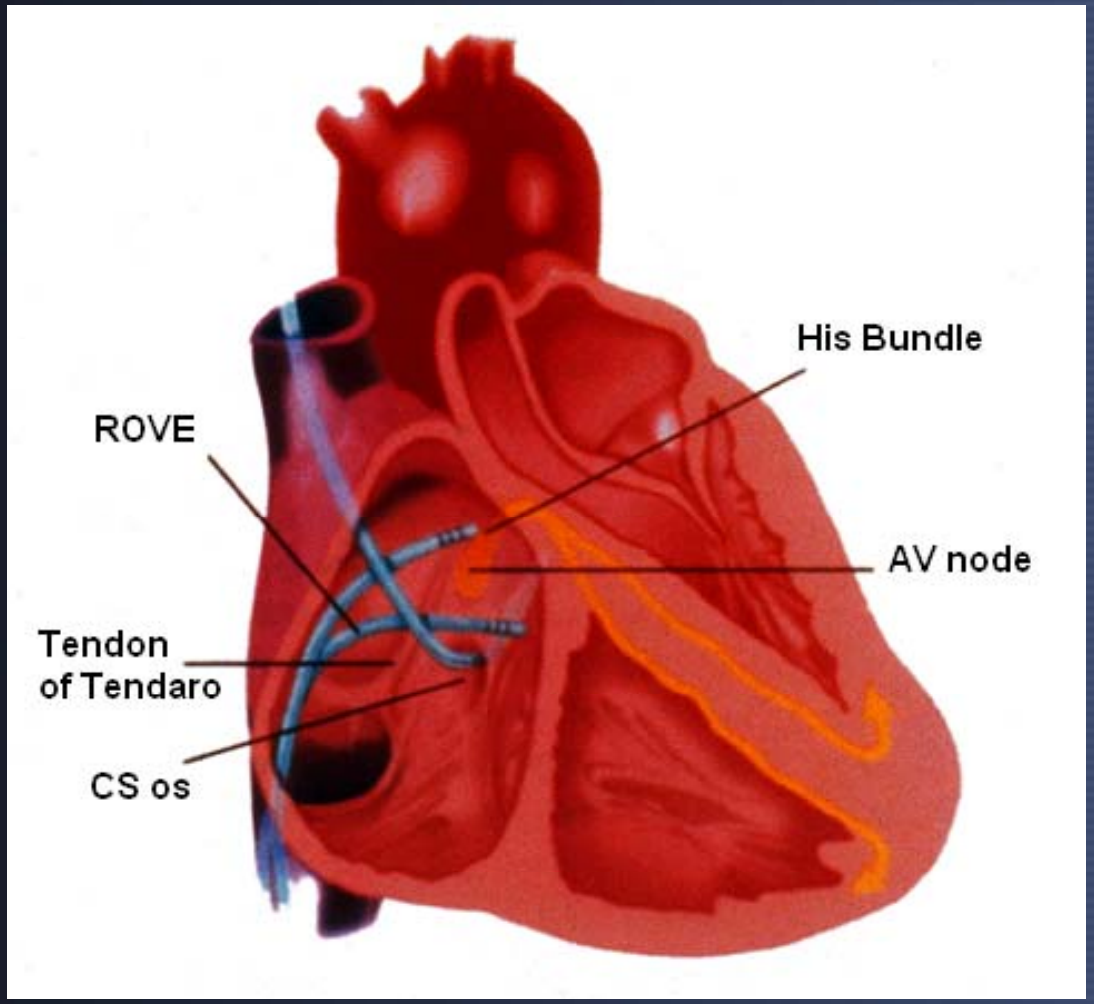
ECG's


Tomova, TTerezka
ID:
Tomova, TTerezka
ID:
SR with WPW
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
0.16-150 Hz
50.0 mm/s
10.0 mm/mV
0.16-150 Hz
50.0 mm/s
10.0 mm/mV
Blahova, Ka
50mm/s
10mm/mV
10mm/mV
100Hz
Mar 3
5'9"



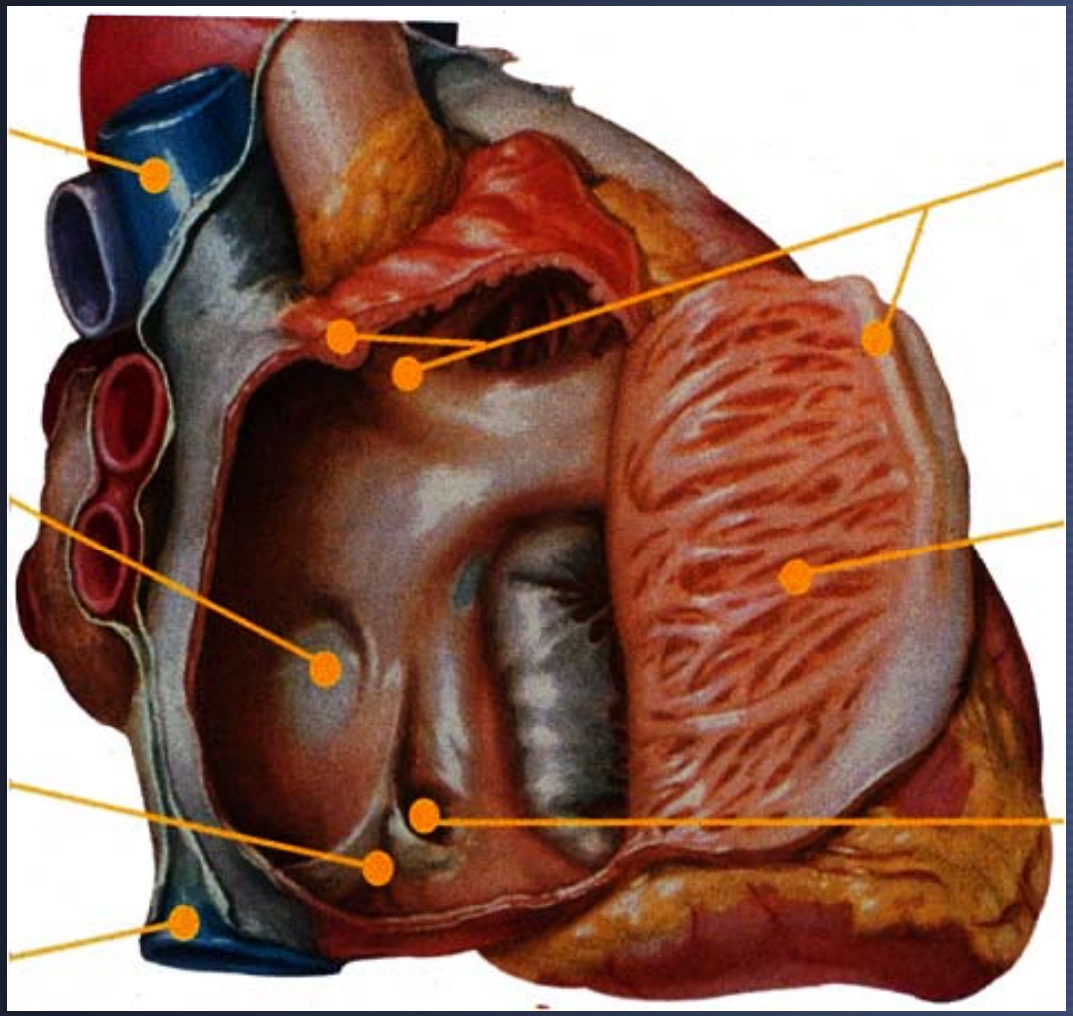
Thank you for your attention!

Site of Slow Pathway Ablation



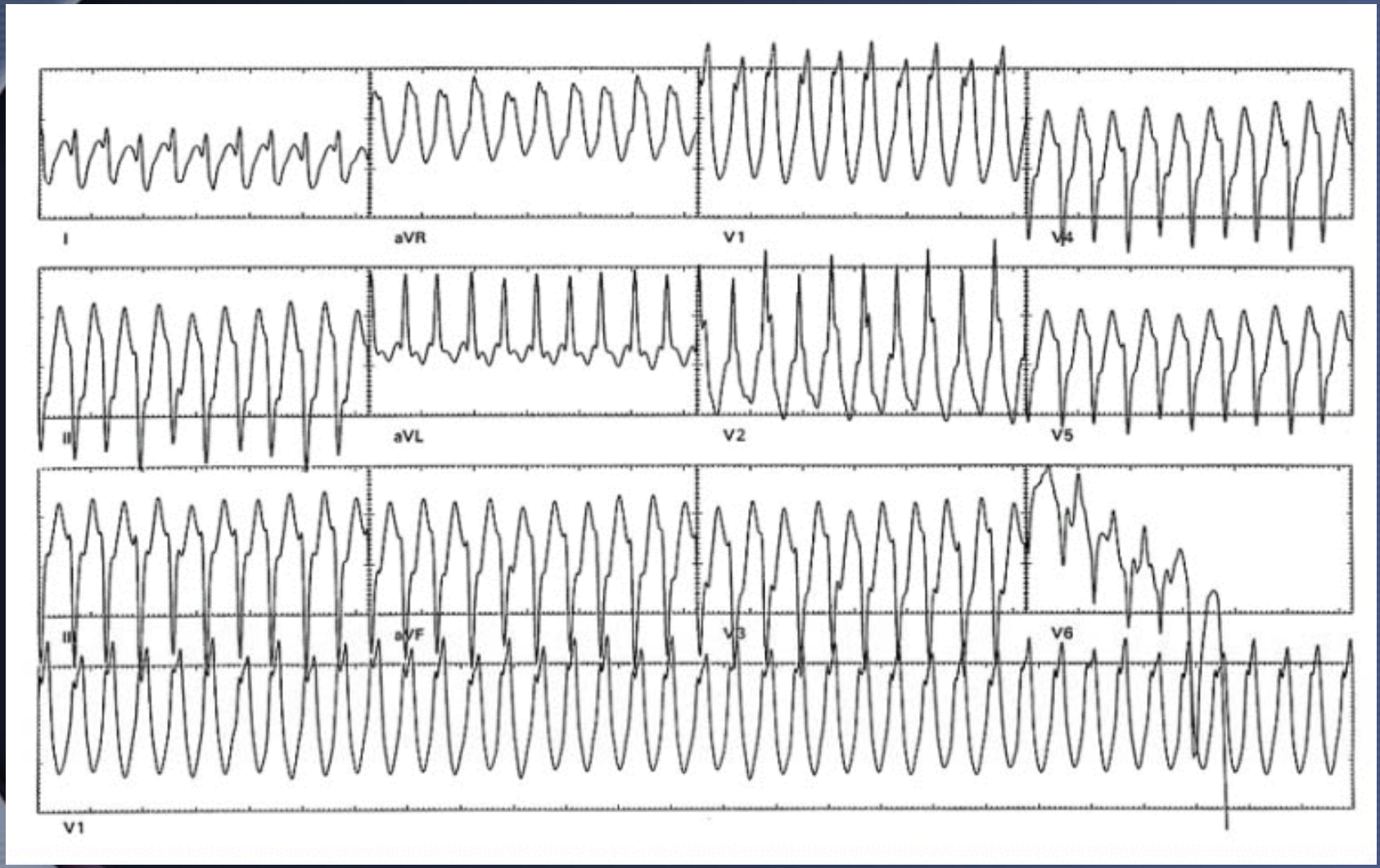
Source: Scheinman, M.M. Emerging Technologies in Antiarrhythmic Therapy; Creative Medical Communications, Inc., NY 1992: 1-33.

Oblique View of Right Atrium



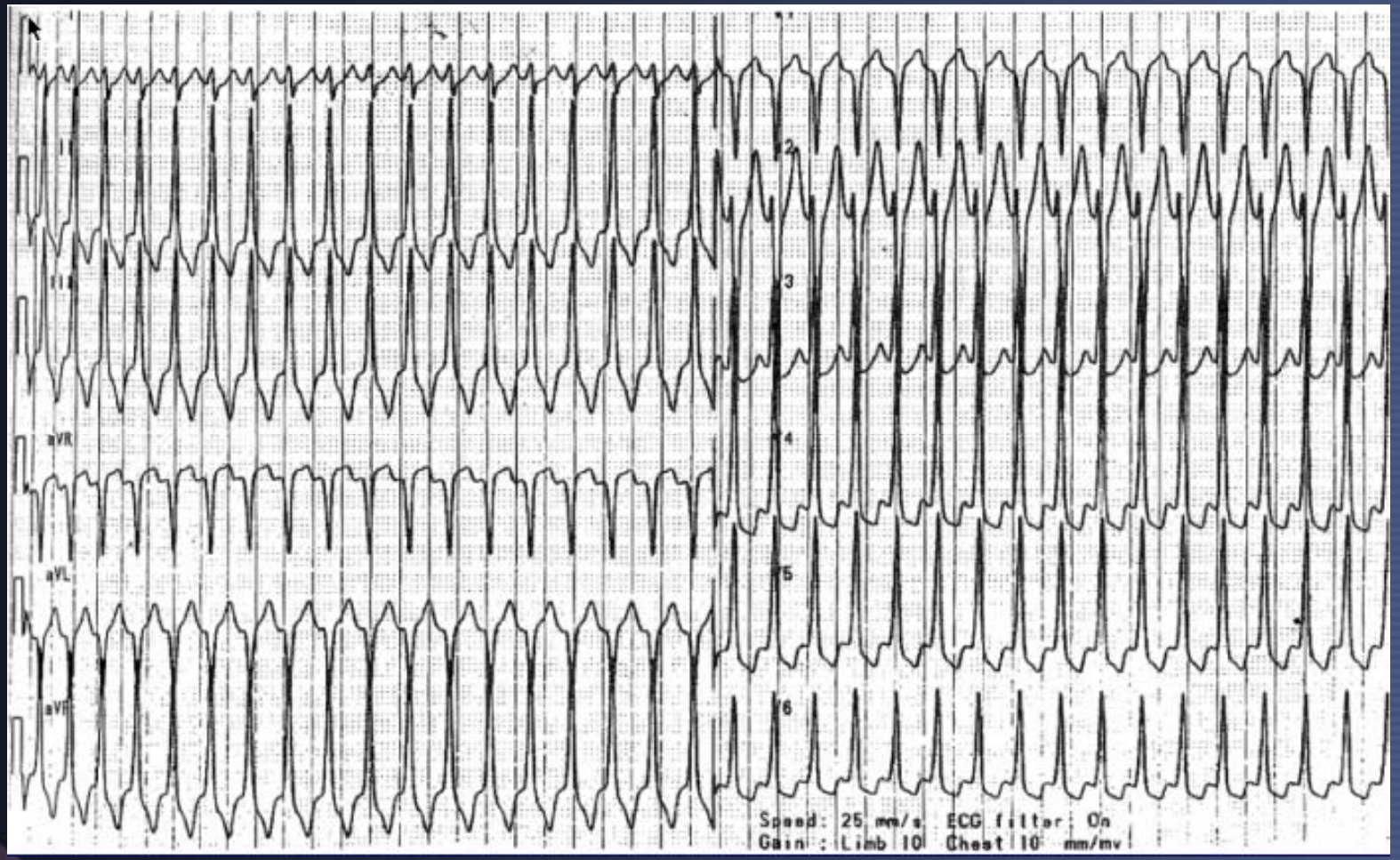
Netter F. Atlas of Human Anatomy. 1989;Plate 208.

WPW: Case Study ECG



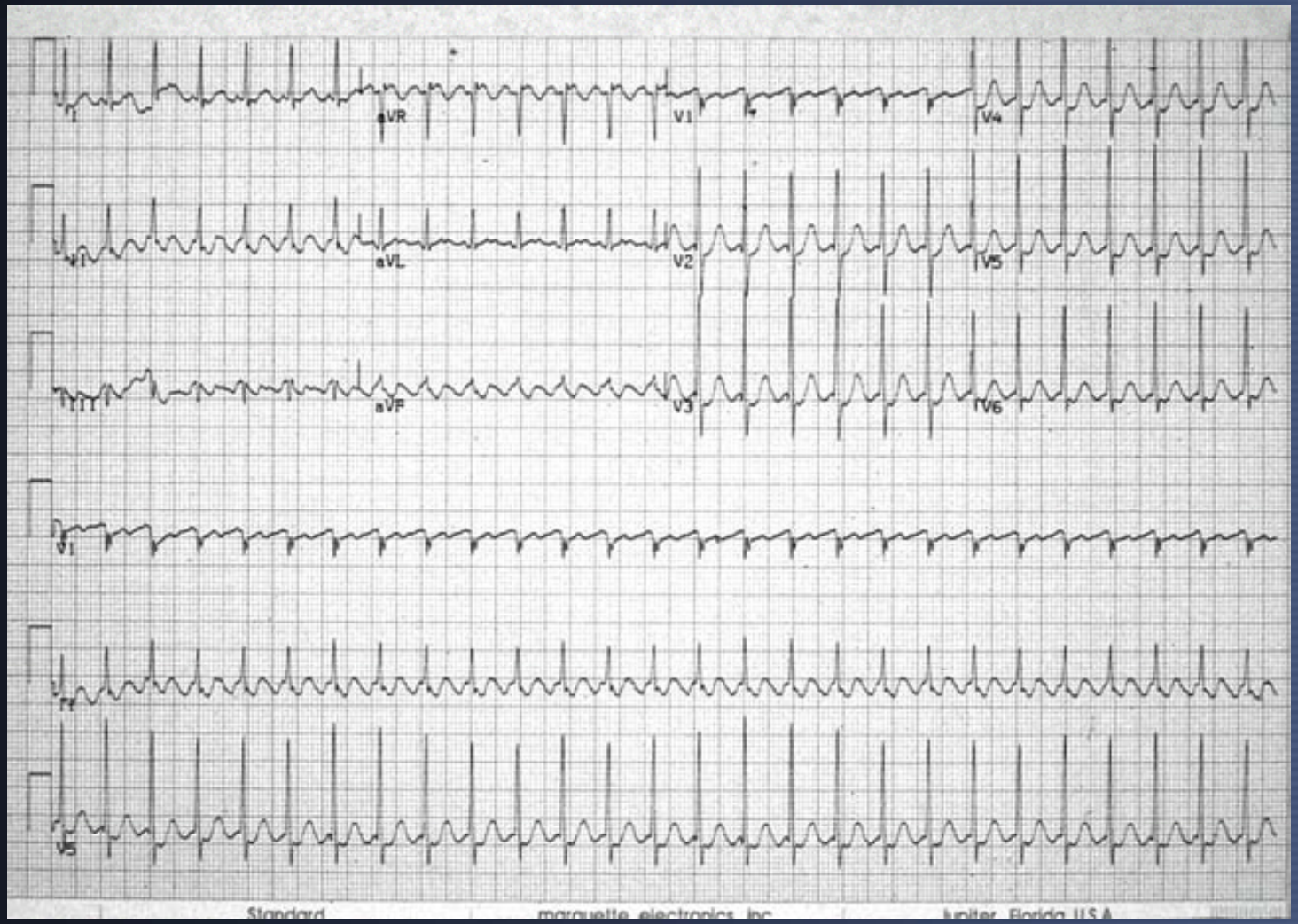
Courtesy of Dr. Brian Olshansky.

Orthodromic Reciprocating Tachycardia



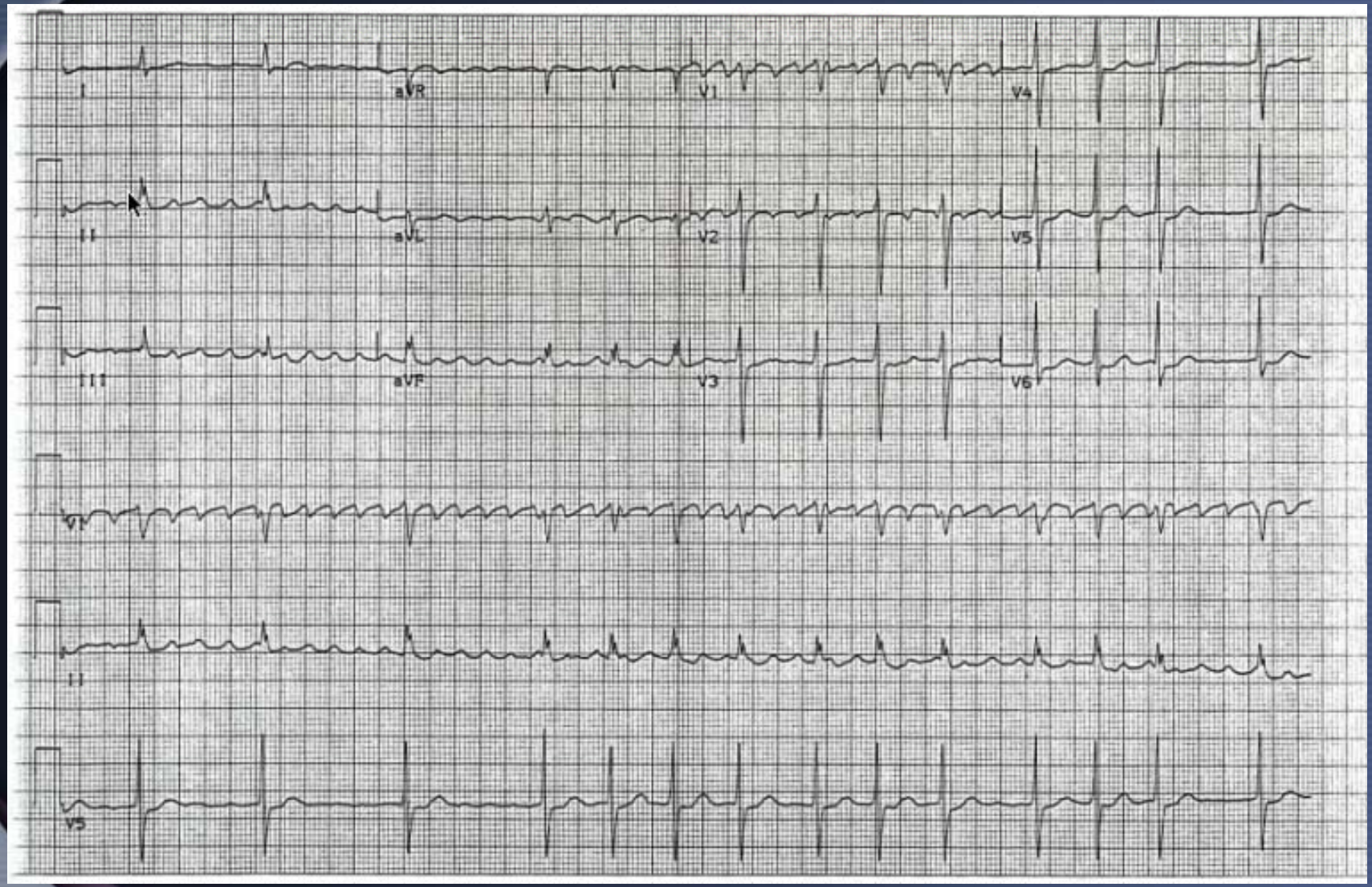
Kay NG. Am J of Med. 1996;10:344-356.

Counterclockwise Atrial Flutter



Courtesy of Dr. Brian Olshansky.

Clockwise Atrial Flutter



Courtesy of Dr. Brian Olshansky.