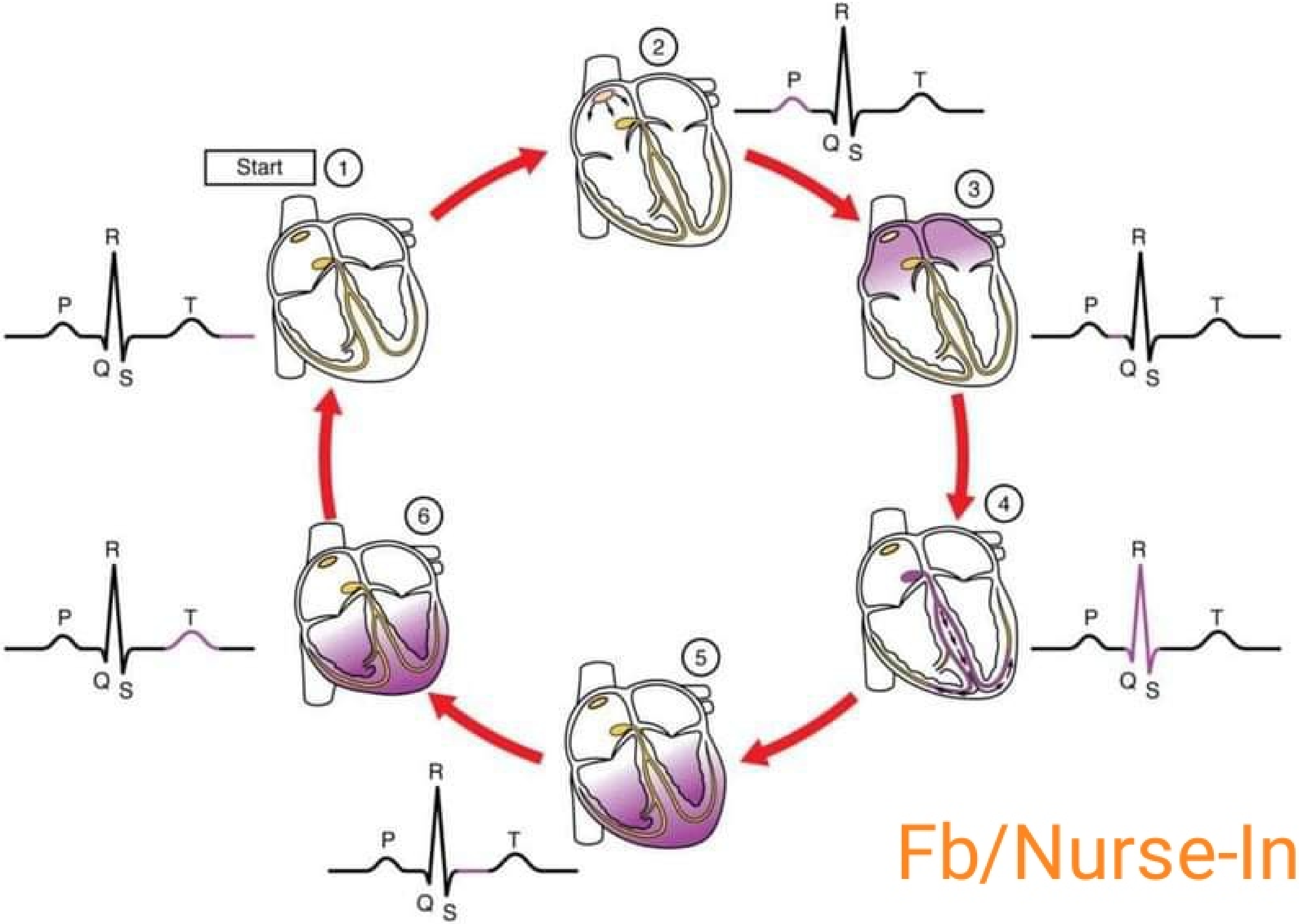
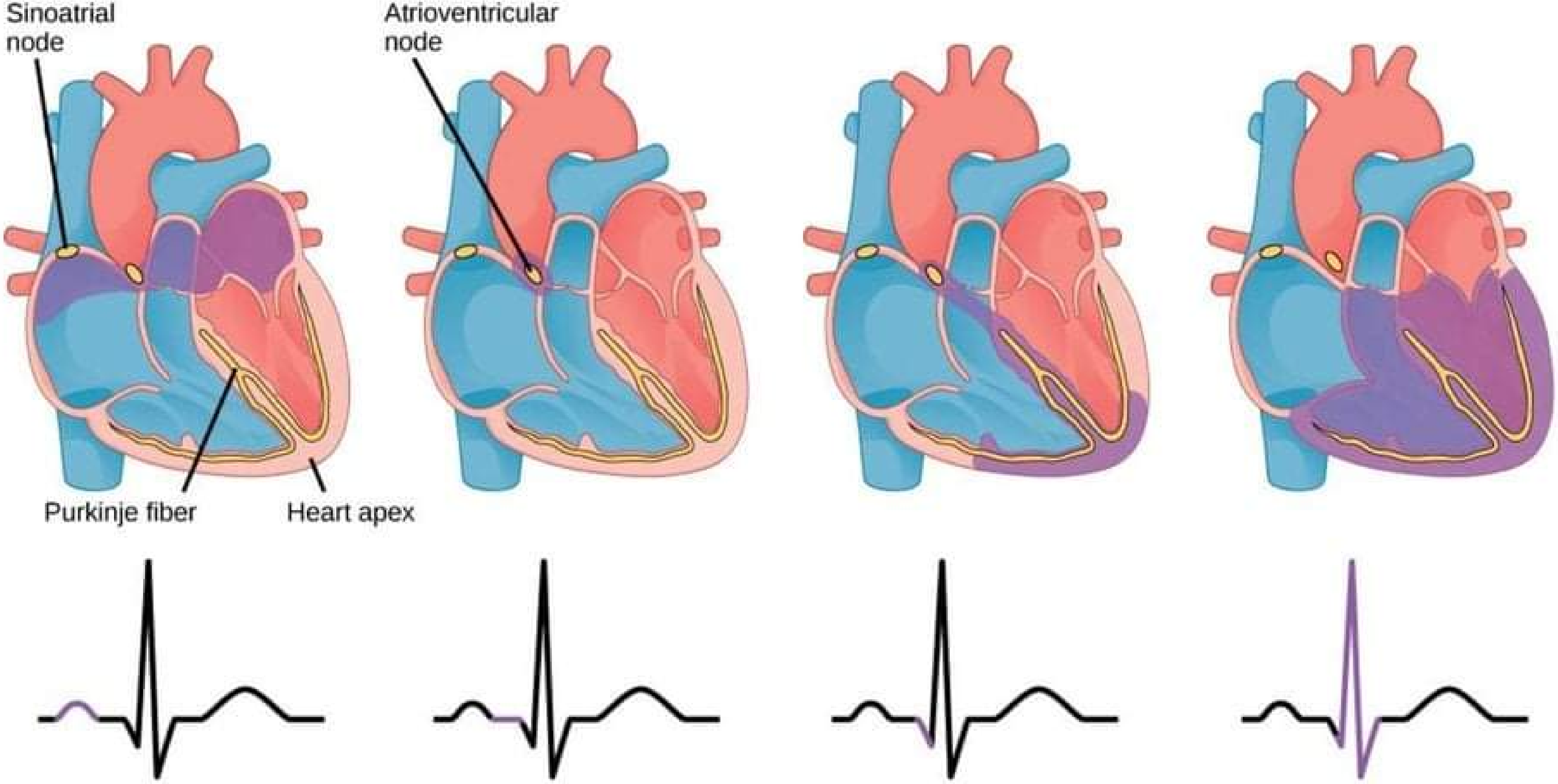
The cardiac cycle and ECG

Fb/Nurse-Info



Fb/Nurse-Info



(a) An electrical impulse travels from the sinoatrial node to the walls of the atria, causing them to contract.

(b) The impulse reaches the atrioventricular node, which delays it by about 0.1 second.

(c) Bundle branches carry signals from the atrioventricular node to the heart apex.

(d) The signal spreads through the ventricle walls, causing them to contract.

Cardiac cycle

Your heart beats around **70 times a minute**. The cardiac cycle is the sequence of events which makes up one heart beat.

Three stages in this cycle.

- **Atrial systole**
- **Ventricular systole**
- **Ventricular diastole**

Atrial systole

The heart is filled with blood and the muscle in the **atrial walls contracts.** This stage is called **atrial systole.**

The pressure developed by this contraction is not very great, because the muscular walls of the atria are only thin, but it is enough to force the blood in the atria down through the atrioventricular valves into the ventricles. The blood from the atria does not go back into the pulmonary veins or the venae cavae, because these have semilunar valves to prevent backflow.

Ventricular systole

About 0.1 seconds after the **atria contract**, the **ventricles contract**. This is called **ventricular systole**.

The thick, **muscular walls of the ventricles squeeze inwards on the blood, increasing its pressure** and **pushing it out of the heart**. As soon as the **pressure in the ventricles** becomes greater than the pressure in the atria, this pressure difference pushes the **atrioventricular valves shut**, preventing blood from going back into the atria.

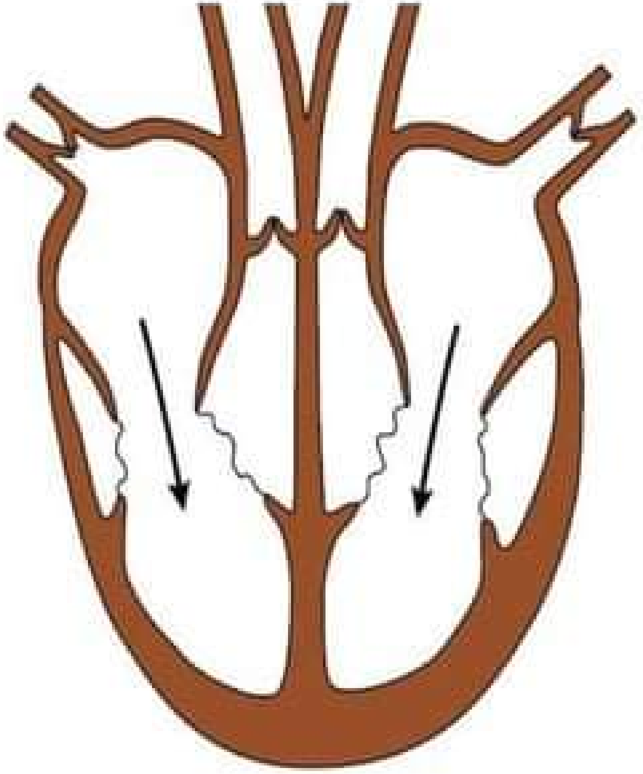
Instead, the **blood rushes upwards into the aorta** and the **pulmonary artery**, pushing open the semilunar valves in these vessels as it does so.

Ventricular diastole

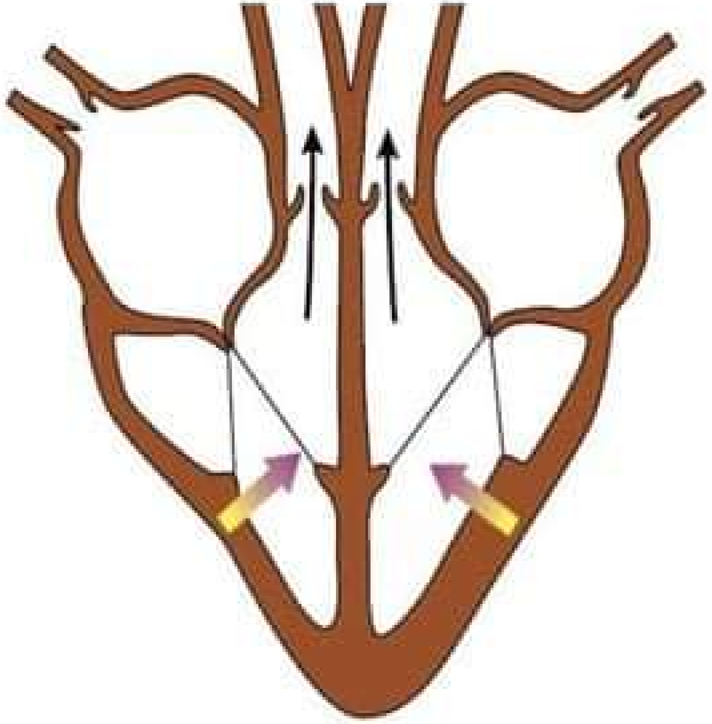
Ventricular systole lasts for about 0.3 seconds. The **muscle then relaxes**, and the stage called **ventricular diastole** begins.

As the **muscle relaxes**, the **pressure in the ventricles drops**. The high-pressure blood which has just been pushed into the arteries would flow back into the ventricles but for the presence of the semilunar valves, which snap shut as the blood fills their cusps.

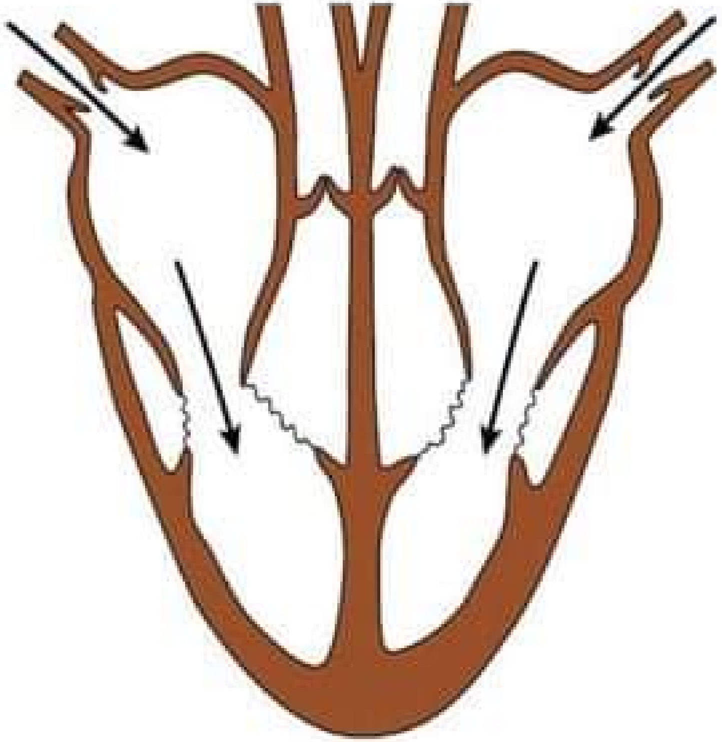
During diastole, as the whole of the **heart muscle relaxes**, **blood from the veins flows into the two atria**. The **blood** is at **a very low pressure**, but the thin walls of the atria are easily distended, providing very little resistance to the blood flow.



1 **Atrial systole.** Both atria contract. Blood flows from the atria into the ventricles. Backflow of blood into the veins is prevented by closure of the valves in the veins.



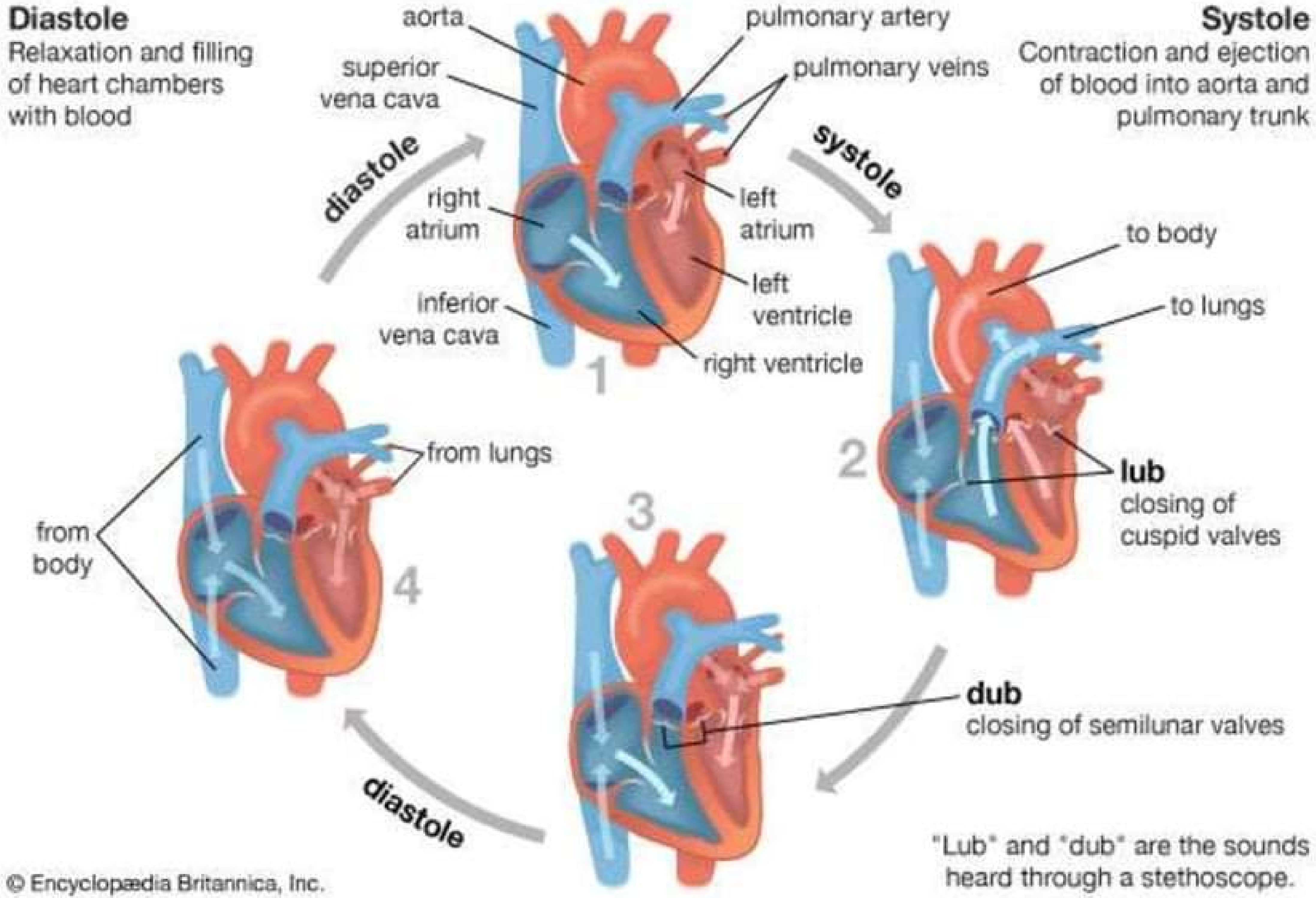
2 **Ventricular systole.** Both ventricles contract. The atrioventricular valves are pushed shut by the pressurised blood in the ventricles. The semilunar valves in the aorta and pulmonary artery are pushed open. Blood flows from the ventricles into the arteries.

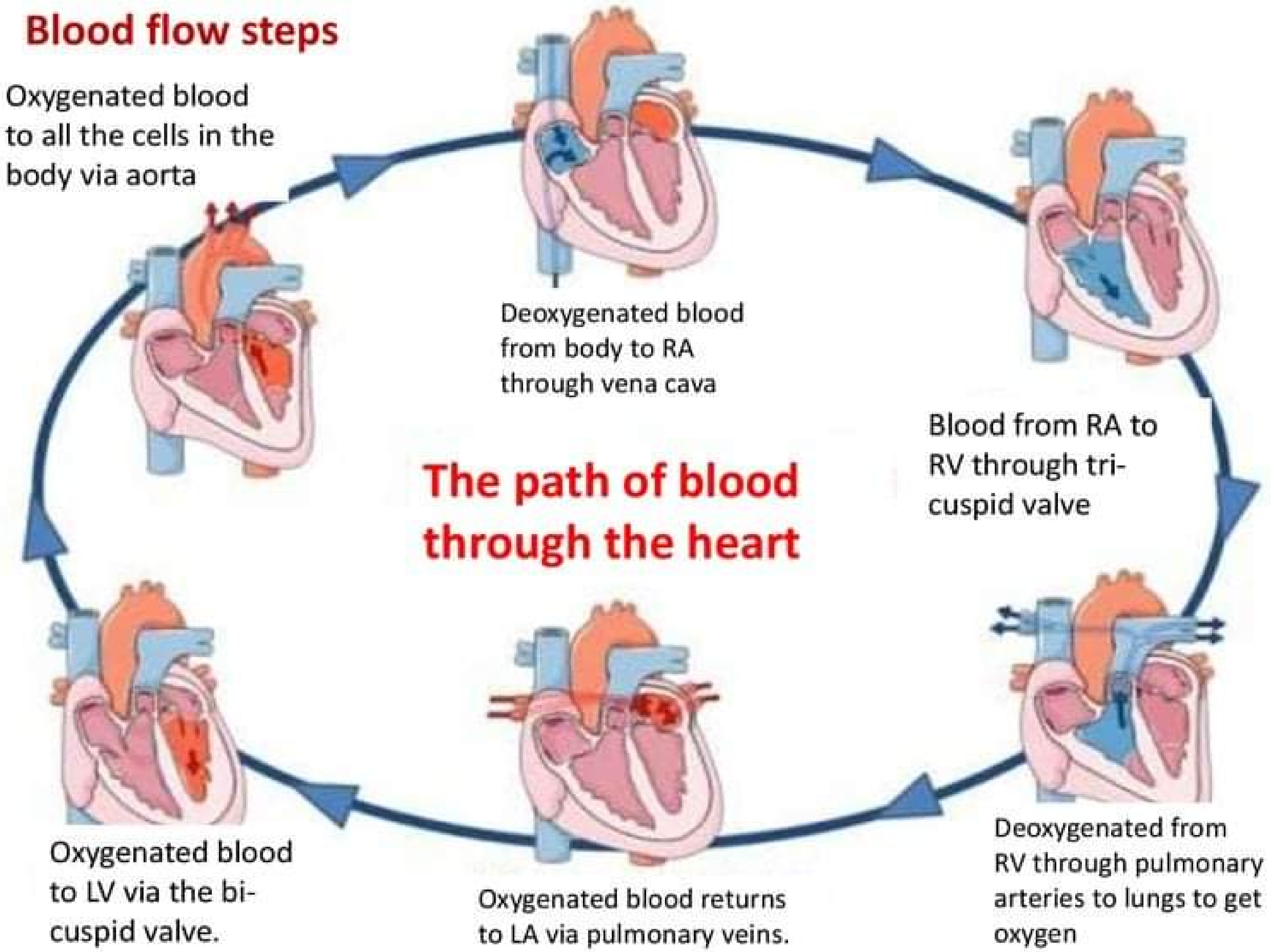


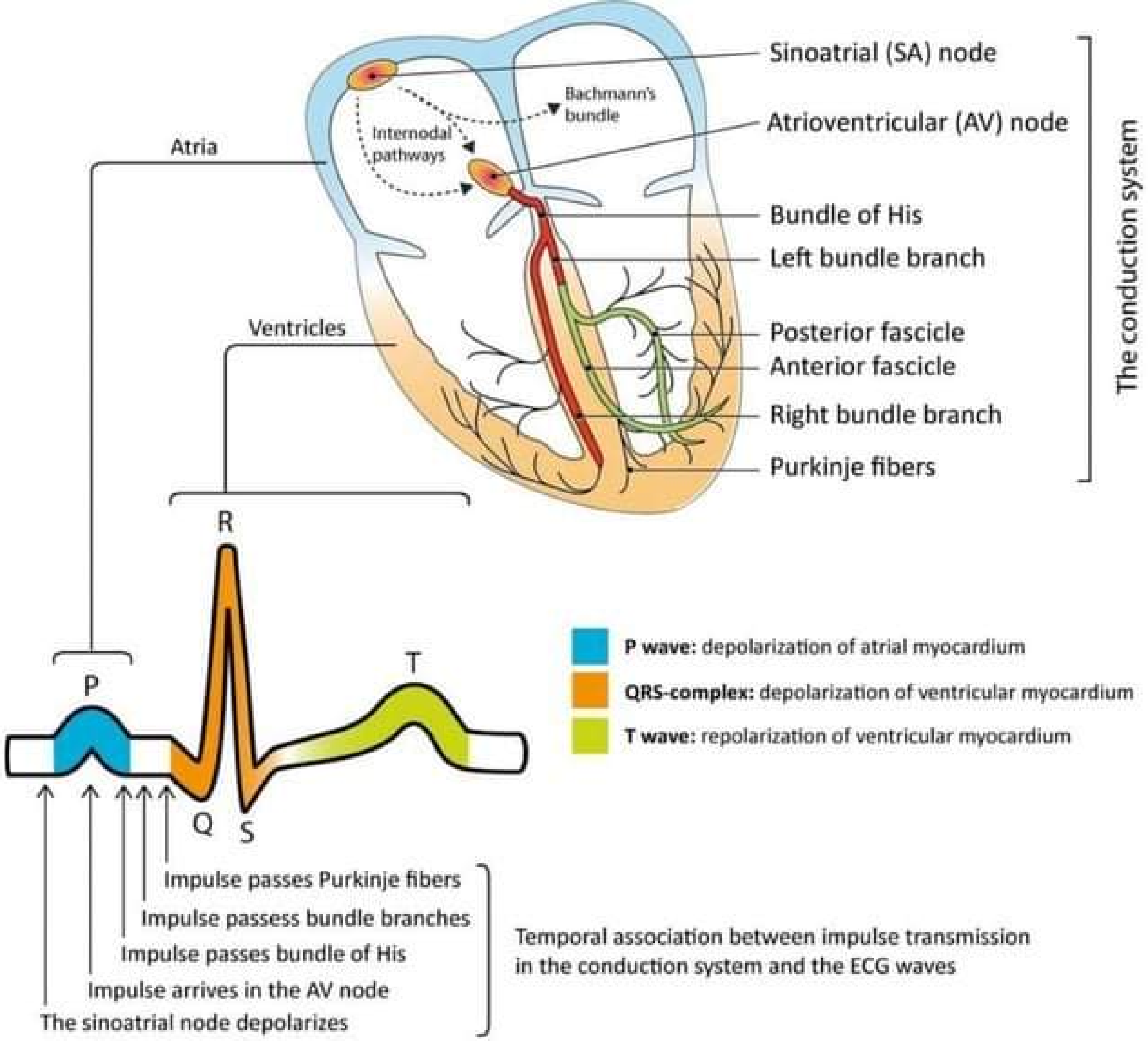
3 **Ventricular diastole.** Atria and ventricles relax. The semilunar valves in the aorta and pulmonary artery are pushed shut. Blood flows from the veins through the atria and into the ventricles.

pressure exerted by contraction of muscle

movement of blood


Diastole
Relaxation and filling of heart chambers with blood
Systole
Contraction and ejection of blood into aorta and pulmonary trunk
aorta
superior vena cava
pulmonary artery
pulmonary veins
diastole
systole
right atrium
left atrium
left ventricle
inferior vena cava
right ventricle
1
to body
to lungs
2
lub
closing of cuspid valves
from lungs
from body
4
3
dub
closing of semilunar valves
diastole
"Lub" and "dub" are the sounds heard through a stethoscope.


Blood flow steps
Oxygenated blood to all the cells in the body via aorta
Deoxygenated blood from body to RA through vena cava
Blood from RA to RV through tri-cuspid valve
The path of blood through the heart
Deoxygenated from RV through pulmonary arteries to lungs to get oxygen
Oxygenated blood returns to LA via pulmonary veins.
Oxygenated blood to LV via the bi-cuspid valve.



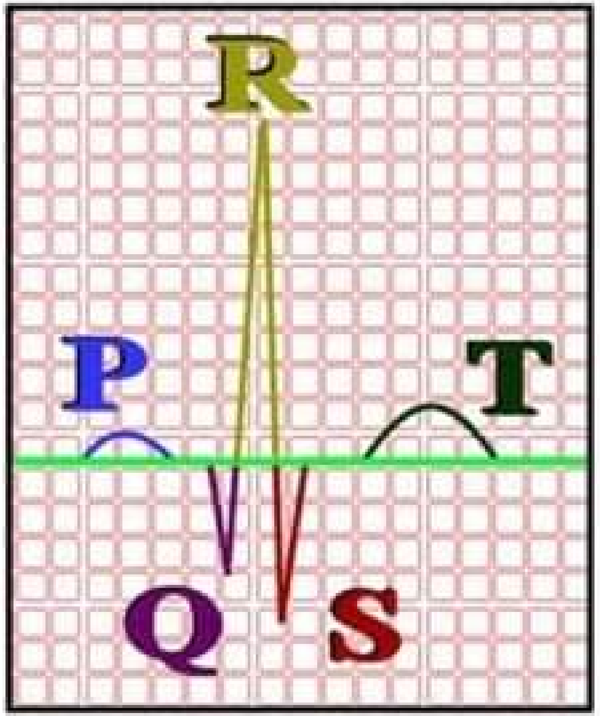
Sinoatrial (SA) node
Bachmann's bundle
Atrioventricular (AV) node
Internodal pathways
Atria
Bundle of His
Left bundle branch
Posterior fascicle
Ventricles
Anterior fascicle
Right bundle branch
Purkinje fibers
The conduction system
R
P
T
Q
S
P wave: depolarization of atrial myocardium
QRS-complex: depolarization of ventricular myocardium
T wave: repolarization of ventricular myocardium
Impulse passes Purkinje fibers
Impulse passess bundle branches
Impulse passes bundle of His
Impulse arrives in the AV node
The sinoatrial node depolarizes
Temporal association between impulse transmission in the conduction system and the ECG waves

Electrocardiograms (ECGs)

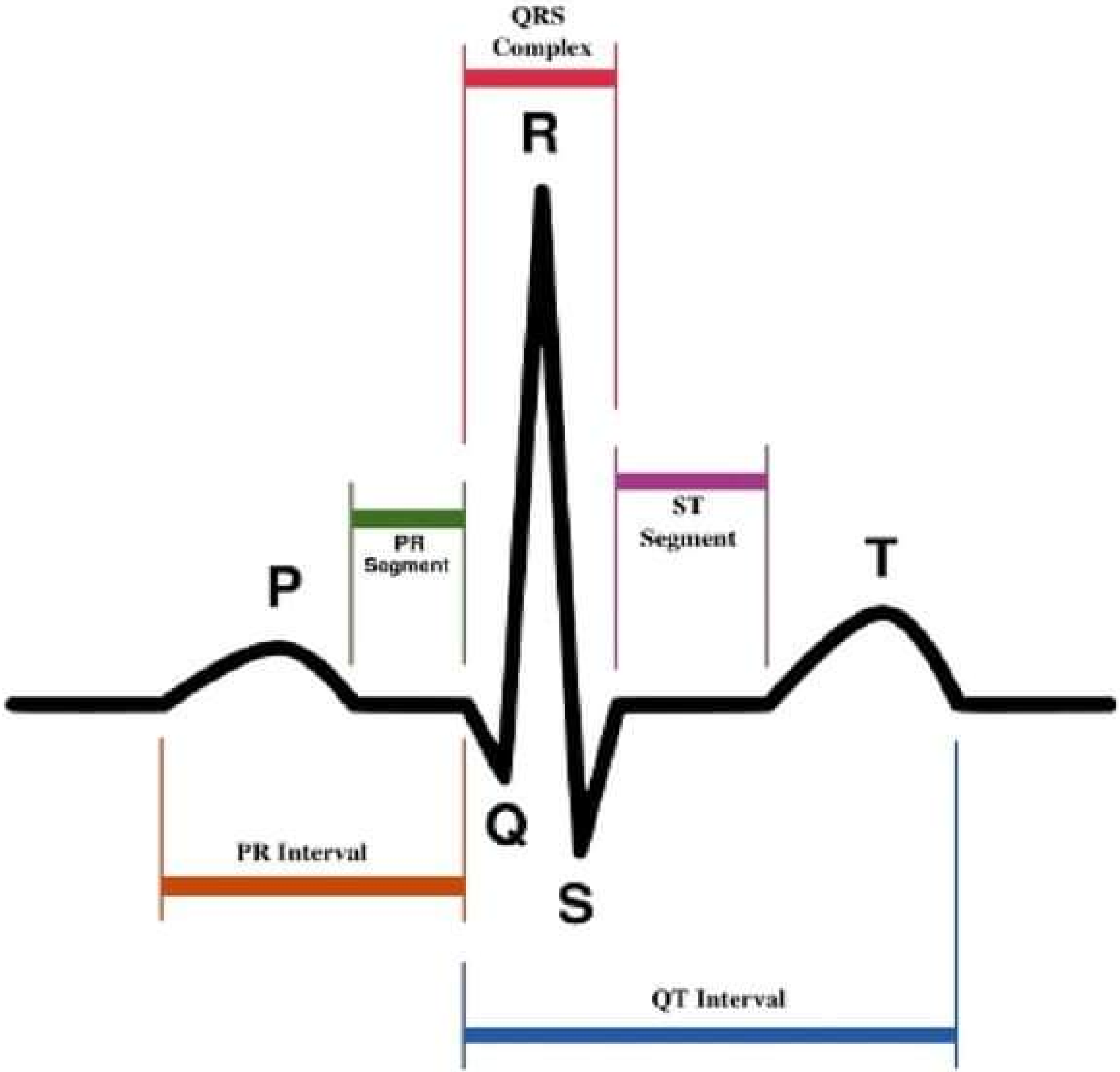
It is relatively easy to detect and record the waves of excitation flowing through heart muscle. Electrodes can be placed on the skin over opposite sides of the heart, and the **electrical potentials generated recorded with time.** The result, which is **essentially a graph of voltage against time, is an electrocardiogram (ECG)**. The part labelled **P** represents the wave of e**xcitation** sweeping over the **atrial walls**. The parts labelled **Q, R and S** represent the wave of **excitation in the ventricle walls.** The **T** section indicates the **recovery of the ventricle walls.**

<u>ECG – electrocardiogram</u> – a recording of the electrical events (changes) during a cardiac cycle

- <u>P Wave</u> – depolarization of the atria (atrial contraction – systole)
- <u>QRS Complex</u> – depolarization of the ventricles (ventricular contraction, systole)
- <u>T Wave</u> – Repolarization of the ventricles



<u>Heart Sounds</u> – opening and closing of the valves, flow of blood into and out of the chambers, vibrations in muscle

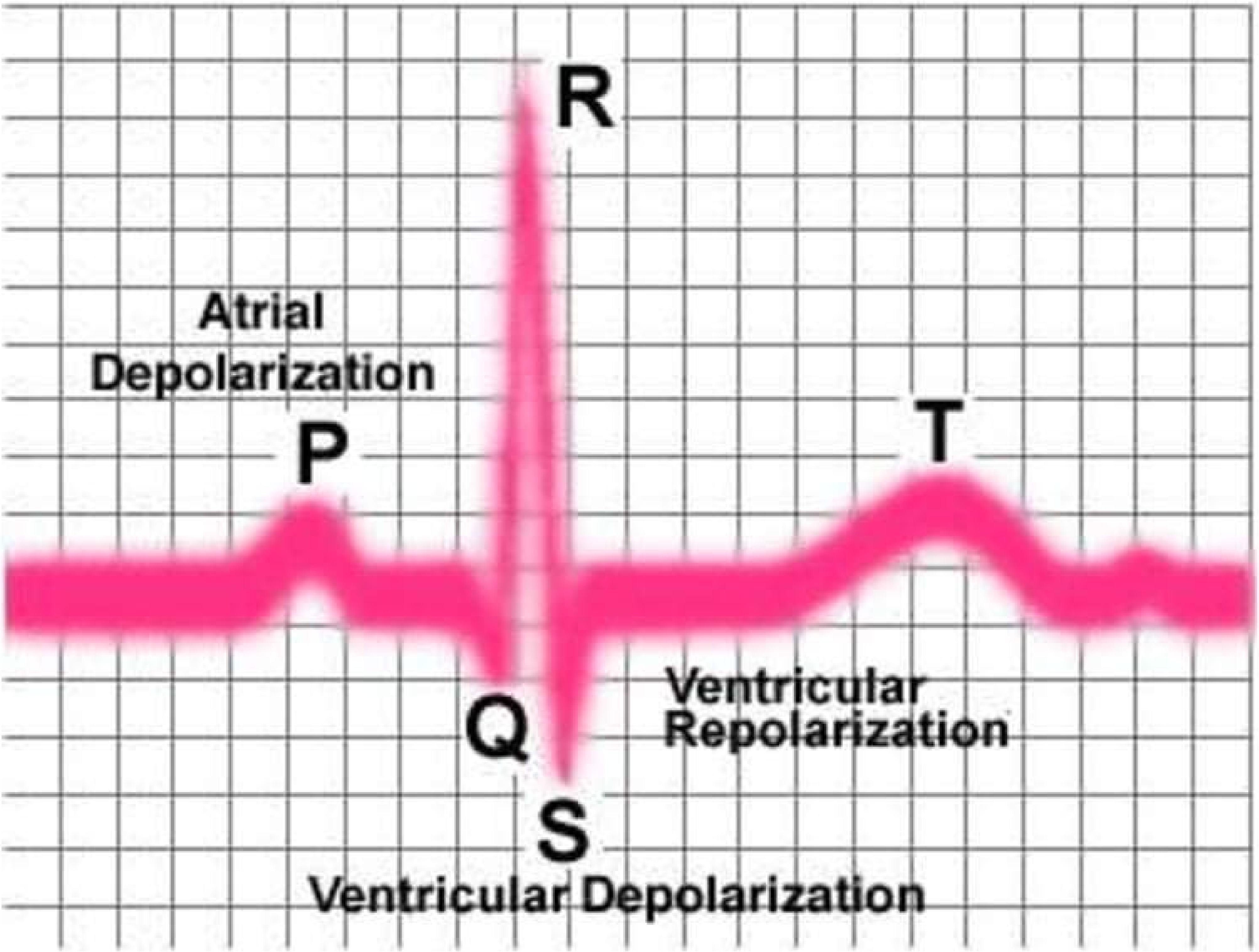


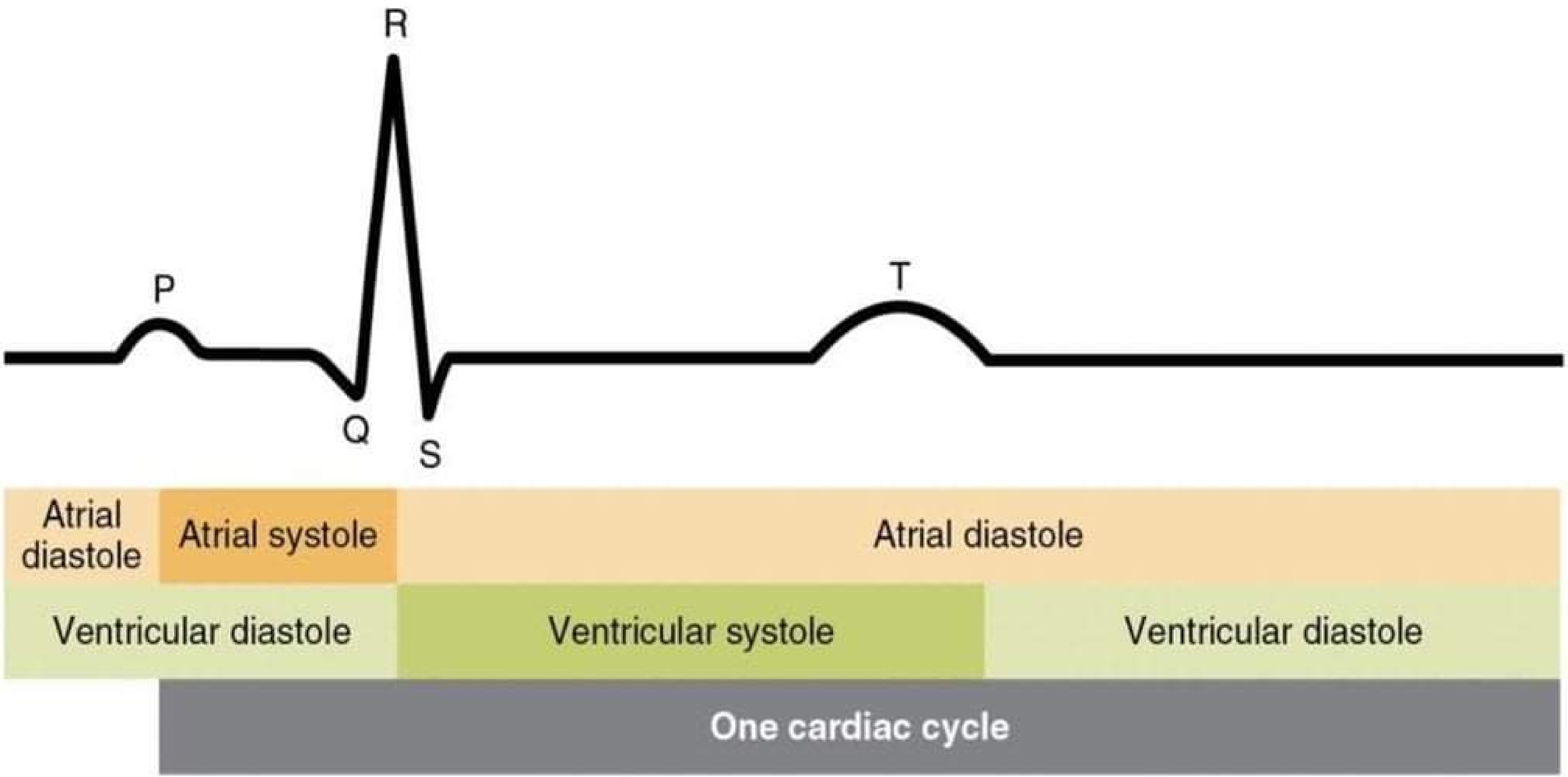
ECG teeth

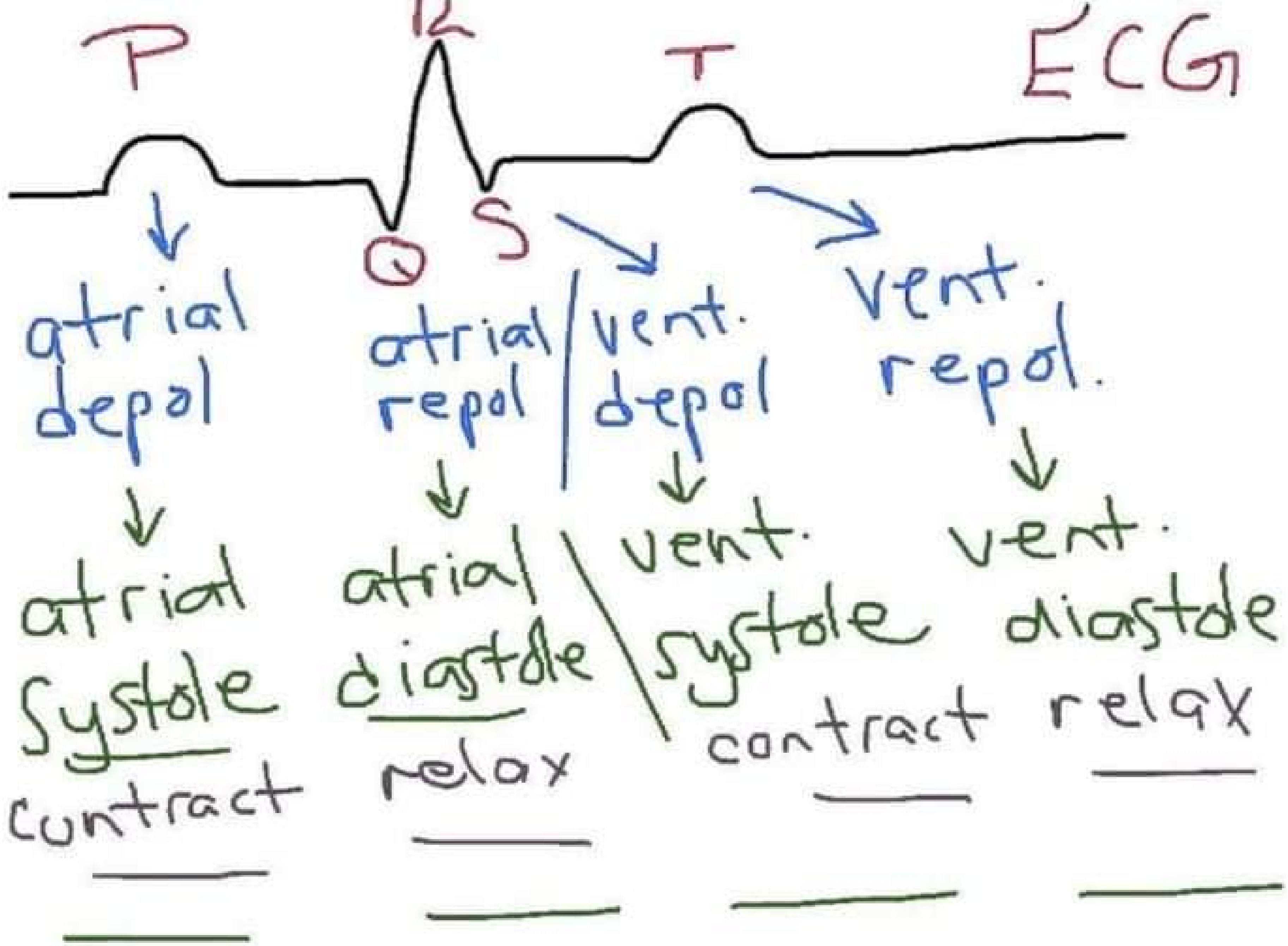
P- the sinoatrial node despoliation, impulse arrive in the AV node and impulse passes buddle of His

QRS complex - depolarization of ventricular myocardium

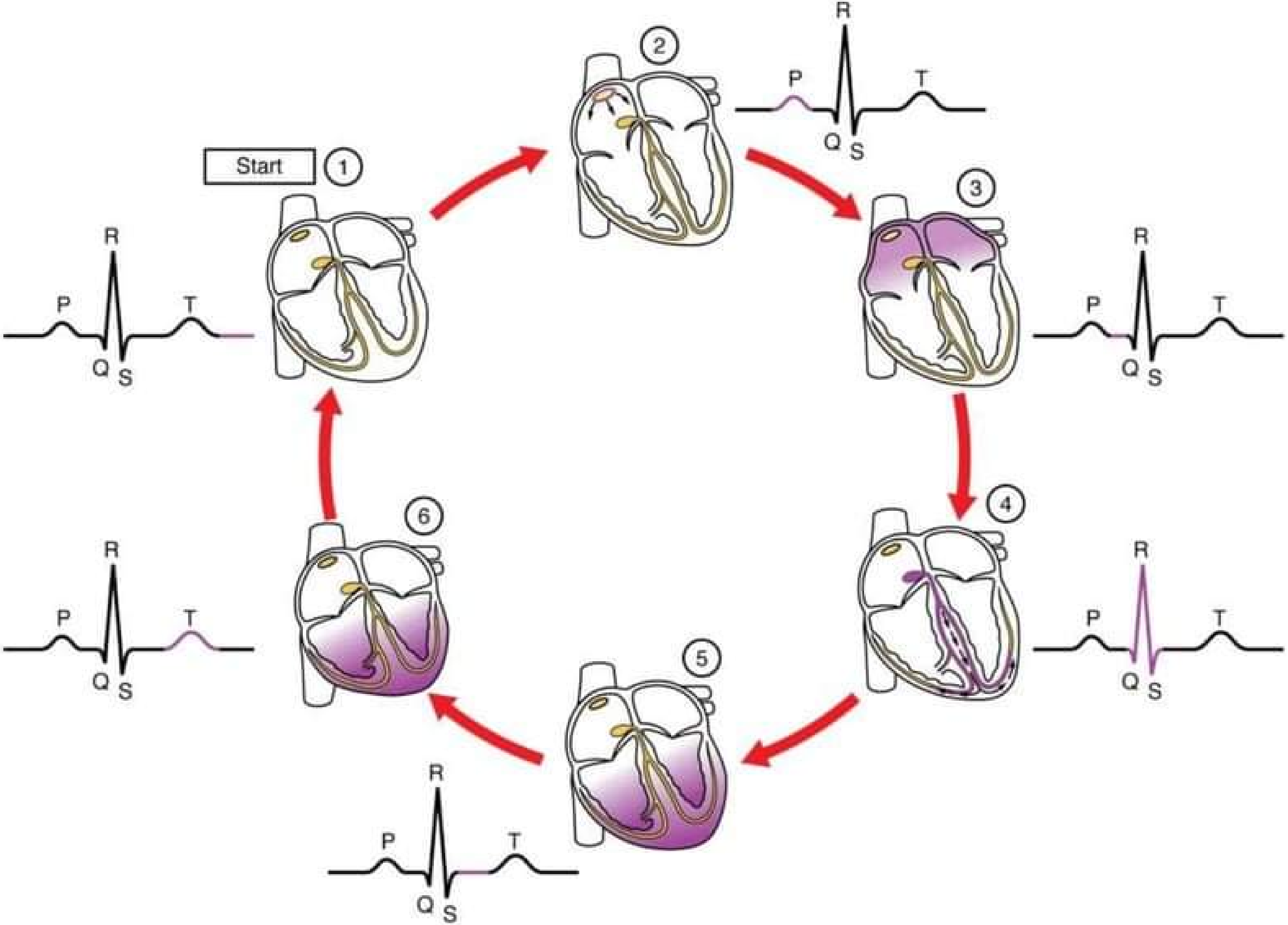
T- repolarization of ventricular myocardium

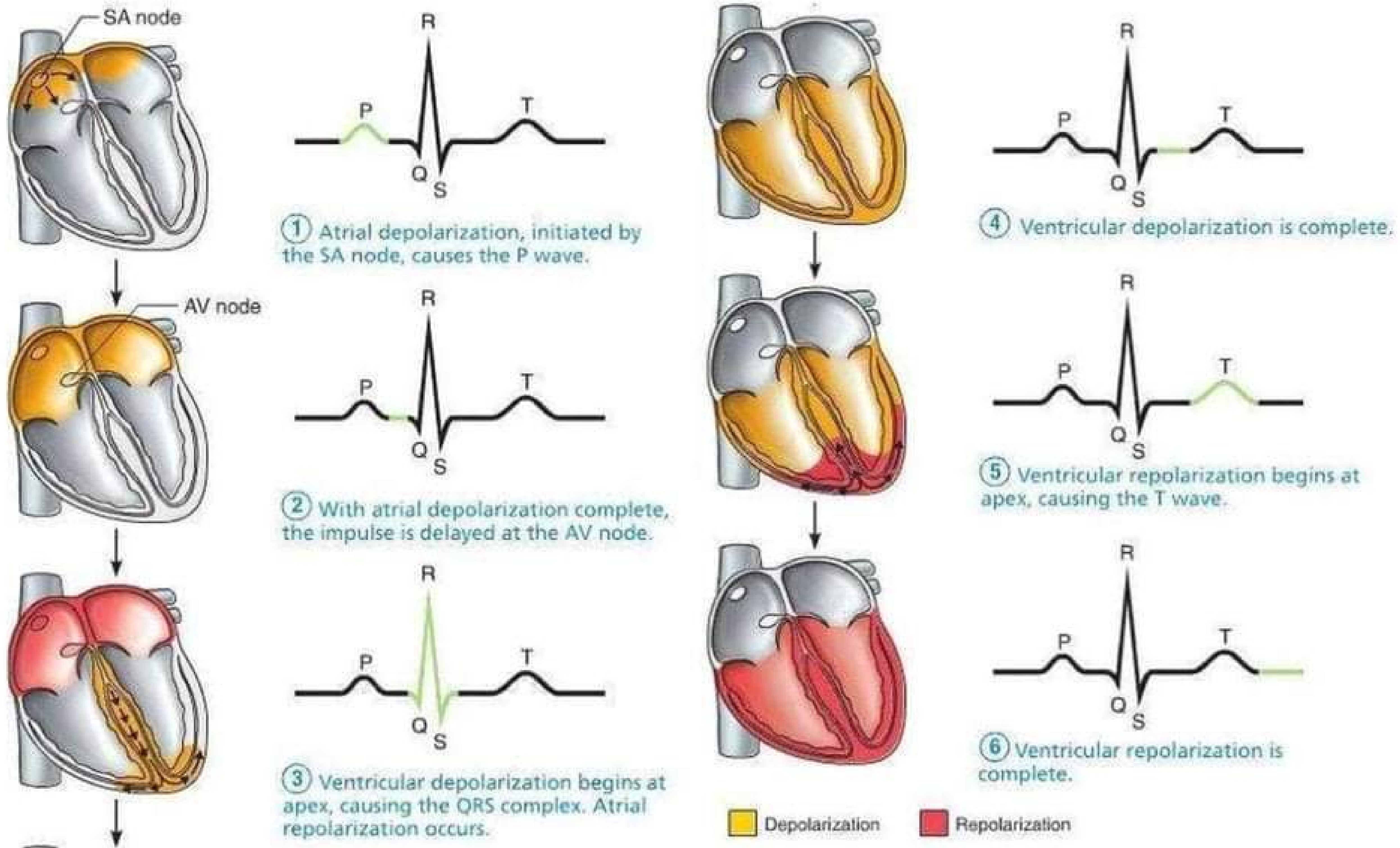

R
Atrial
Depolarization
P
T
Q
Ventricular
Repolarization
S
Ventricular Depolarization


R
P
T
Q
S
Atrial diastole
Atrial systole
Atrial diastole
Ventricular diastole
Ventricular systole
Ventricular diastole
One cardiac cycle



ECG
P
R
T
Q
S
atrial depol
atrial repol
vent. depol
vent. repol.
atrial systole
contract
atrial diastole
relax
vent. systole
contract
vent. diastole
relax


Start
1
2
3
4
5
6
P
Q
R
S
T



SA node
AV node
P
Q
R
S
T
1 Atrial depolarization, initiated by the SA node, causes the P wave.
2 With atrial depolarization complete, the impulse is delayed at the AV node.
3 Ventricular depolarization begins at apex, causing the QRS complex. Atrial repolarization occurs.
4 Ventricular depolarization is complete.
5 Ventricular repolarization begins at apex, causing the T wave.
6 Ventricular repolarization is complete.
Depolarization
Repolarization

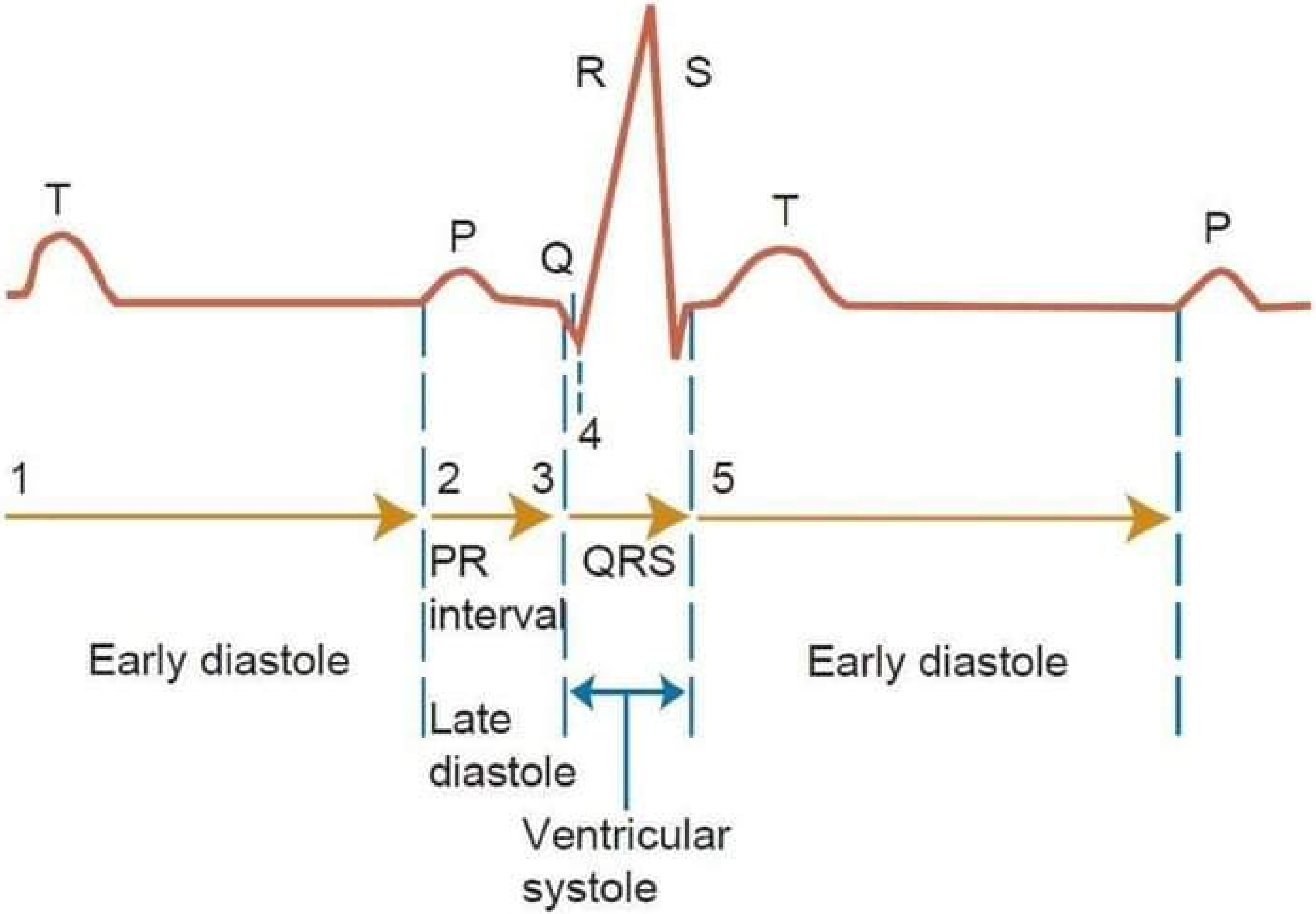
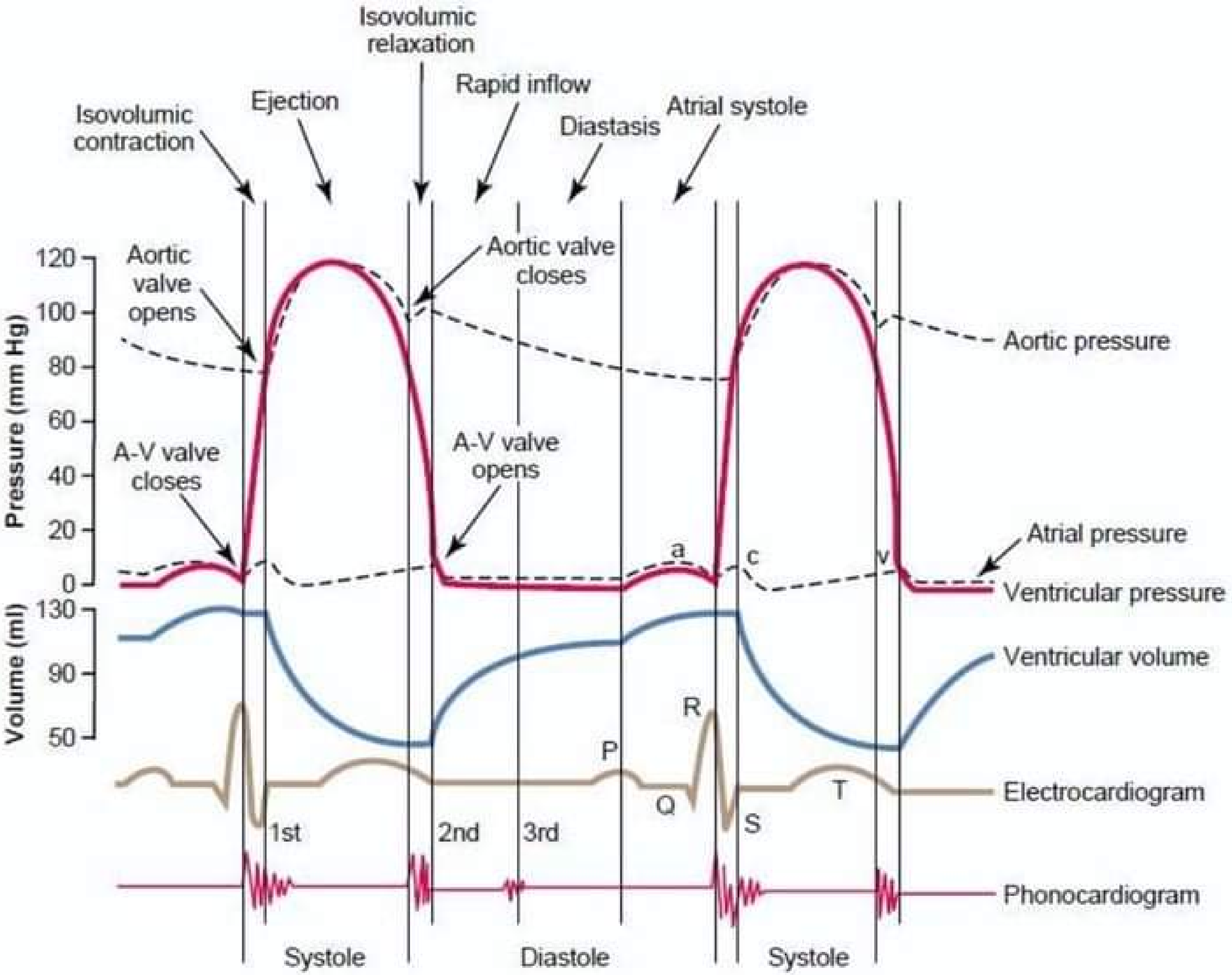
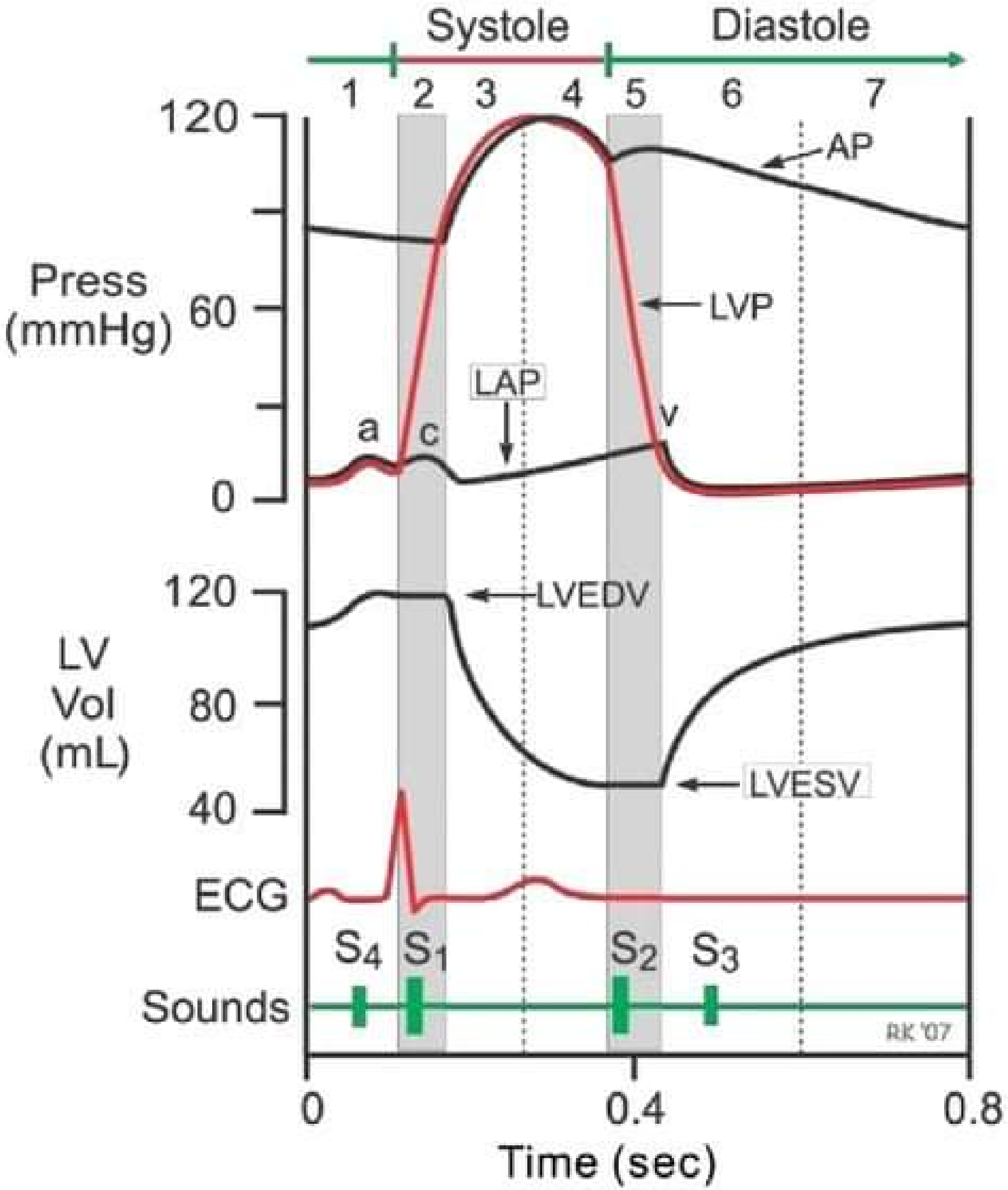
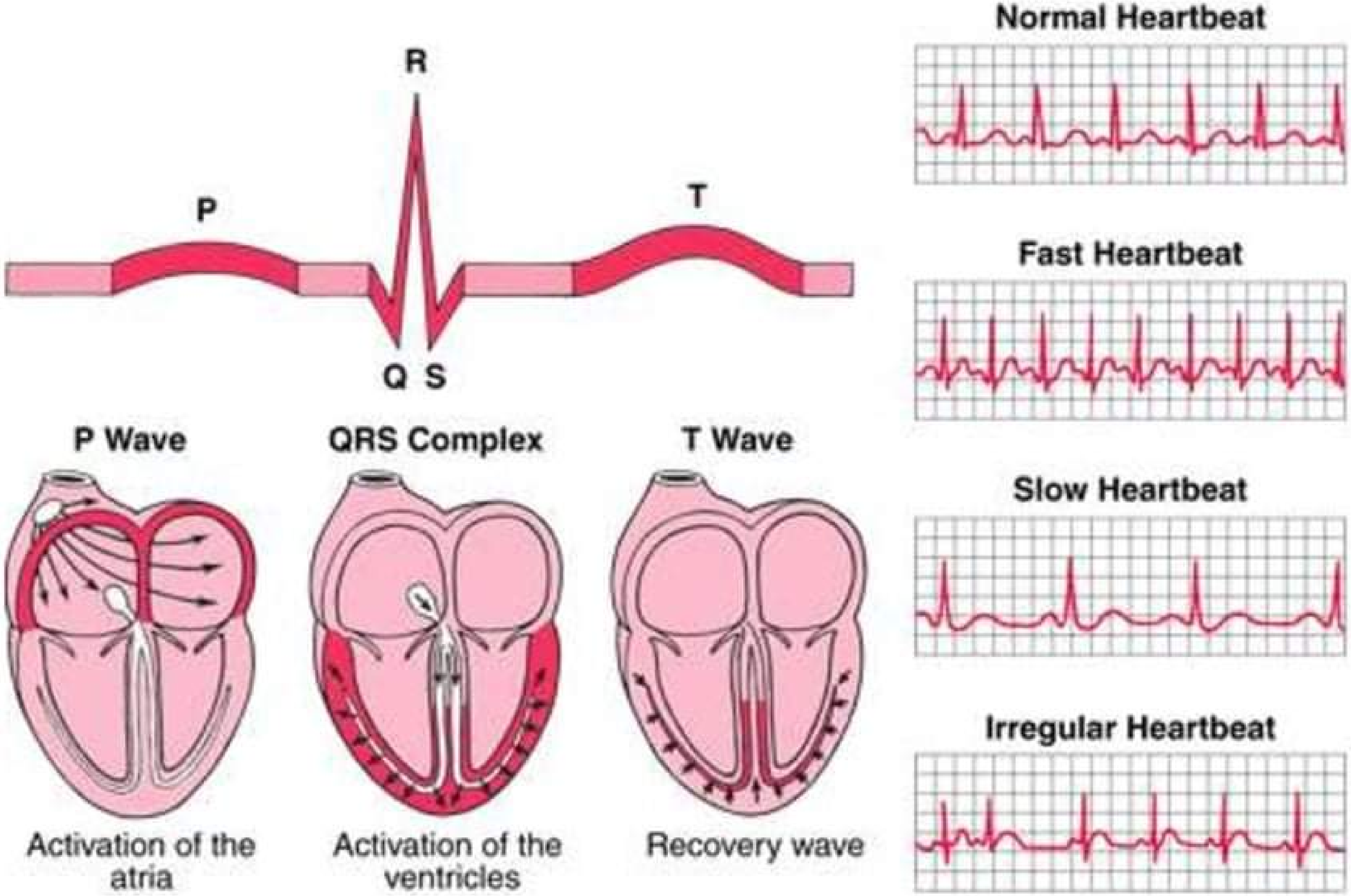


FIGURE 16-8 ▲ Comparison of electrical and mechanical events during one cardiac cycle, using a normal electrocardiogram tracing.


Isovolumic relaxation
Rapid inflow
Ejection
Atrial systole
Isovolumic contraction
Diastasis
Aortic valve opens
Aortic valve closes
120
100
80
60
40
20
0
Pressure (mm Hg)
Aortic pressure
A-V valve closes
A-V valve opens
Atrial pressure
a
c
v
Ventricular pressure
130
90
50
Volume (ml)
Ventricular volume
R
P
Q
S
T
Electrocardiogram
1st
2nd
3rd
Phonocardiogram
Systole
Diastole
Systole



Systole
Diastole
1
2
3
4
5
6
7
120
60
0
Press (mmHg)
AP
LVP
LAP
a
c
v
120
80
40
LV Vol (mL)
LVEDV
LVESV
ECG
S_4
S_1
S_2
S_3
Sounds
RK '07
0
0.4
0.8
Time (sec)


Normal Heartbeat
R
P
T
Q
S
Fast Heartbeat
P Wave
QRS Complex
T Wave
Slow Heartbeat
Irregular Heartbeat
Activation of the atria
Activation of the ventricles
Recovery wave

CHARACTERISTIC OF MURMURS

Organic
Functional
Organic-functional
Physiological

Cardiac
Extracardial
Combined

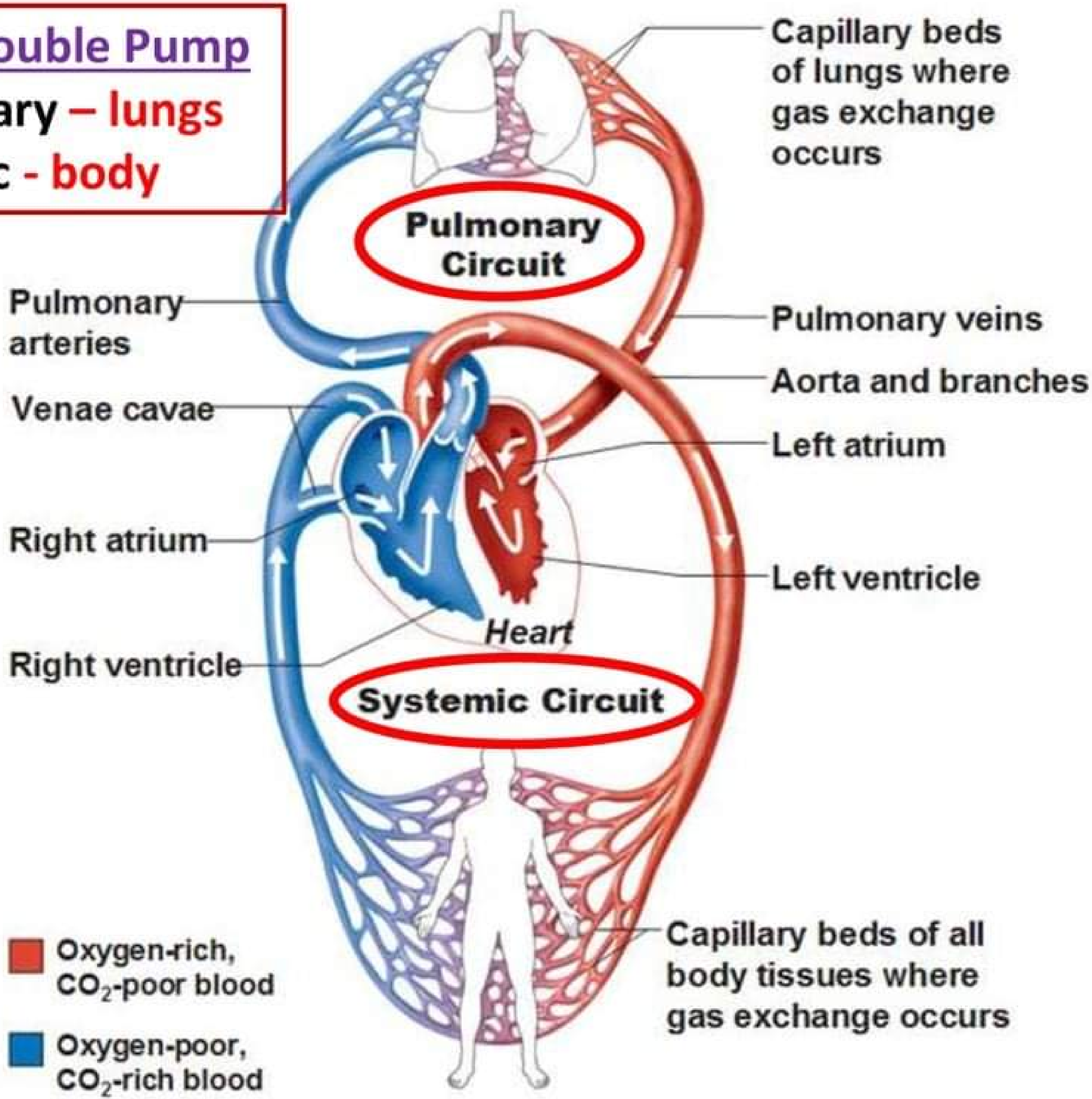
Systolic
Diastolic

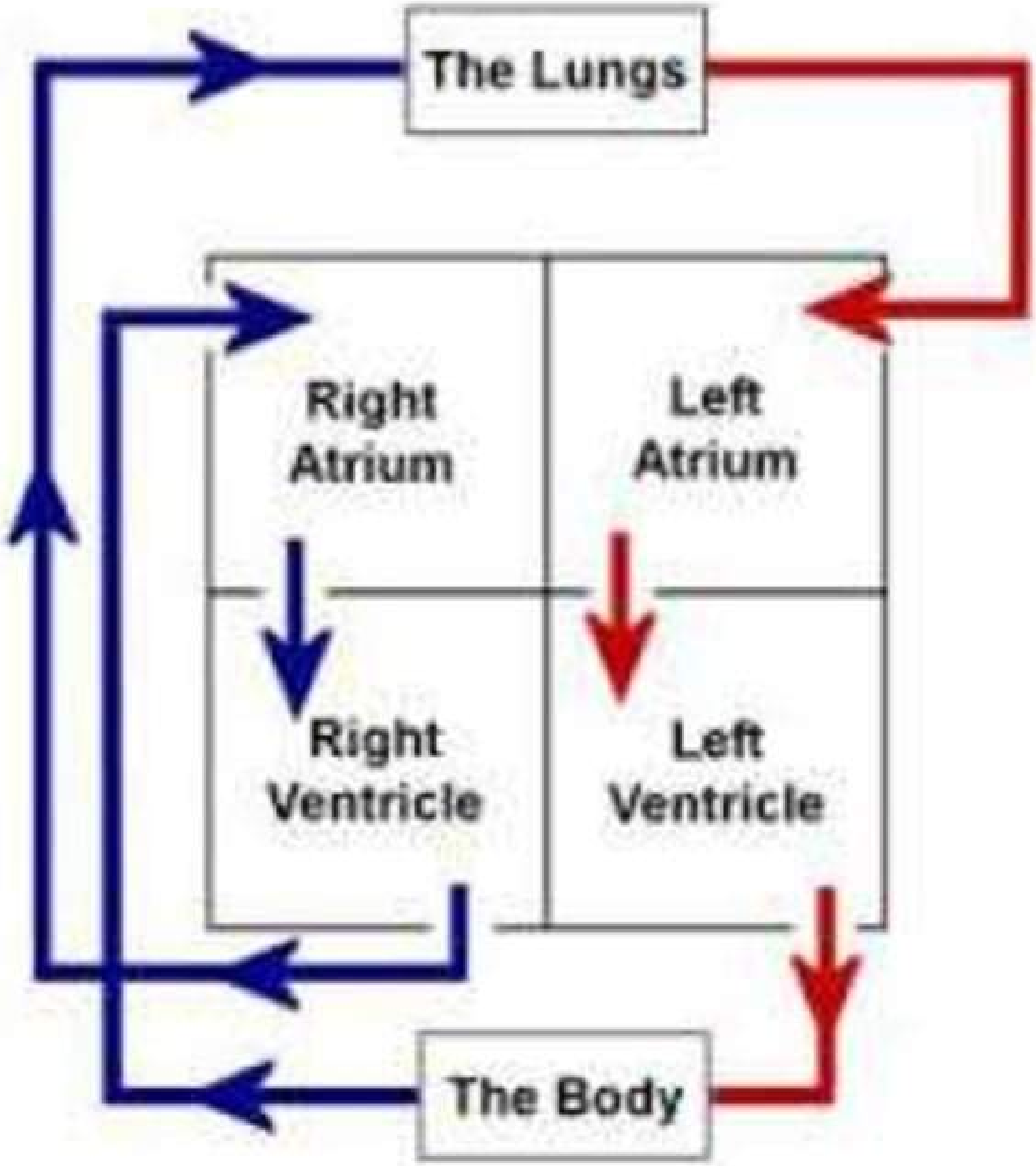
Timbre
Irradiation
Force
Duration

Heart Double Pump

Pulmonary – lungs

Systemic - body



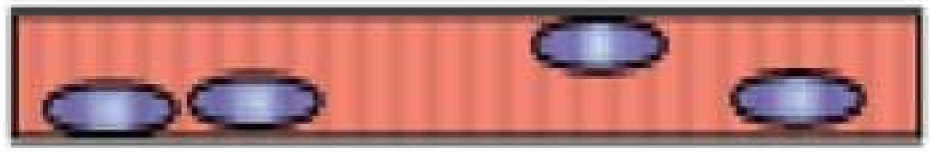


The Lungs
Right Atrium
Left Atrium
Right Ventricle
Left Ventricle
The Body

Three Types of Muscle Tissue

Draw and Label

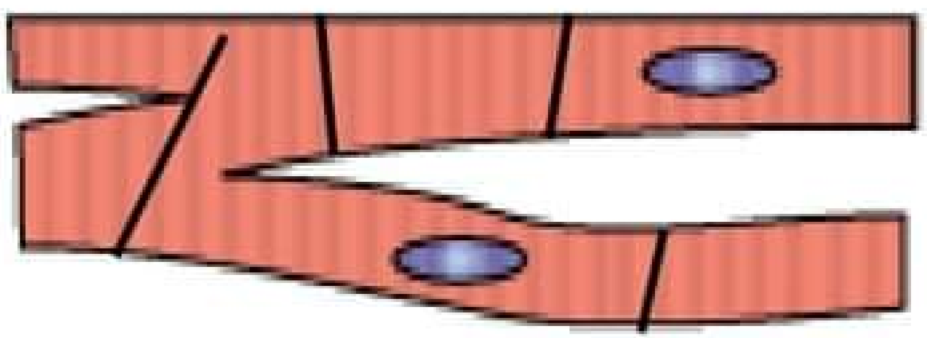
Skeletal



Voluntary Striated

Multinucleated Non-branched

Cardiac

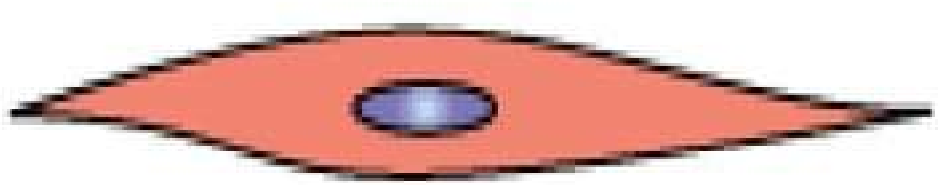


Involuntary Striated

Intercalculated disks

Mononucleated Branched

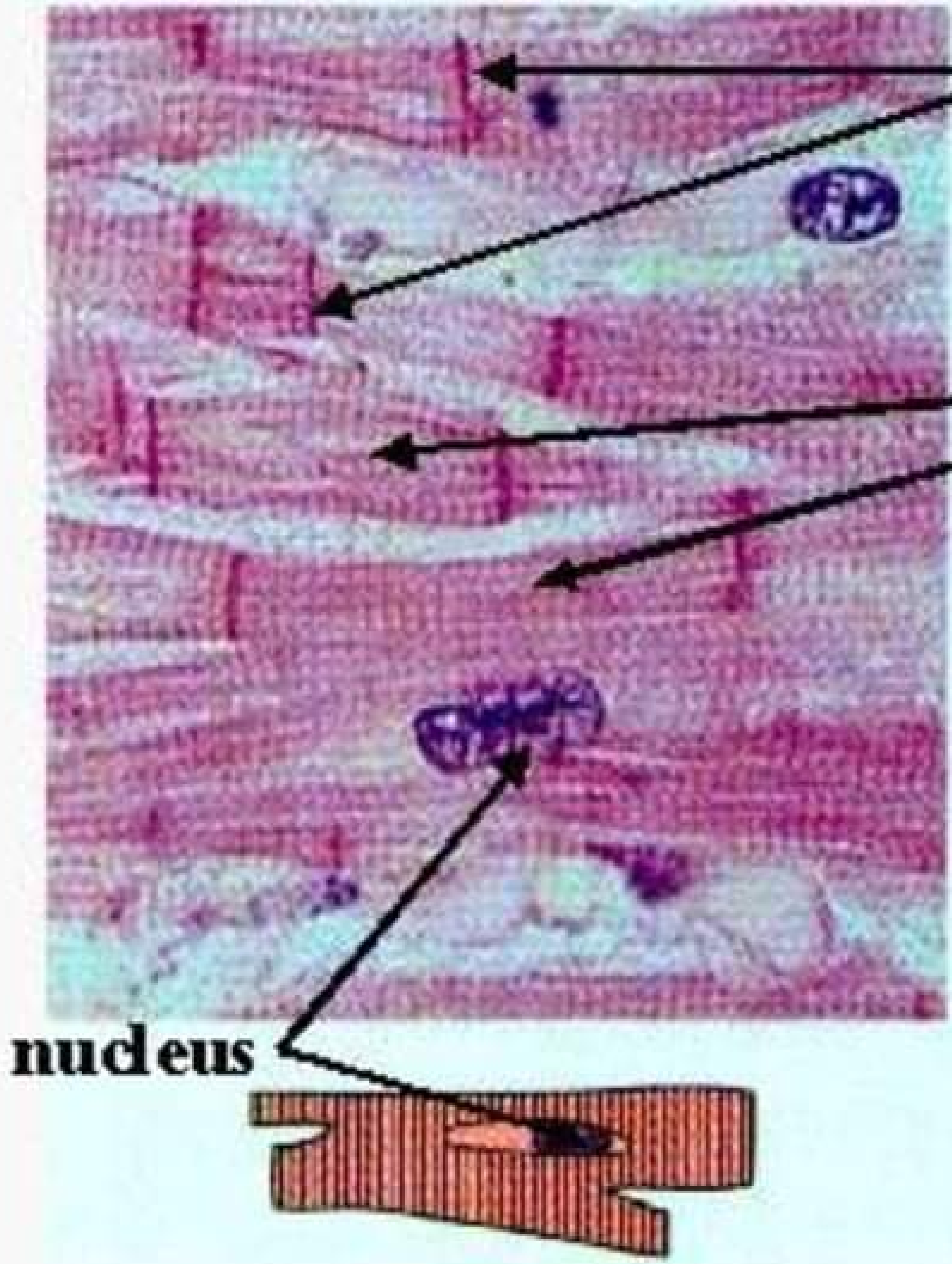
Smooth



Involuntary Non-striated

Mononucleated Tapered

Cardiac Muscle Structure



Intercalated disks are anchoring structures containing gap junctions.

Faintly striated, branching, mononucleated disks to form a functional network.

The action potential travels though all cells connected together forming a **functional syncytium** in which cells function as a unit.

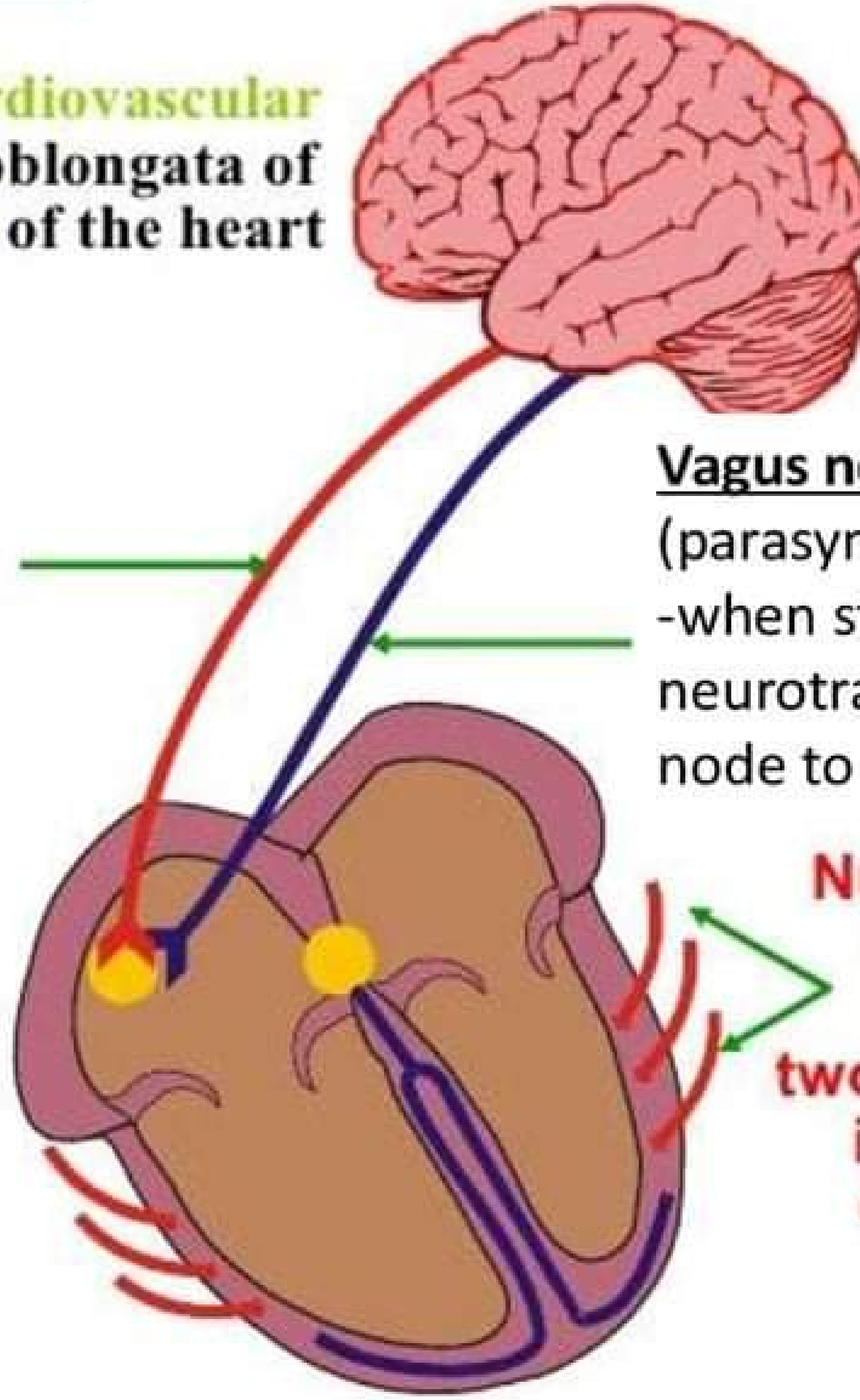
Define the following terms

- **Functional syncytium** –the heart consists of individual cells, the entire mass normally responds as a unit and all of the cells contract together.
- **Myogenic** – cardiac muscle **can contract** without nervous input. **BUT** the strength and the rate of contraction is modified by nervous input.
- **Automaticity** – the cardiac cell's ability to spontaneously generate an electrical impulse (depolarize).

The heart is **myogenic** – it contracts on its own without stimulus from the nervous system.

But, the heart **RATE** is controlled by the nervous system

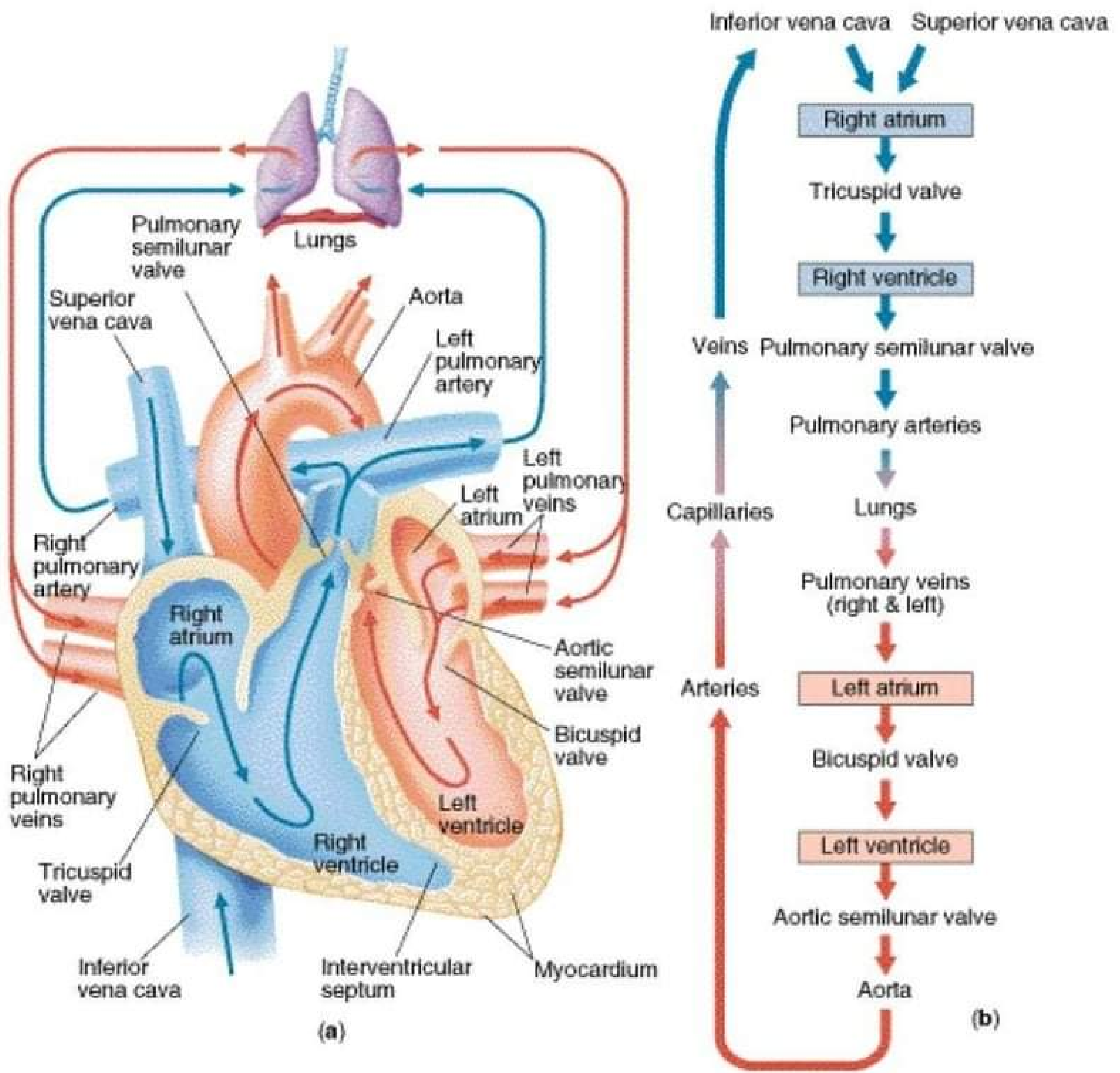
Two nerves link the cardiovascular centre in the medulla oblongata of brain with the SA node of the heart



Accelerator nerve
(sympathetic NS)
- When stimulated releases neurotransmitter at the SA node to increase the heart rate

Vagus nerve
(parasympathetic NS)
-when stimulated releases neurotransmitter to at the SA node to DECREASE the heart rate.

Numerous sympathetic nerves also link to the walls of the two ventricles where they increase the force of contraction of these chambers


Lungs
Pulmonary semilunar valve
Superior vena cava
Aorta
Left pulmonary artery
Left pulmonary veins
Left atrium
Right pulmonary artery
Right atrium
Aortic semilunar valve
Bicuspid valve
Right pulmonary veins
Left ventricle
Right ventricle
Tricuspid valve
Inferior vena cava
Interventricular septum
Myocardium
(a)
Inferior vena cava
Superior vena cava
Right atrium
Tricuspid valve
Right ventricle
Veins
Pulmonary semilunar valve
Pulmonary arteries
Capillaries
Lungs
Pulmonary veins (right & left)
Arteries
Left atrium
Bicuspid valve
Left ventricle
Aortic semilunar valve
Aorta
(b)

Micrograph of tissue found in the heart.

Bundle of His

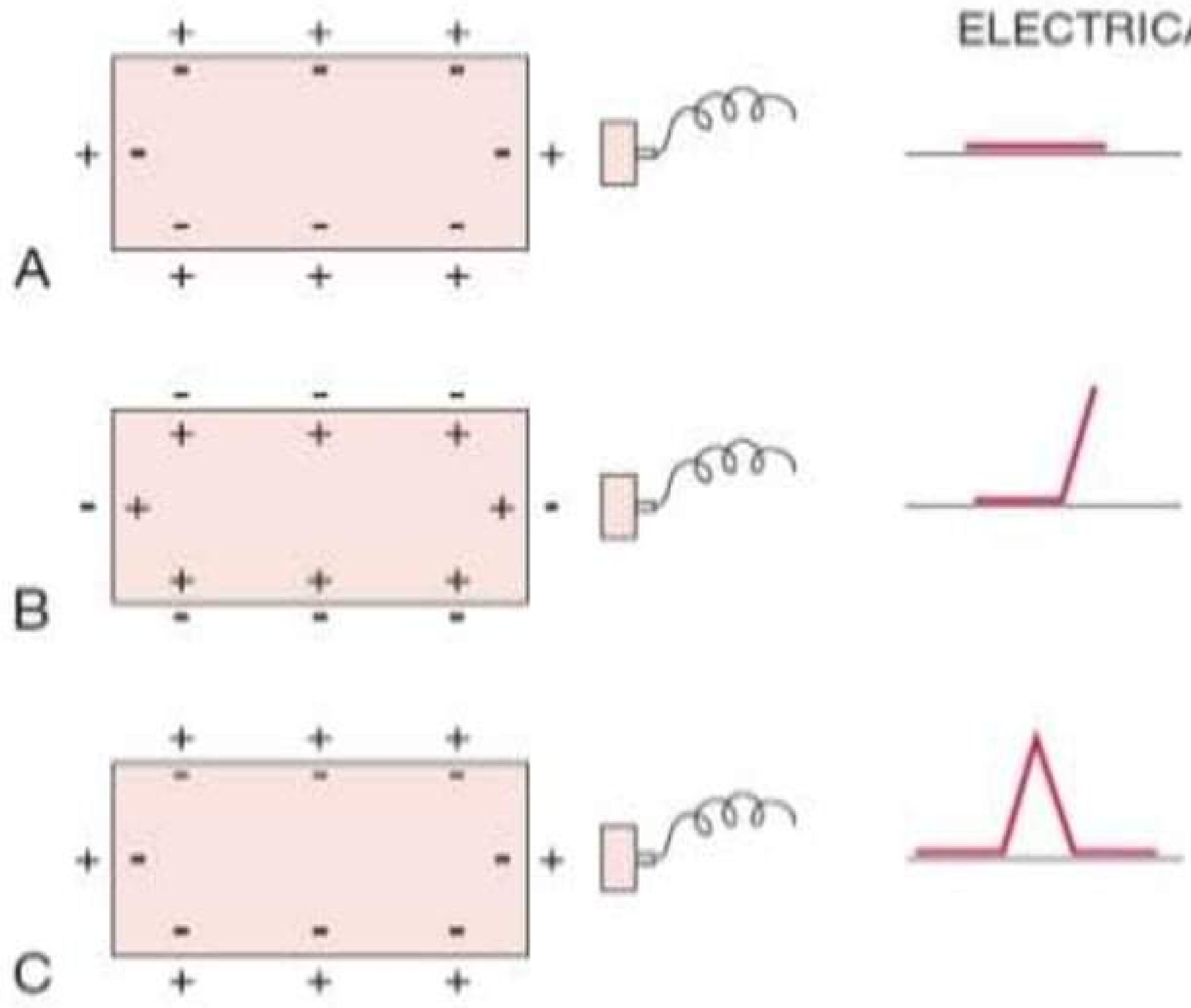
-heart muscle cells specialized for electrical conduction

-transmit electrical impulses from AV node to apex via bundle branches.

Purkinje fibers

-cardiomyocytes that are able to conduct cardiac action potential more efficiently than other heart cells.
consist of
-allow synchronized contraction of the heart ventricles
-essential for maintaining a consistent heart rhythm

Action Potential in cardiac tissue

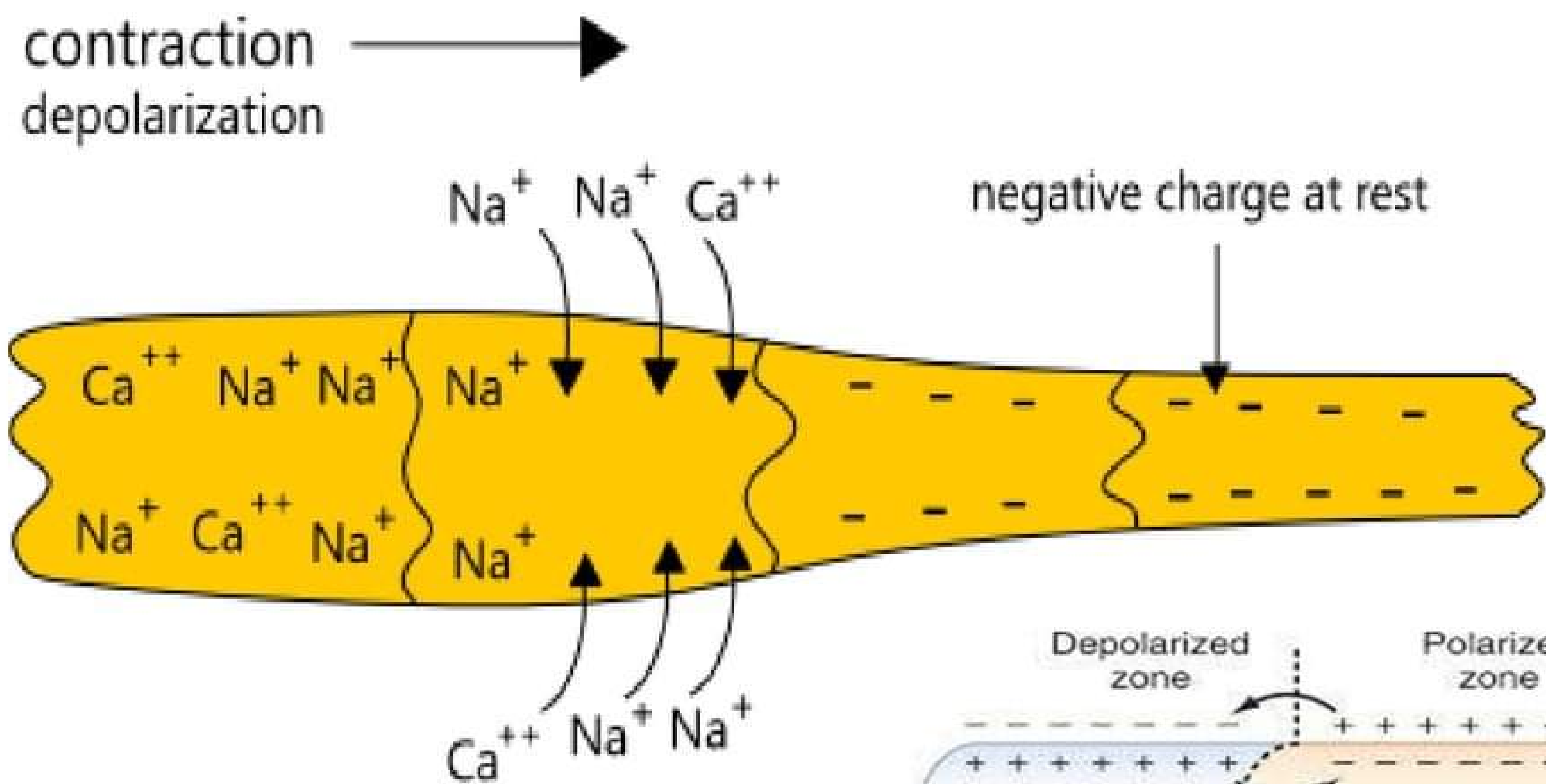


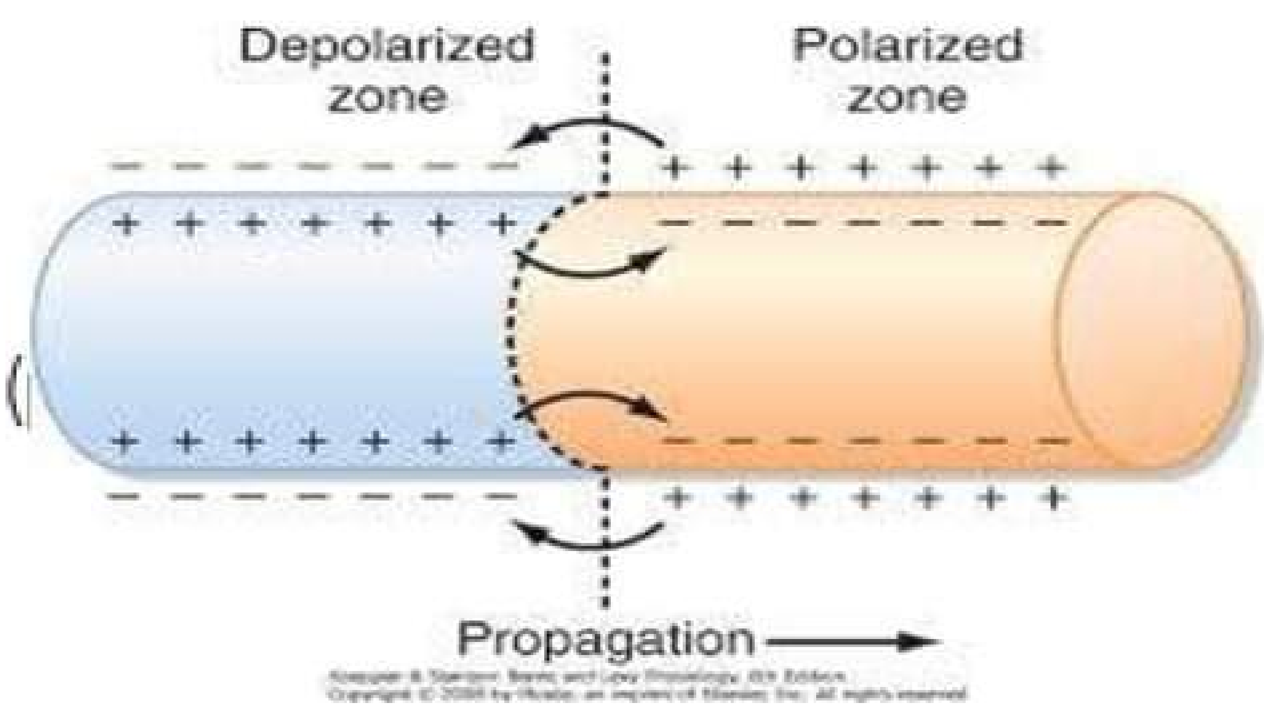
Rest:
(=)+ outside - inside

Depolarization:
(=) - outside + inside

Repolarization:
Returns to:
+ outside - inside

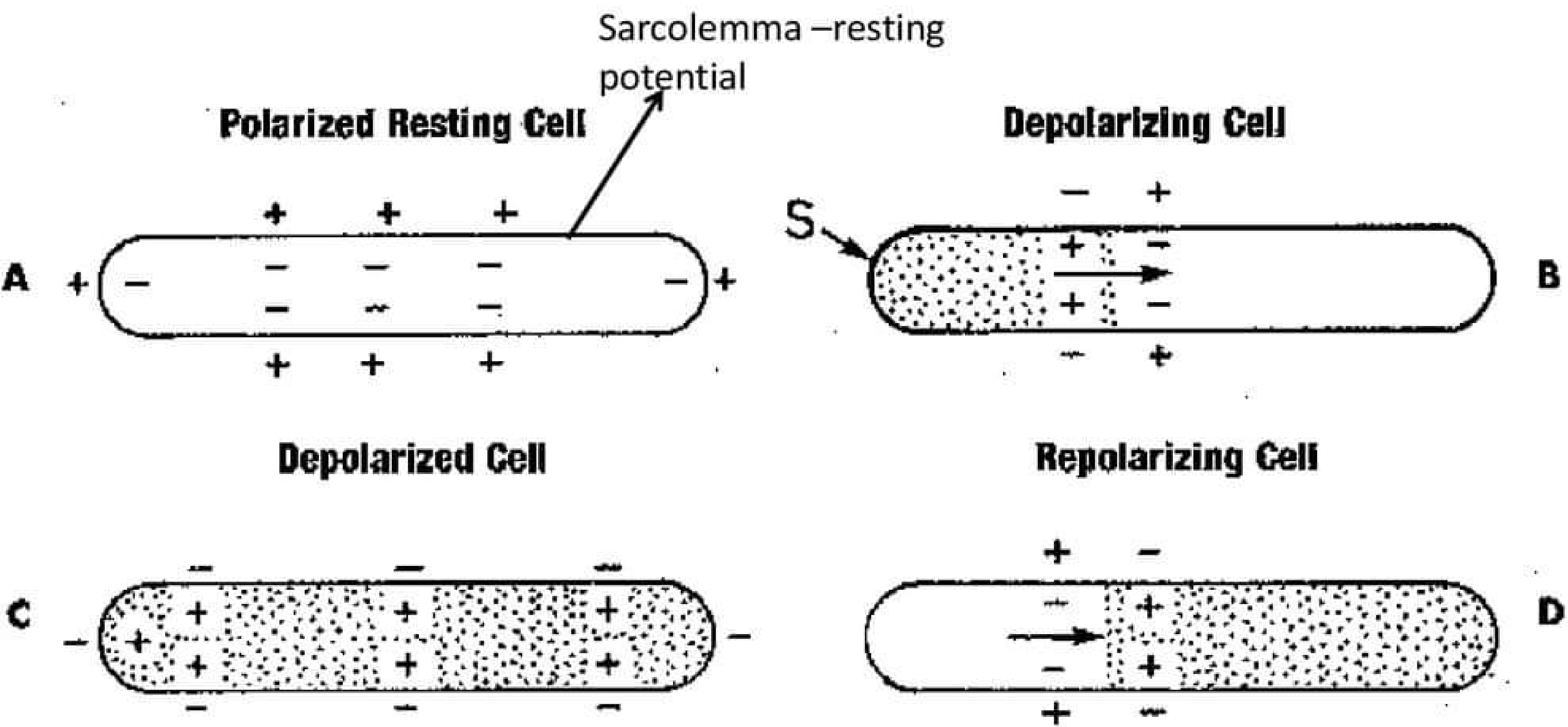
Heart Muscle - depolarization





Influx of Na^+ and Ca^{++} causes depolarization (

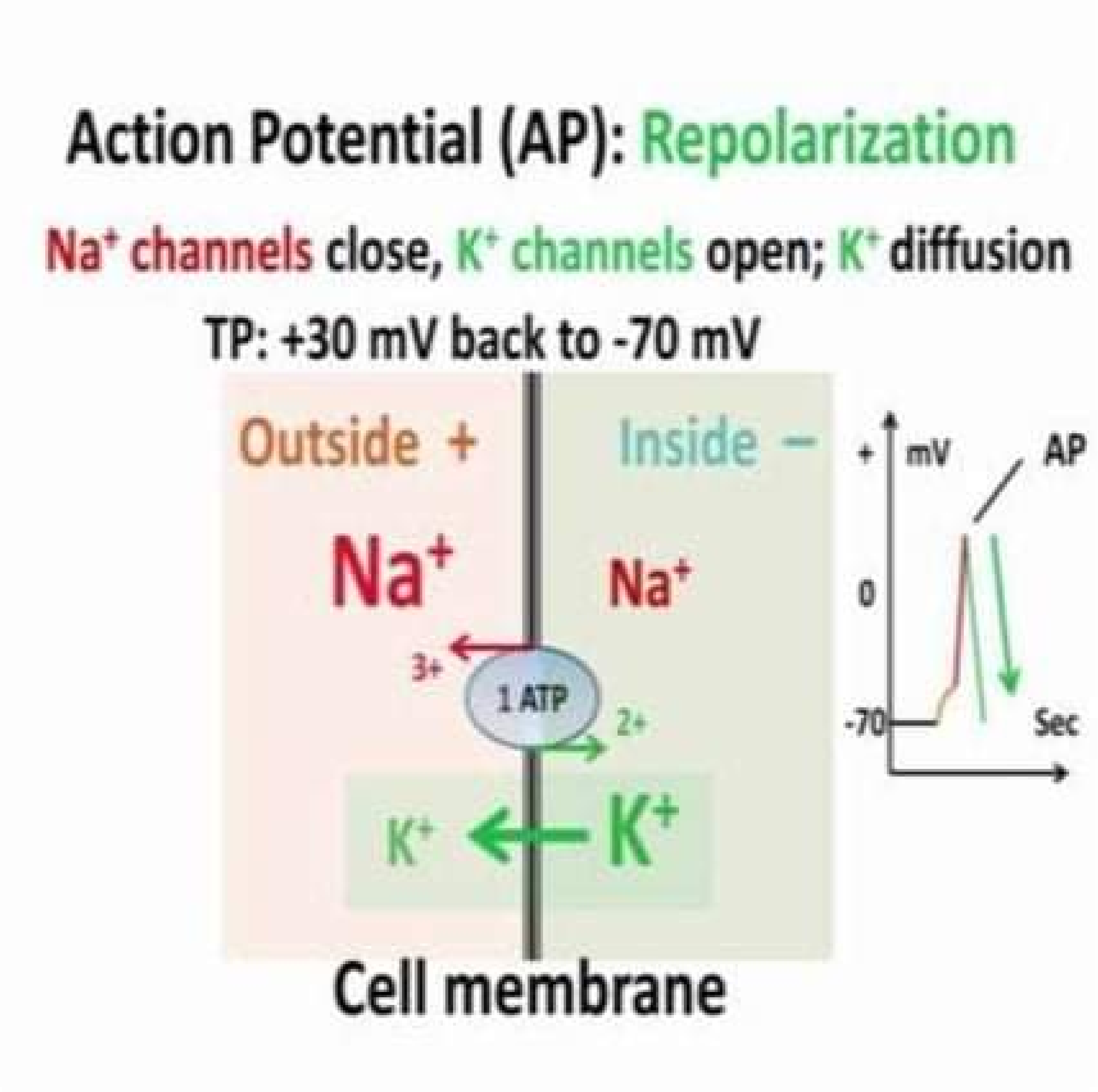
Describe the difference between polarisation, depolarisation and repolarisation.



IONS INVOLVED - K+, Na+ and Ca+ (from sarcoplasmic reticulum)

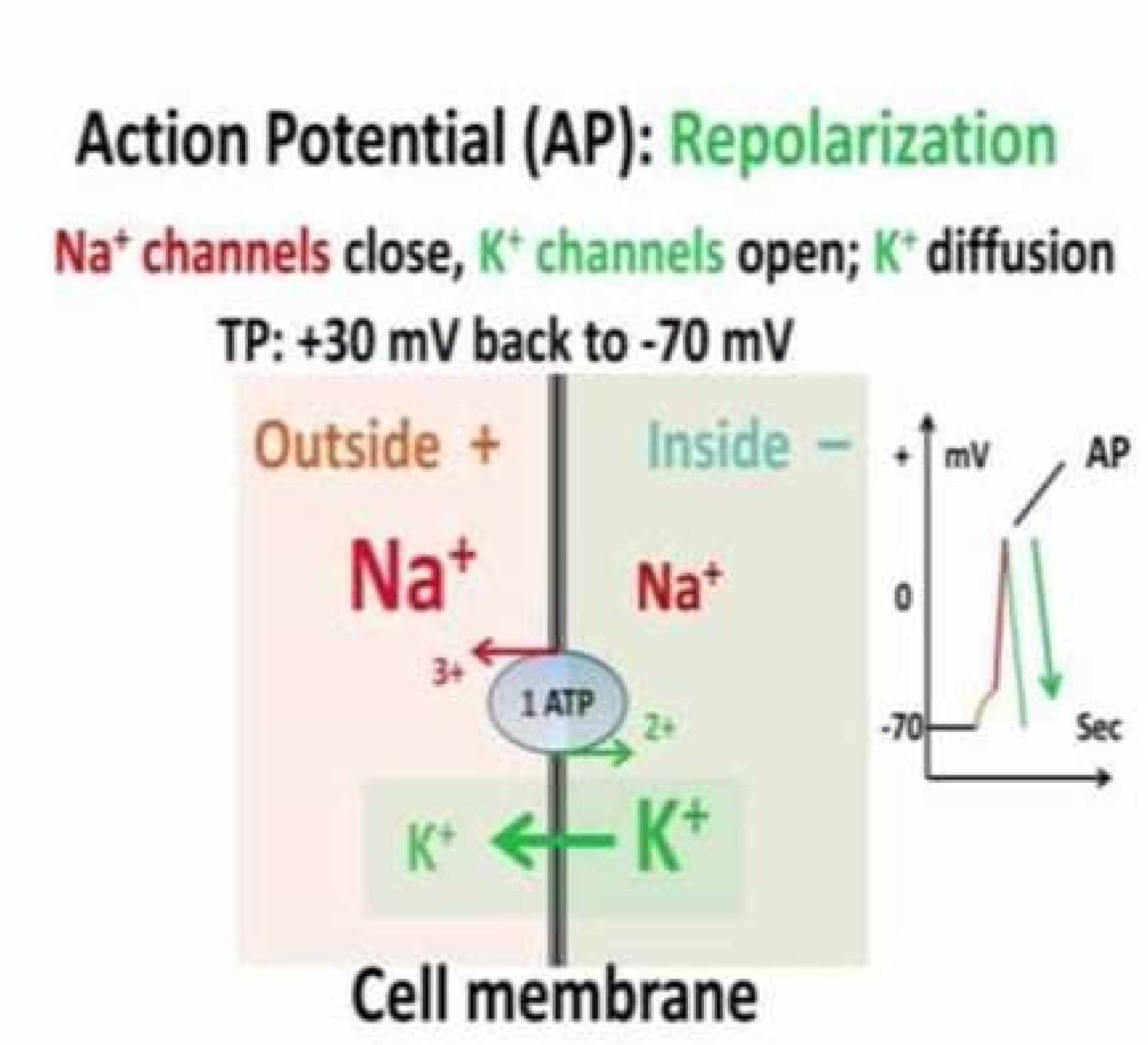
depolarization…..

- Depolarization is when a cell membrane's charge becomes positive to generate an action potential. This is usually caused by positive sodium and calcium ions going into the cell



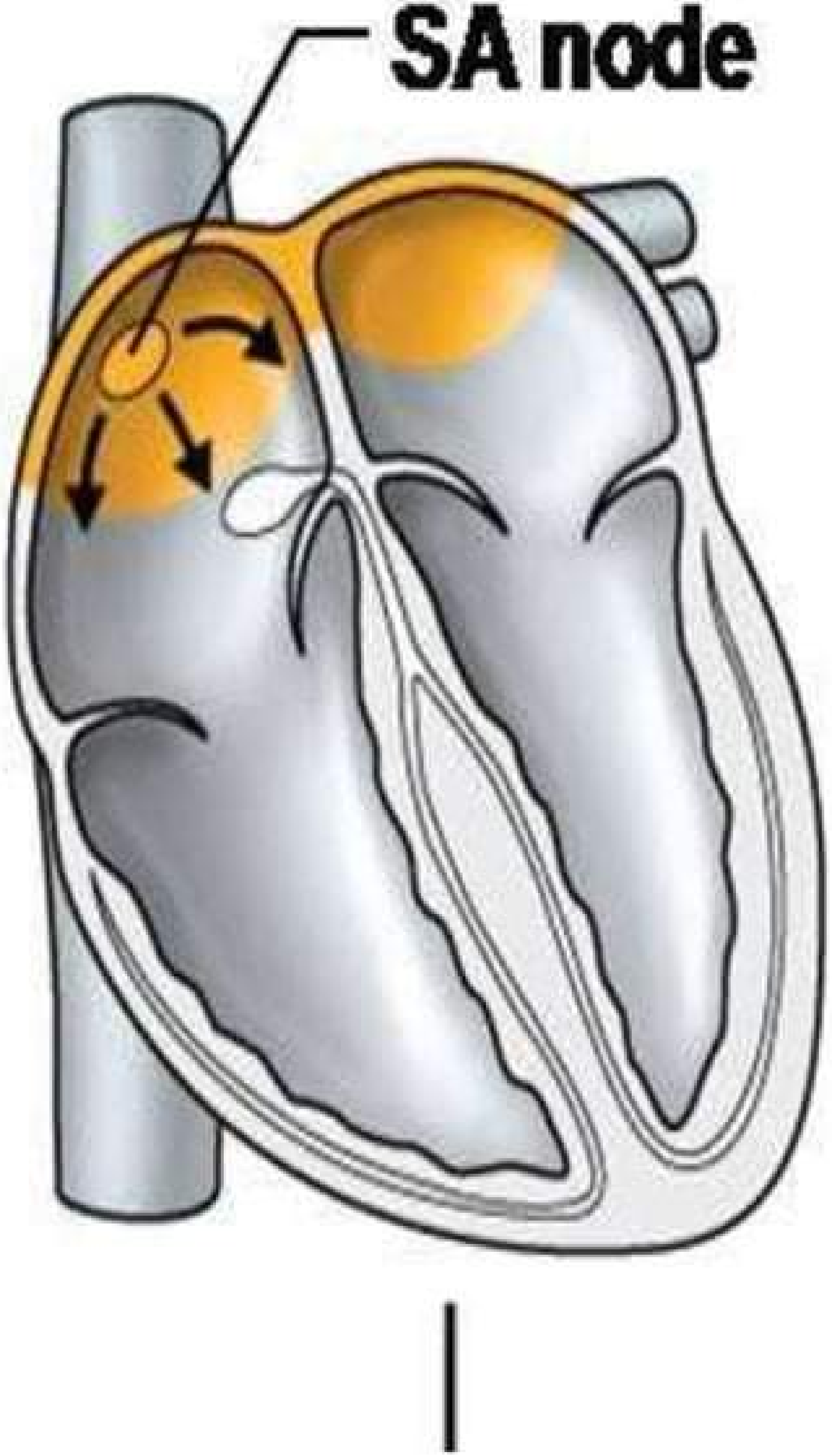
repolarization…..

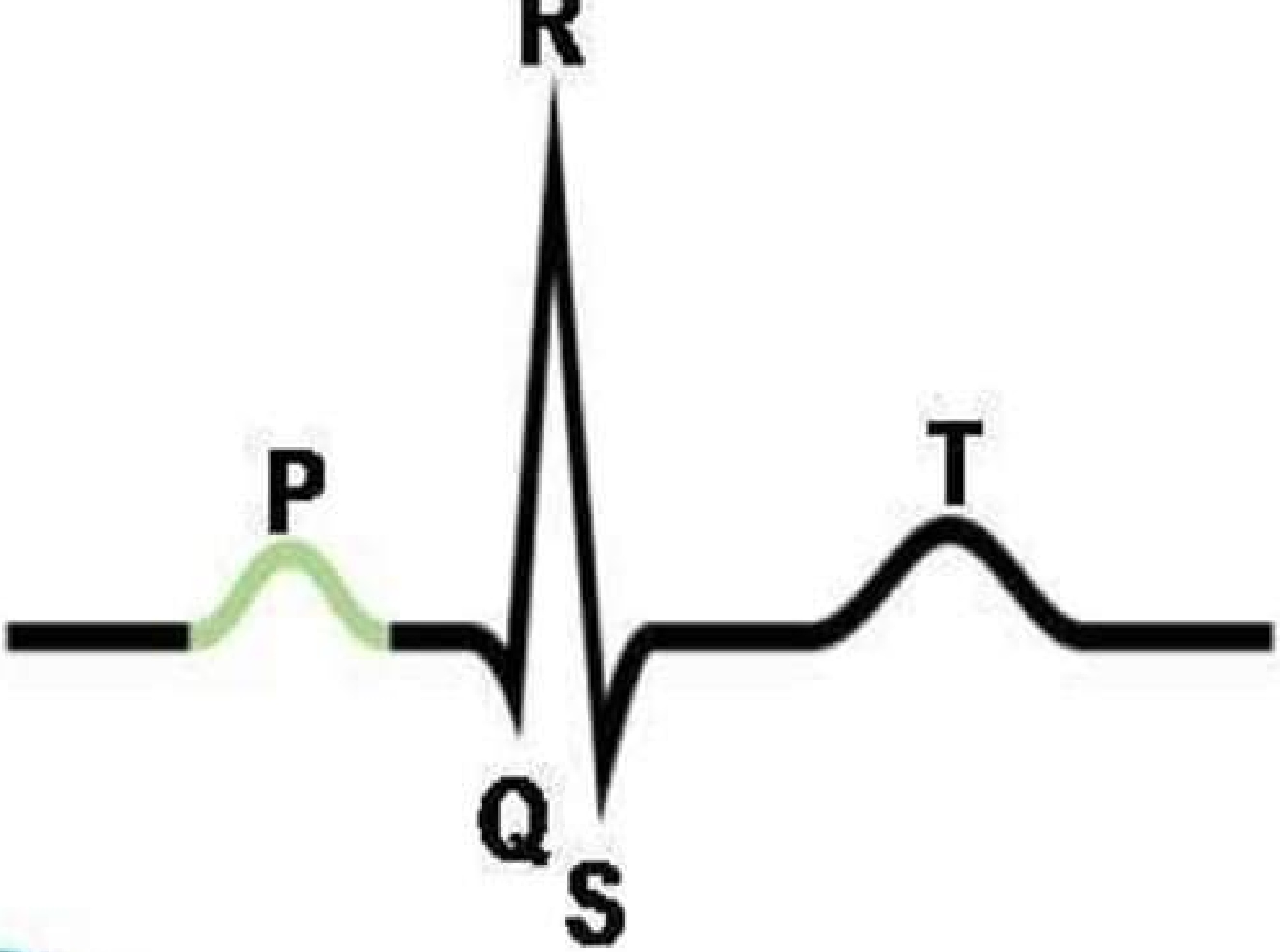
- Repolarization is when a cell membrane's charge returns to negative after depolarization. This is caused by positive potassium ions moving out of the cell.



Depolarization and repolarization video
http://www.youtube.com/watch?v=4vkbywows-o

Stop / play back / stop the animation of the cardiac cycle phases:
http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter22/animation__the_cardiac_cycle__quiz_2_.html



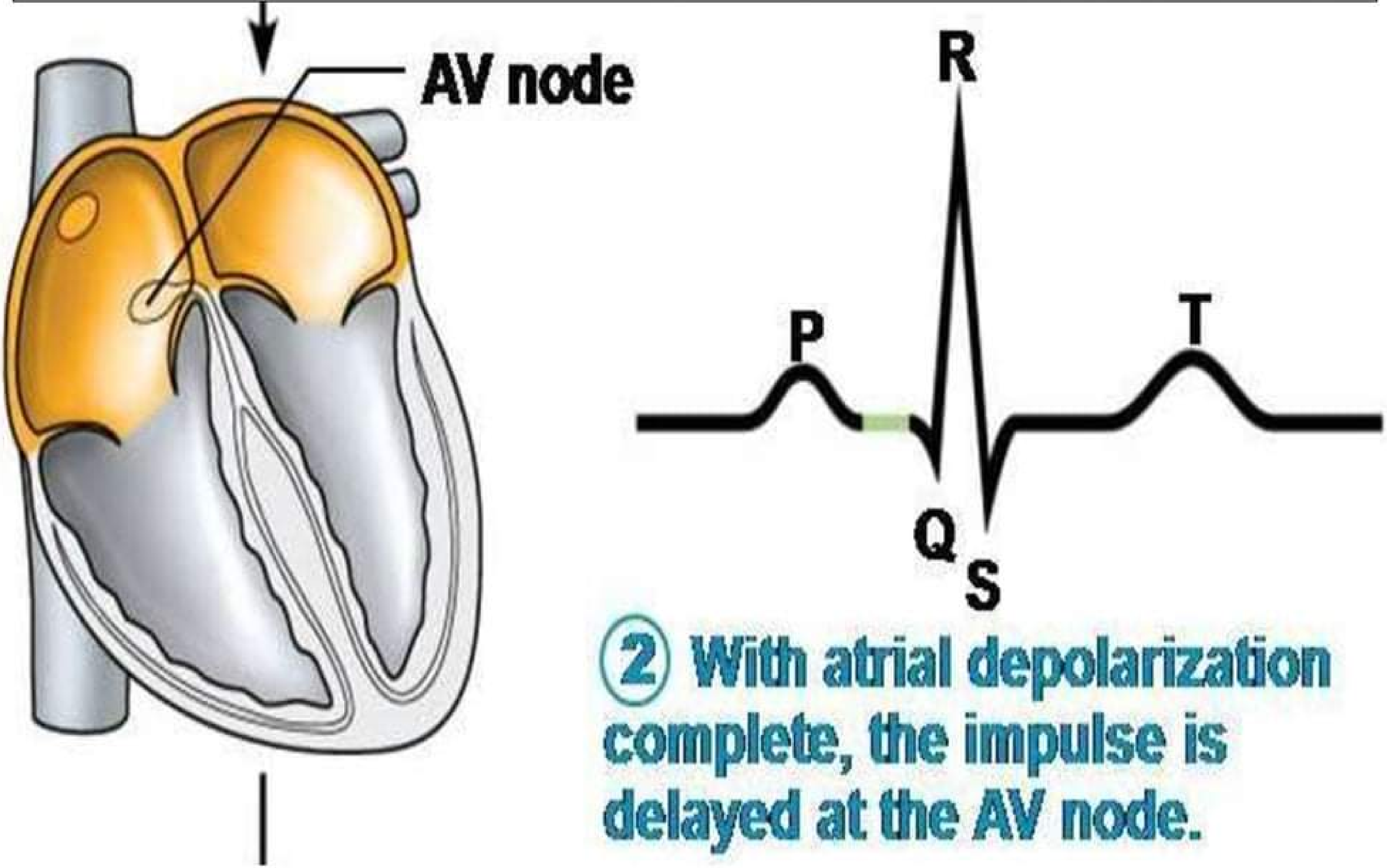


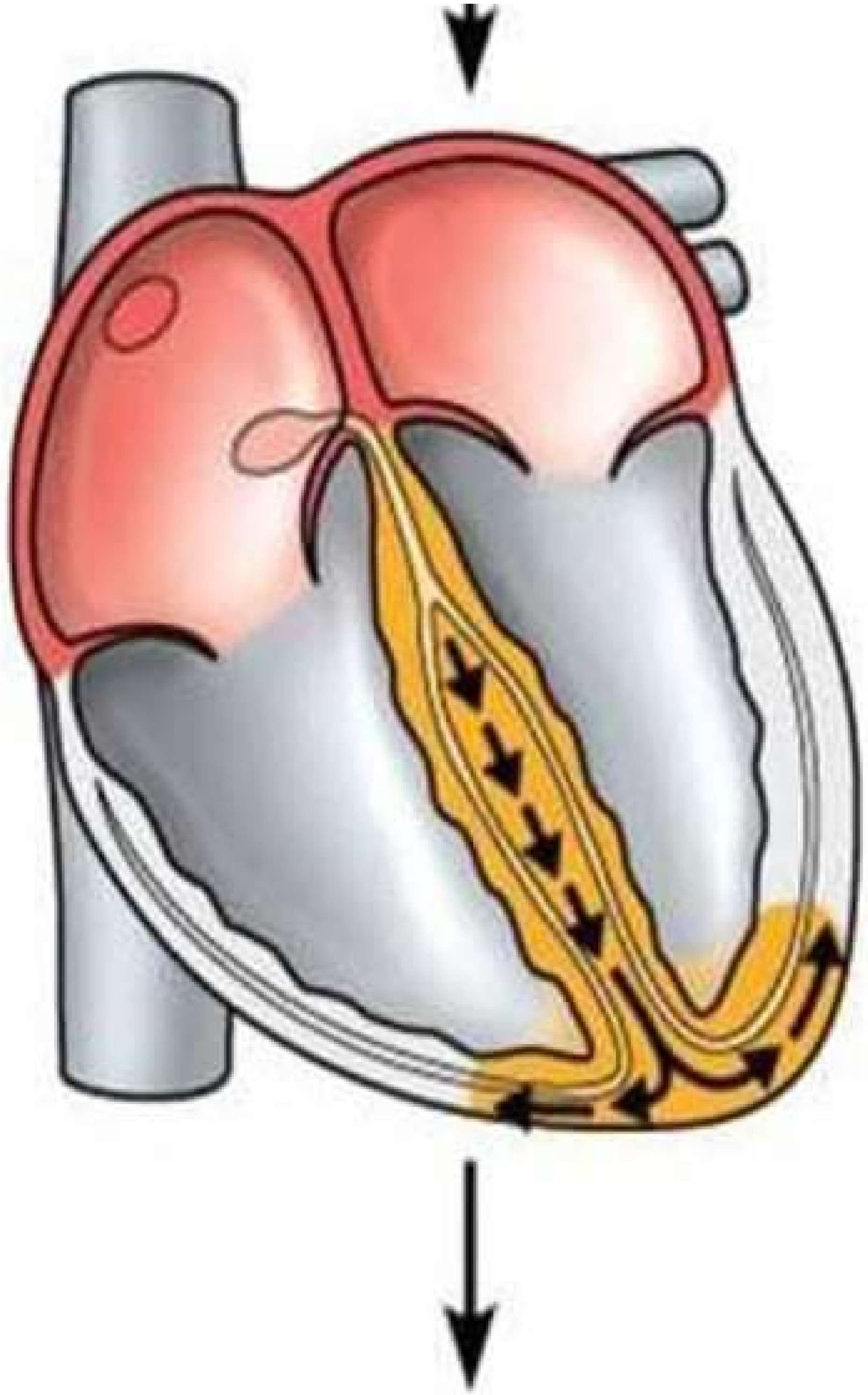
① Atrial depolarization, initiated by the SA node, causes the P wave.

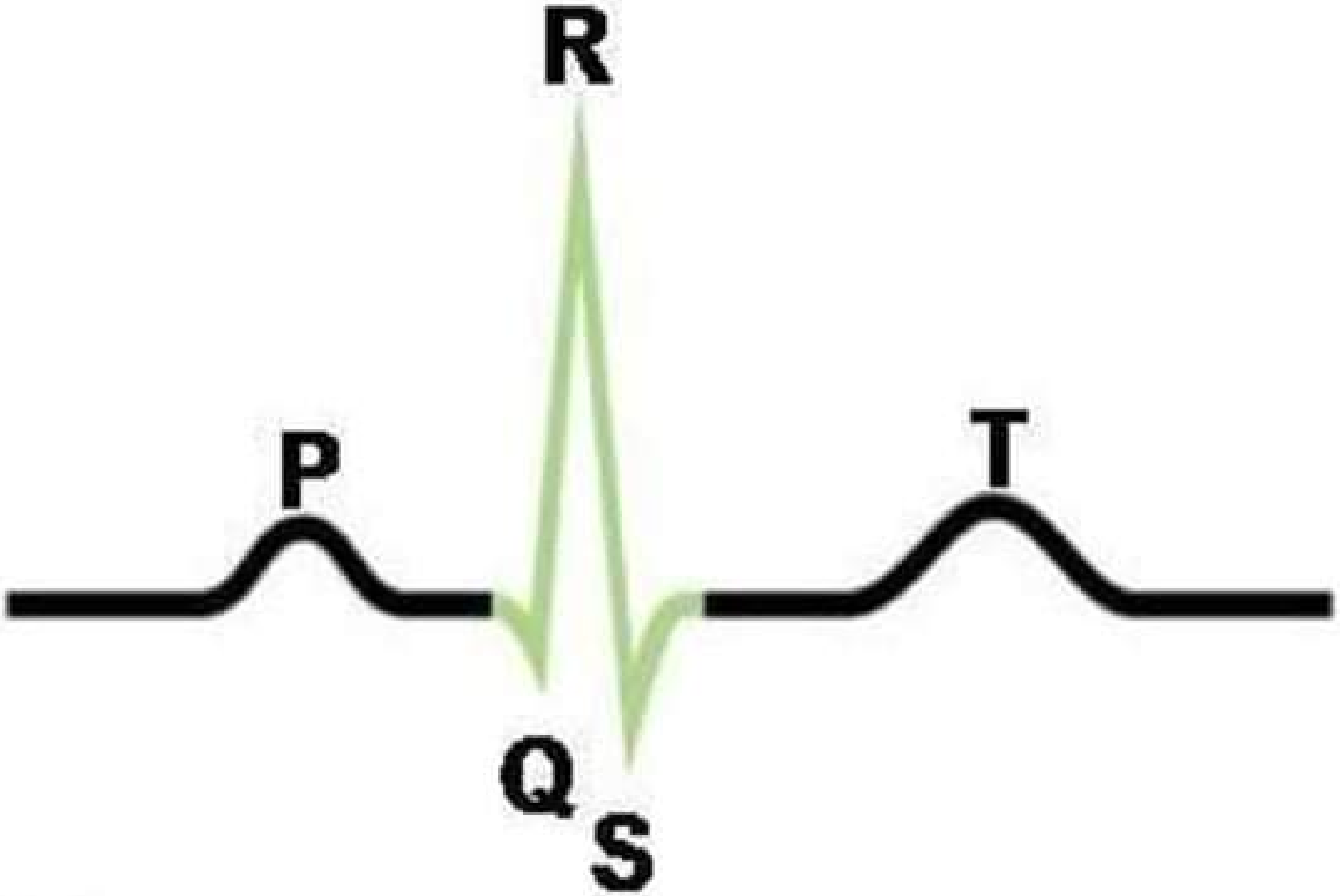
SAN – pacemaker

Cardiac Conduction System 3.45 min https://www.youtube.com/watch?v=RYZ4daFwMa8

0.2 seconds -- time for the impulse to be conducted from the SAN to the ventricles via the AVN (P—R). The edges of the atria have tough fibers that prevents the leakage of impulse from atrias. AVN - gatekeeper

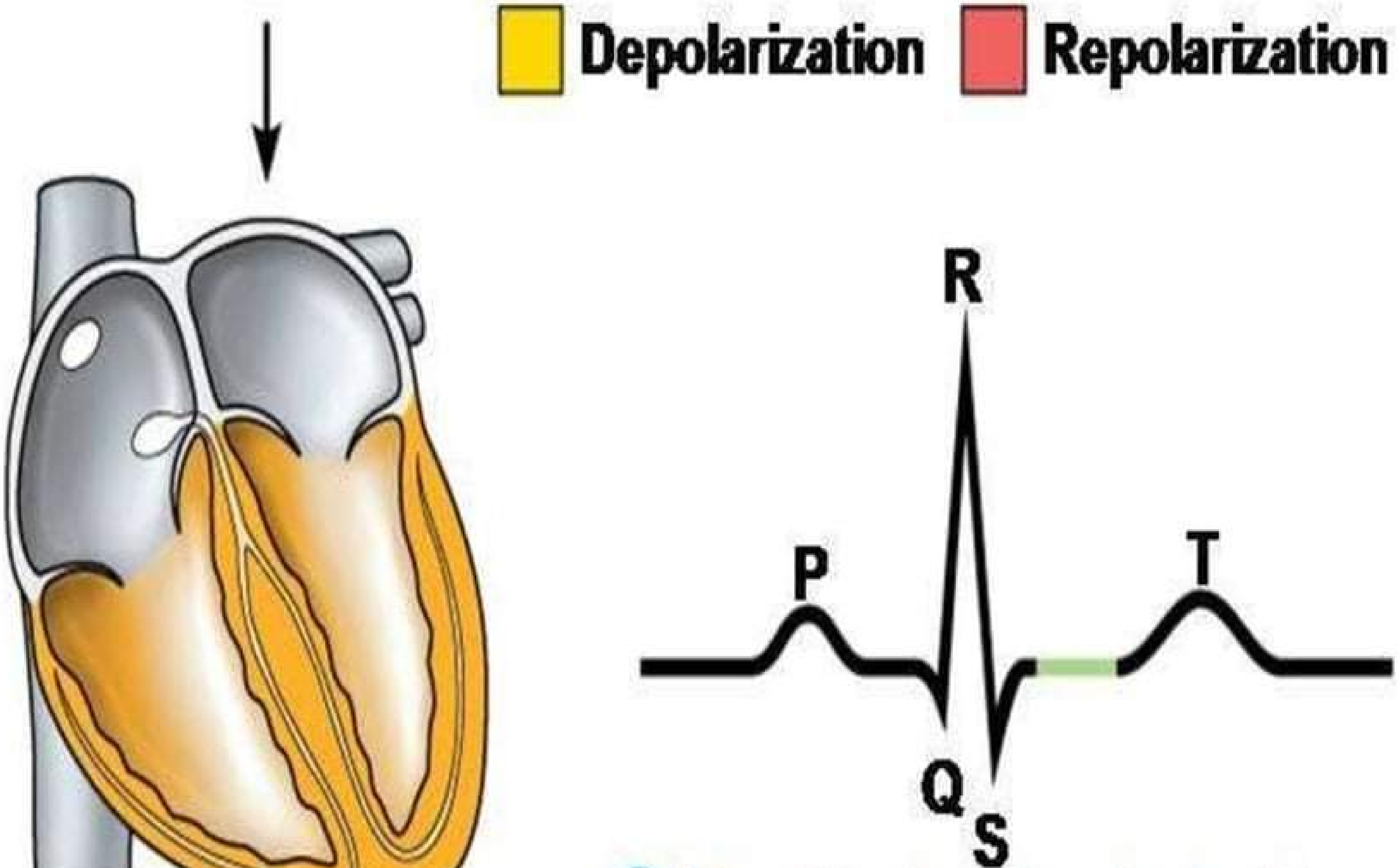




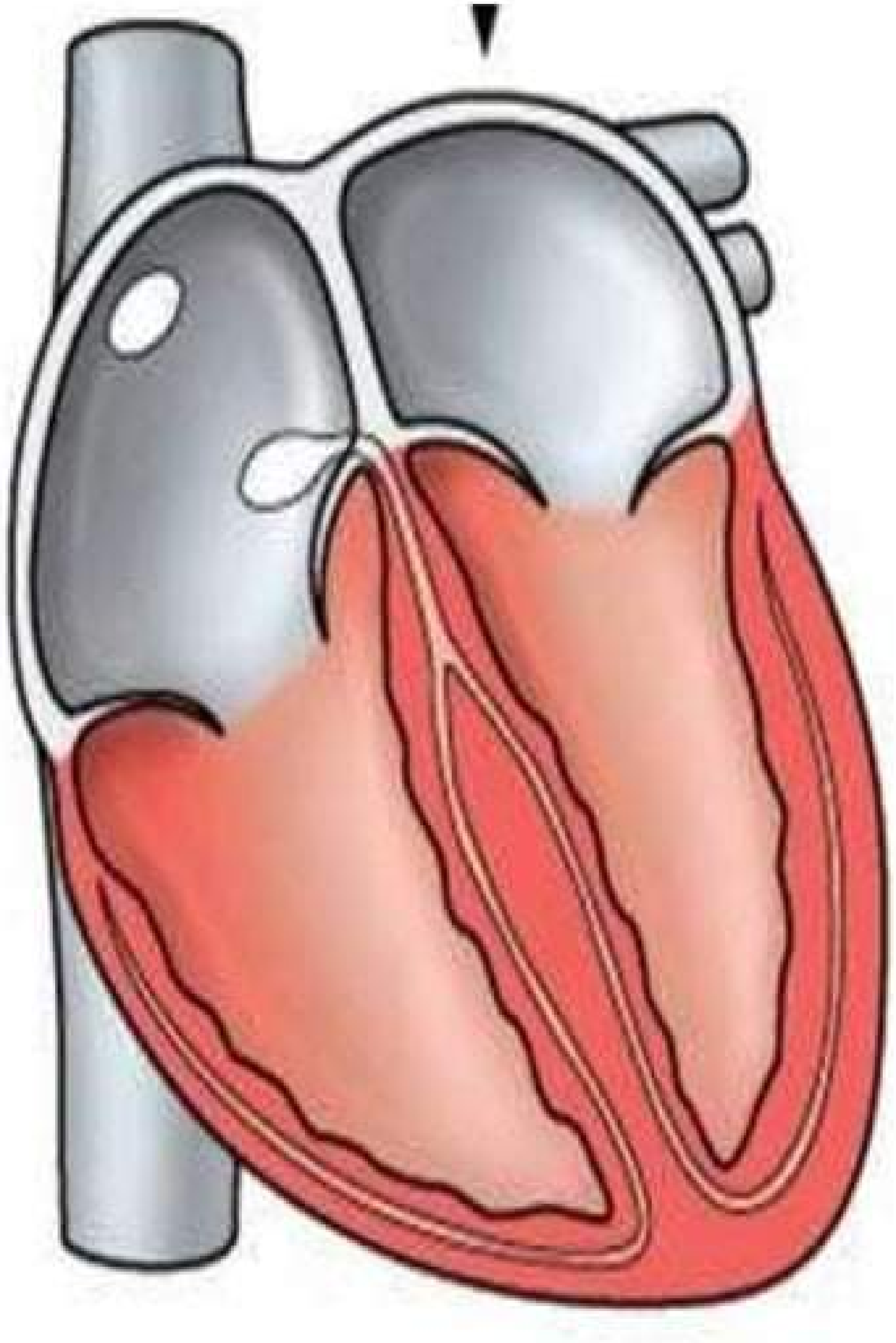


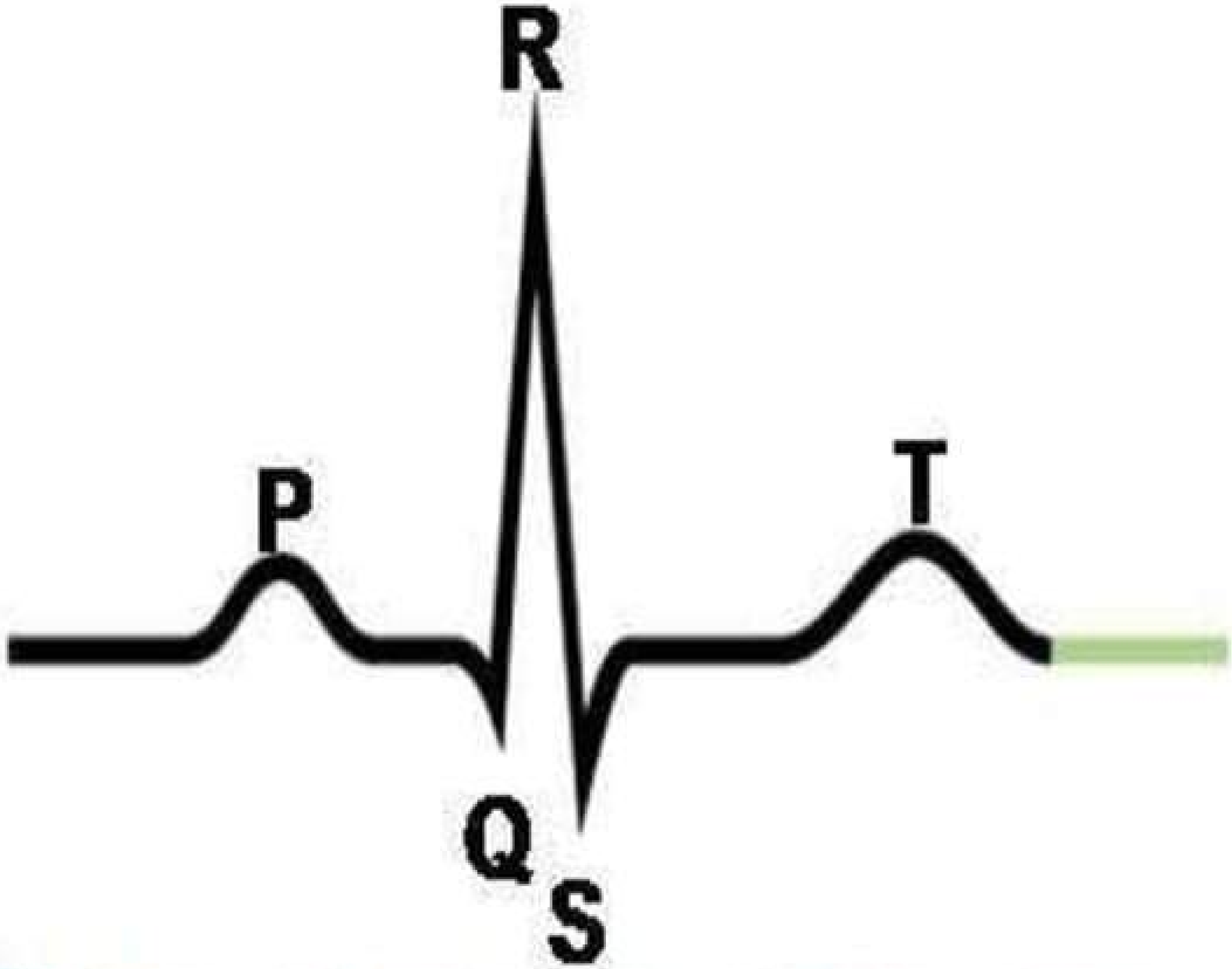
③ Ventricular depolarization begins at apex, causing the QRS complex. Atrial repolarization occurs.

Ventricle contraction –
wave of depolarization flows through the B. of HIS.



④ Ventricular depolarization is complete.





6 Ventricular repolarization is complete.

FACTS

-SAN initiates heartbeat

-Beat of heart is myogenic – spontaneous not started by nervous system stimulus

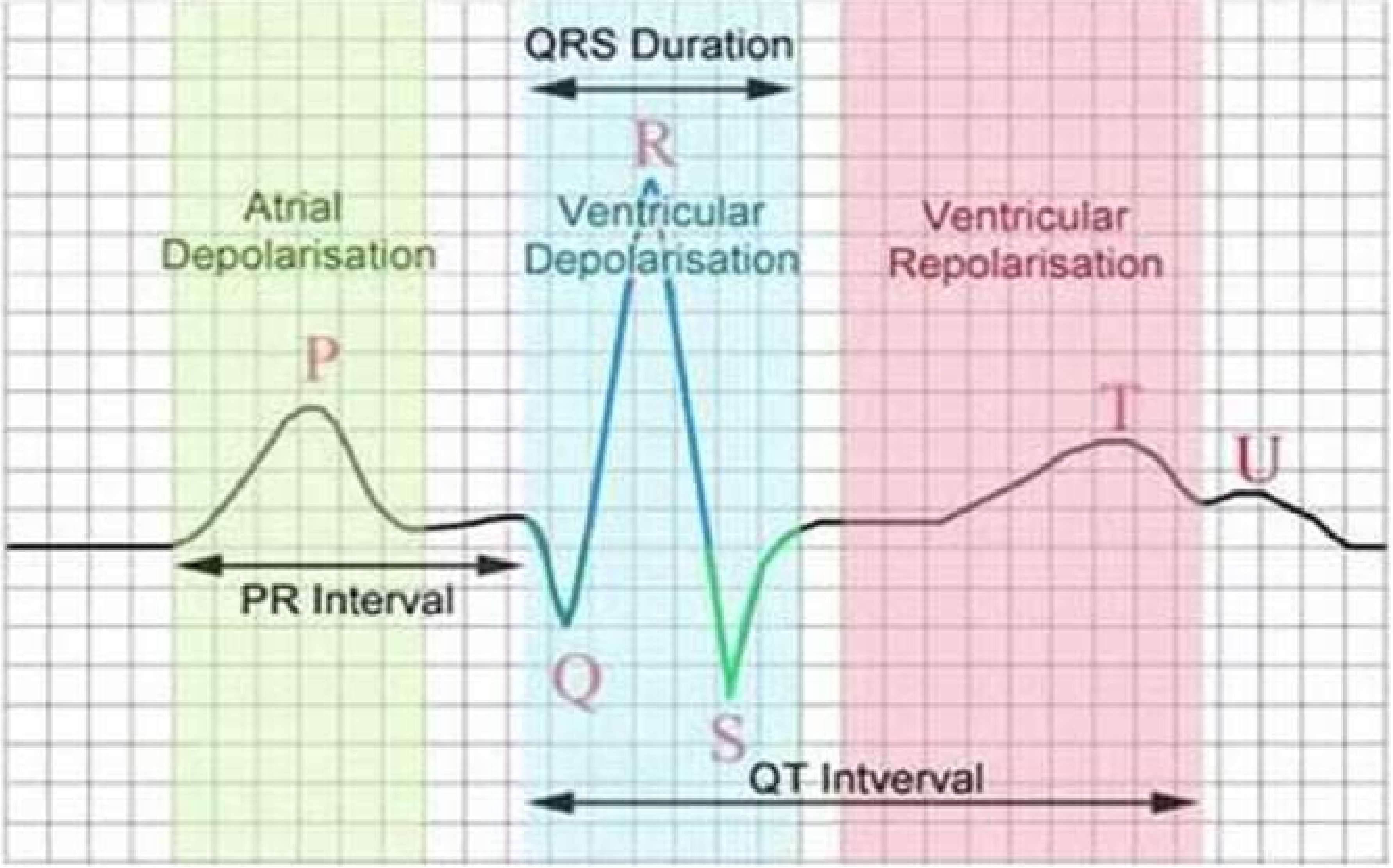
-Rate of heartbeat is influenced by nervous system

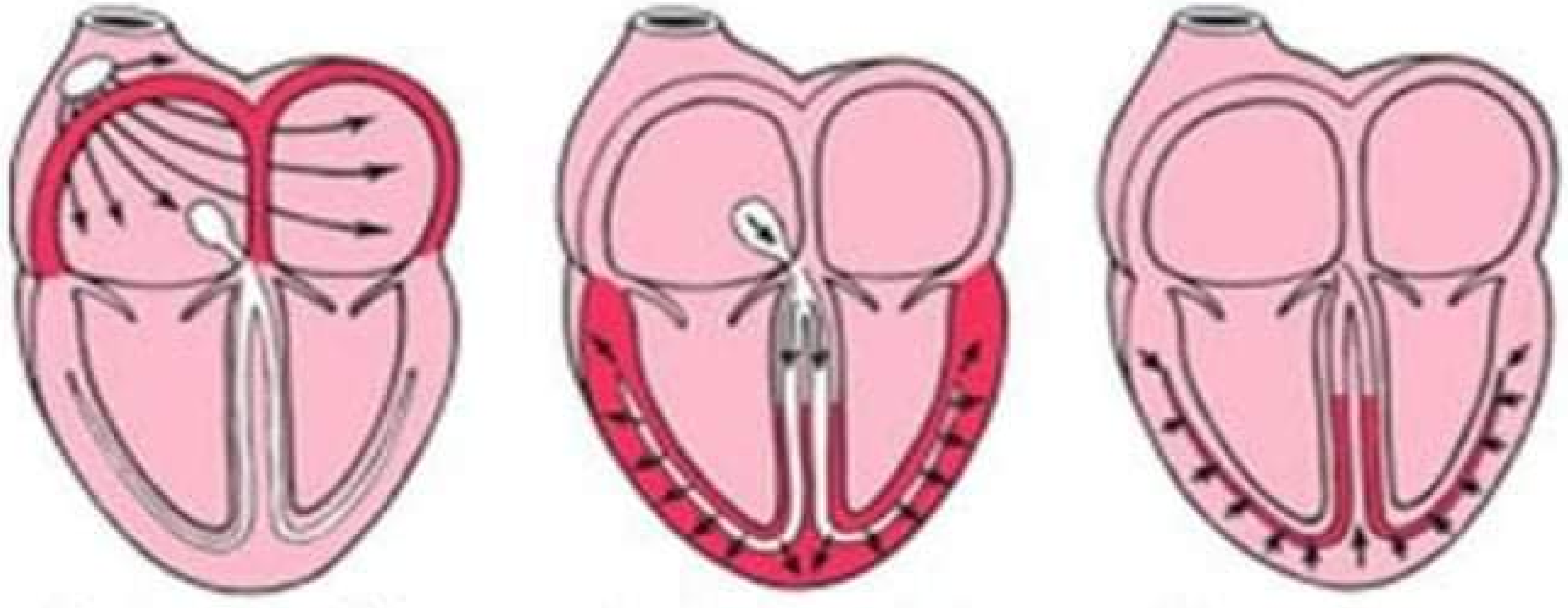
-Wave of electrical activity, impulses over atria triggers contraction of atrium

-Electrical activity may only pass to the ventricles via AVN and bundle of HIS (septum)

-Fibrous tissue prevents passage beyond atria

-Delay at AVN allows ventricles to fill completely from atria





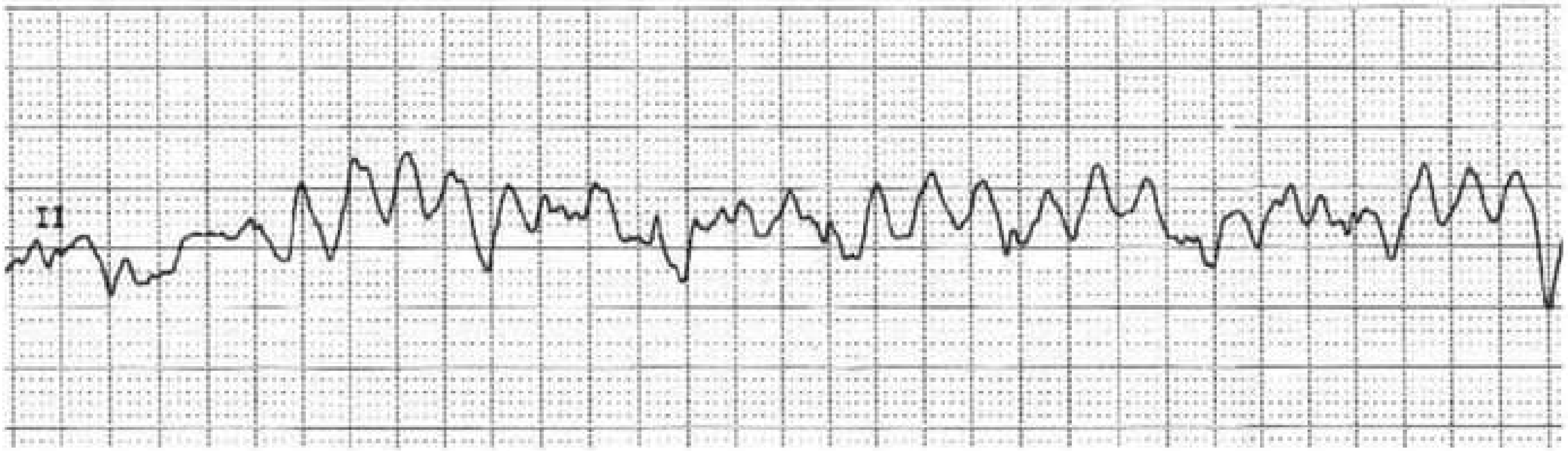
Activation of the atria

Activation of the ventricles

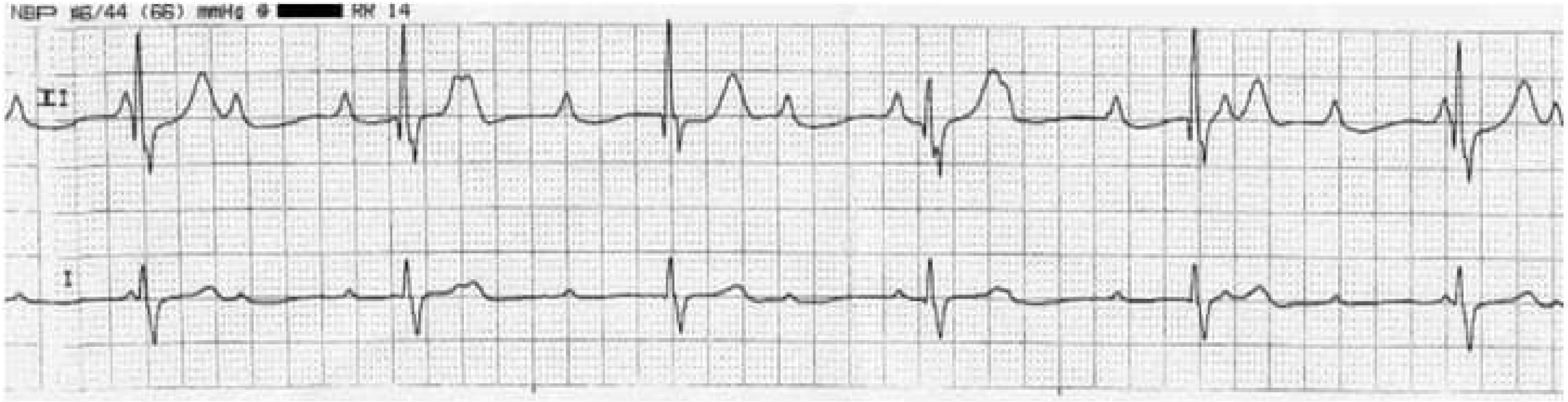
Recovery wave

http://www.ivline.org/2010/05/quick-guide-to-ecg.html#at_pco=smlre-1.0&at_si=5420a7df299cca88&at_ab=per-2&at_pos=0&at_tot=4

Ventricular fibrillation

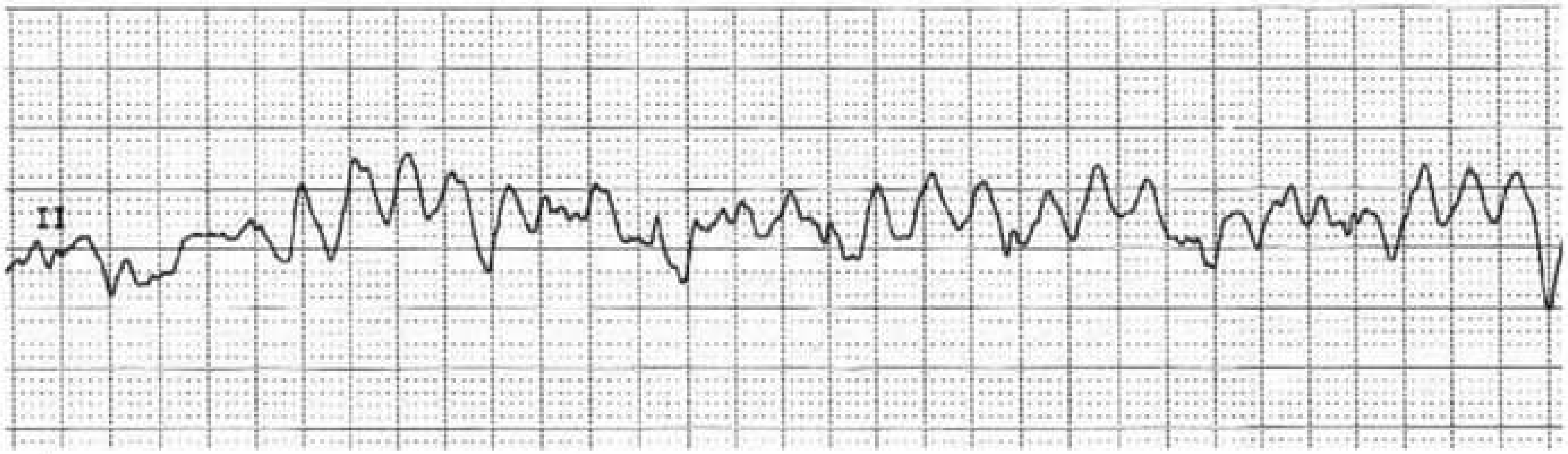


Heart Block



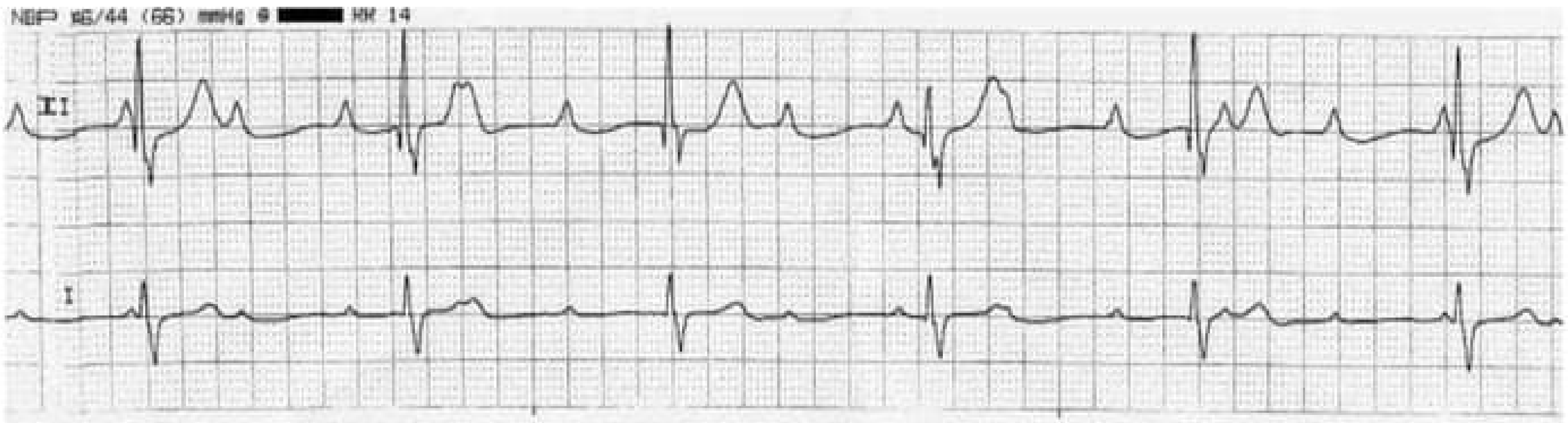
What do you think is happening in the ECG?

Ventricular fibrillation



Uncontrolled contraction of the ventricles causes little blood to be pumped

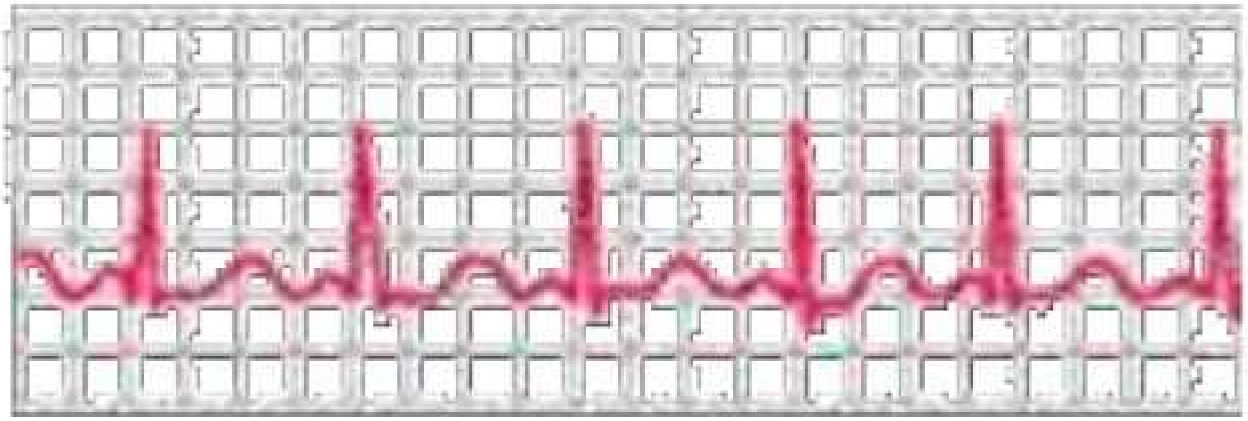
Heart Block

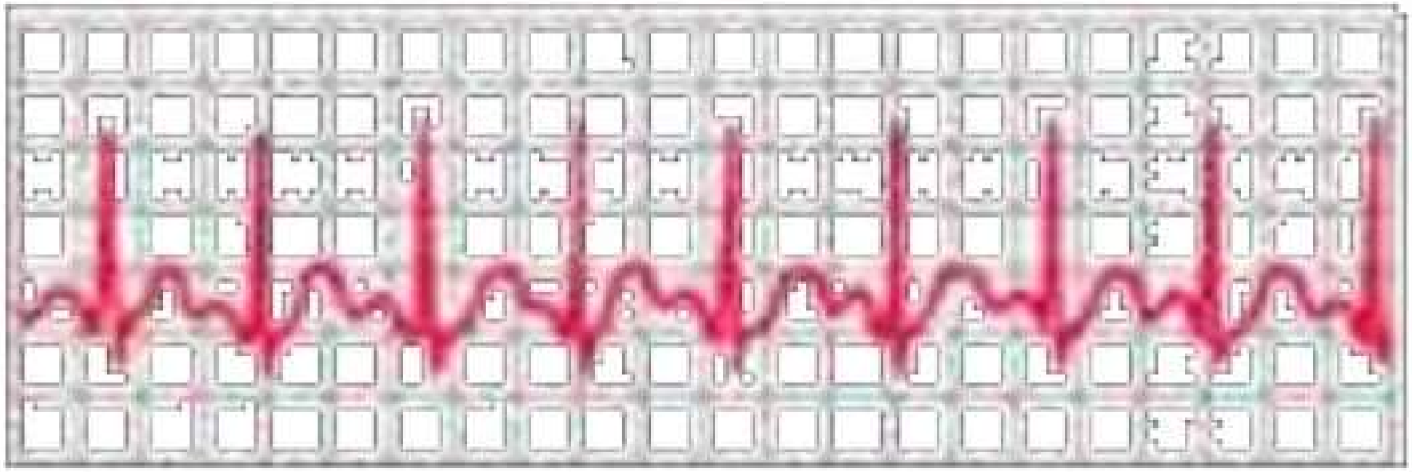


Ventricles are not always stimulated

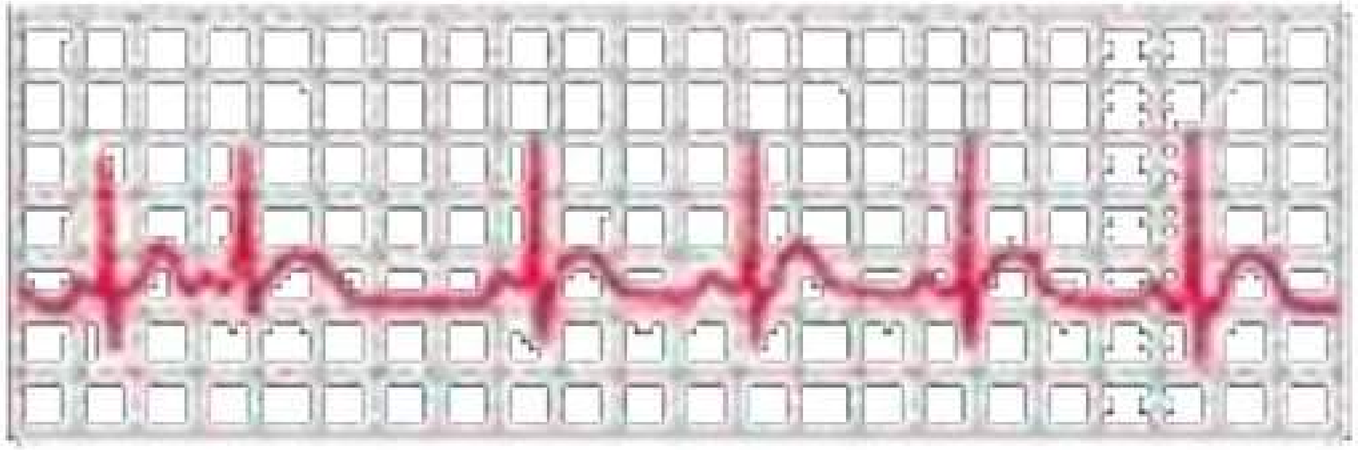
What do you think is happening in the ECG?

Match the beat with the ECG.

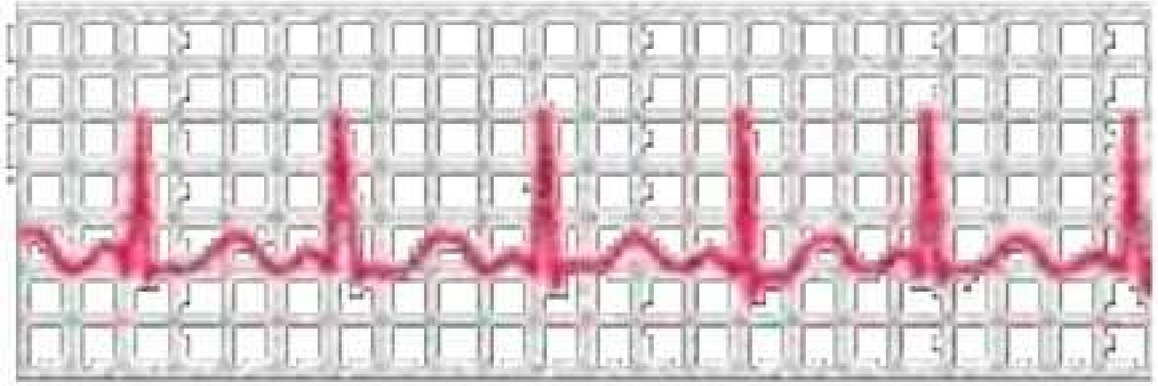




Irregular   Tachycardia   Bradycardia   Normal



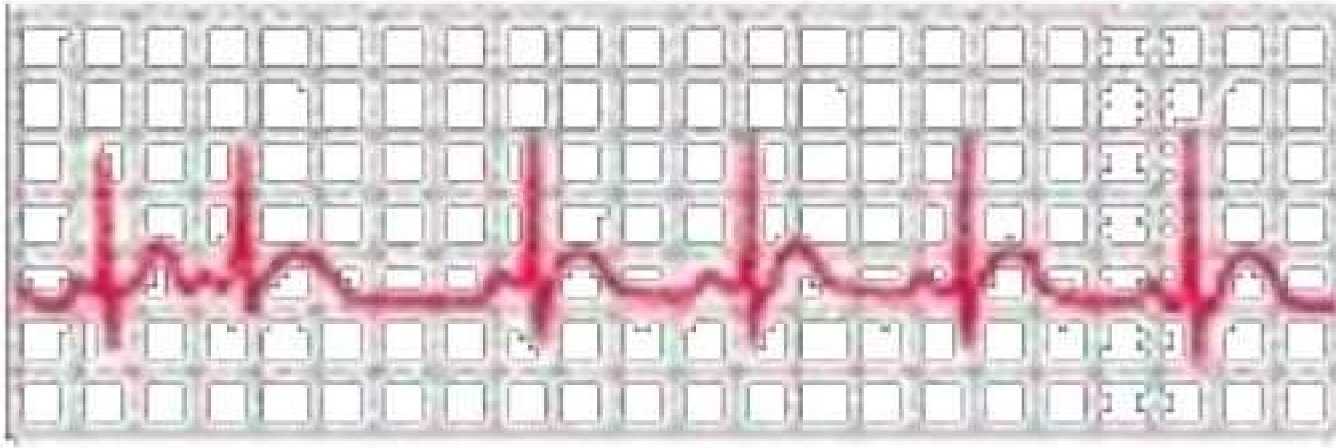
Normal



Tachycardia - Fast

Bradycardia - Slow

Irregular

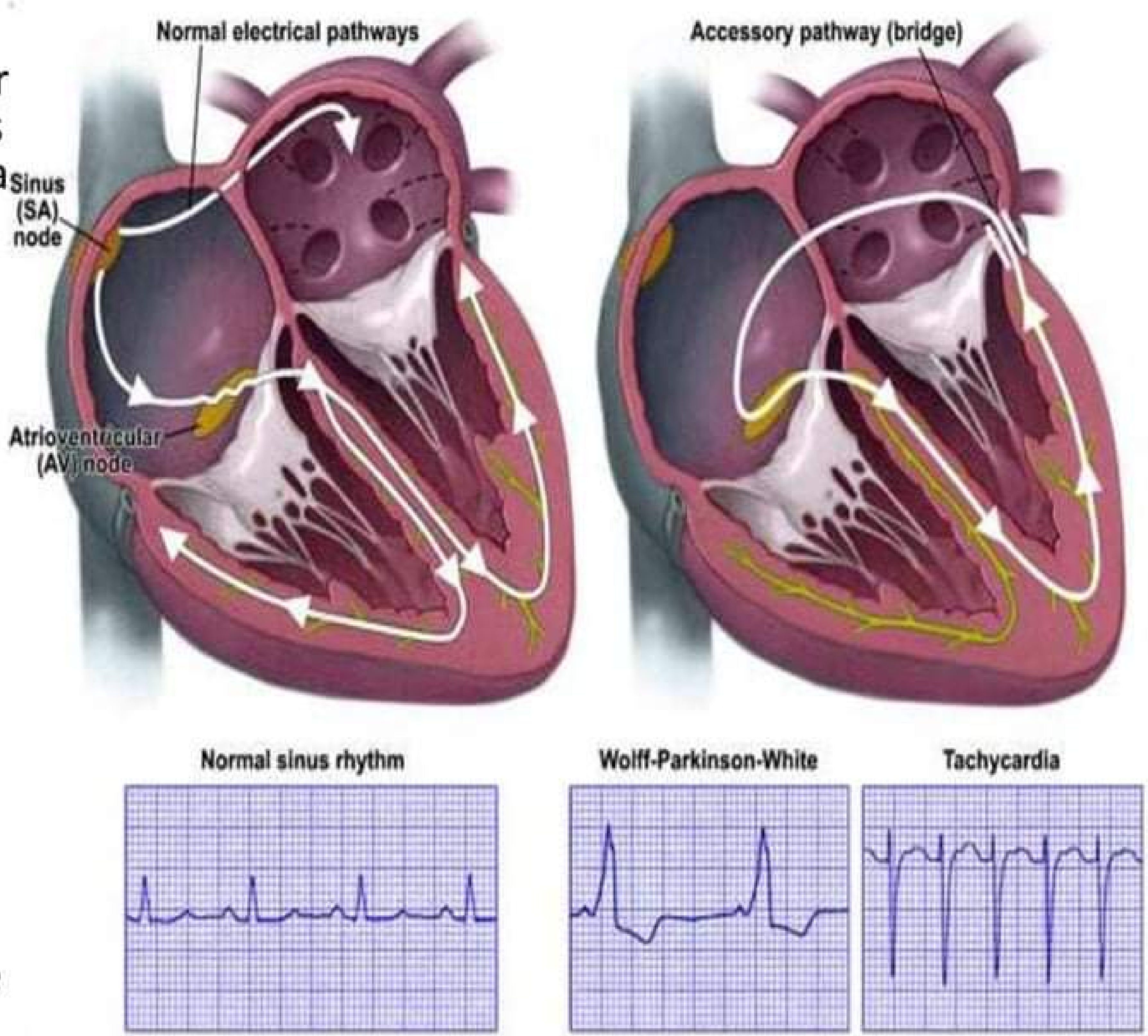


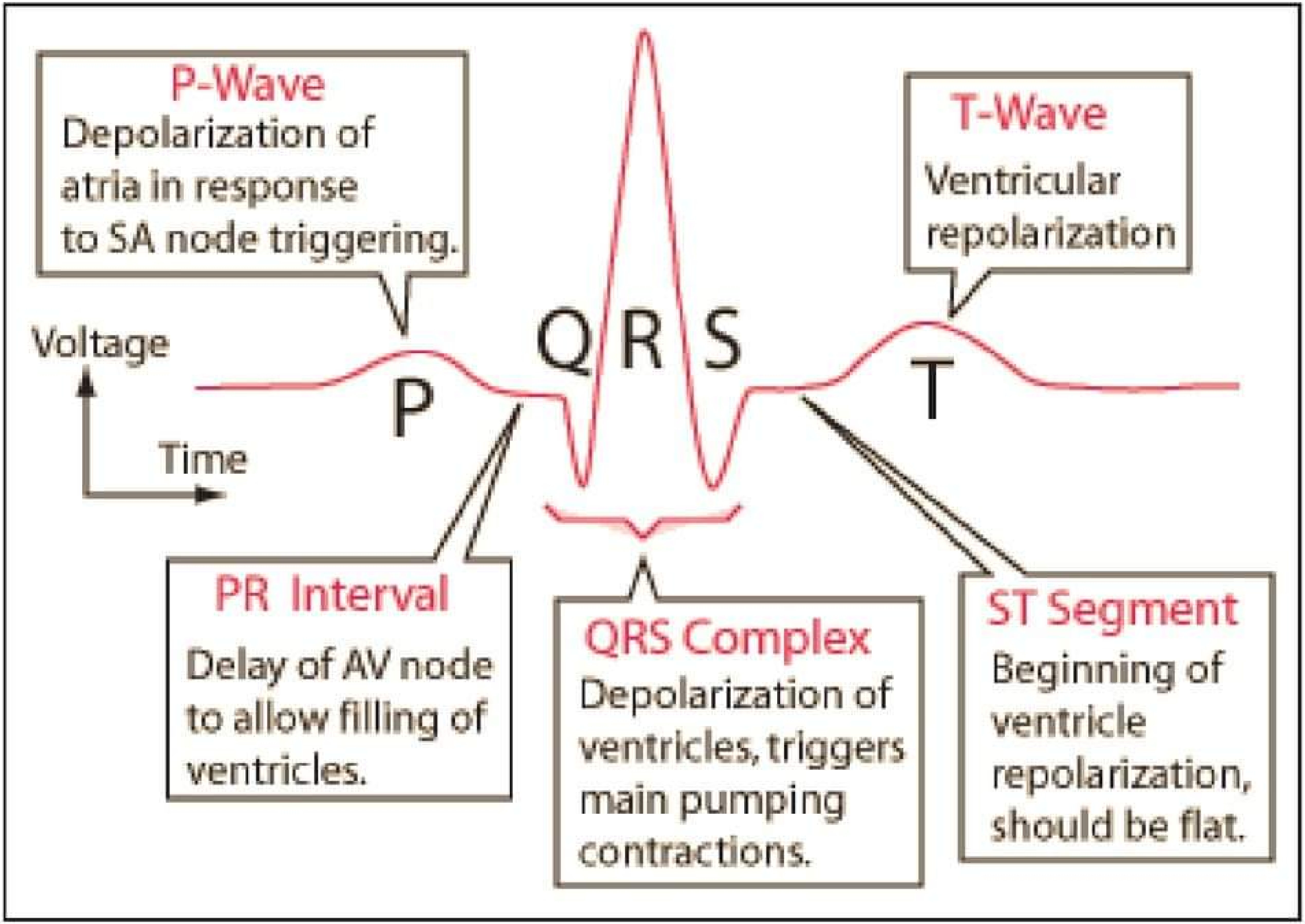
Wolff-Parkinson-White (WPW) Syndrome

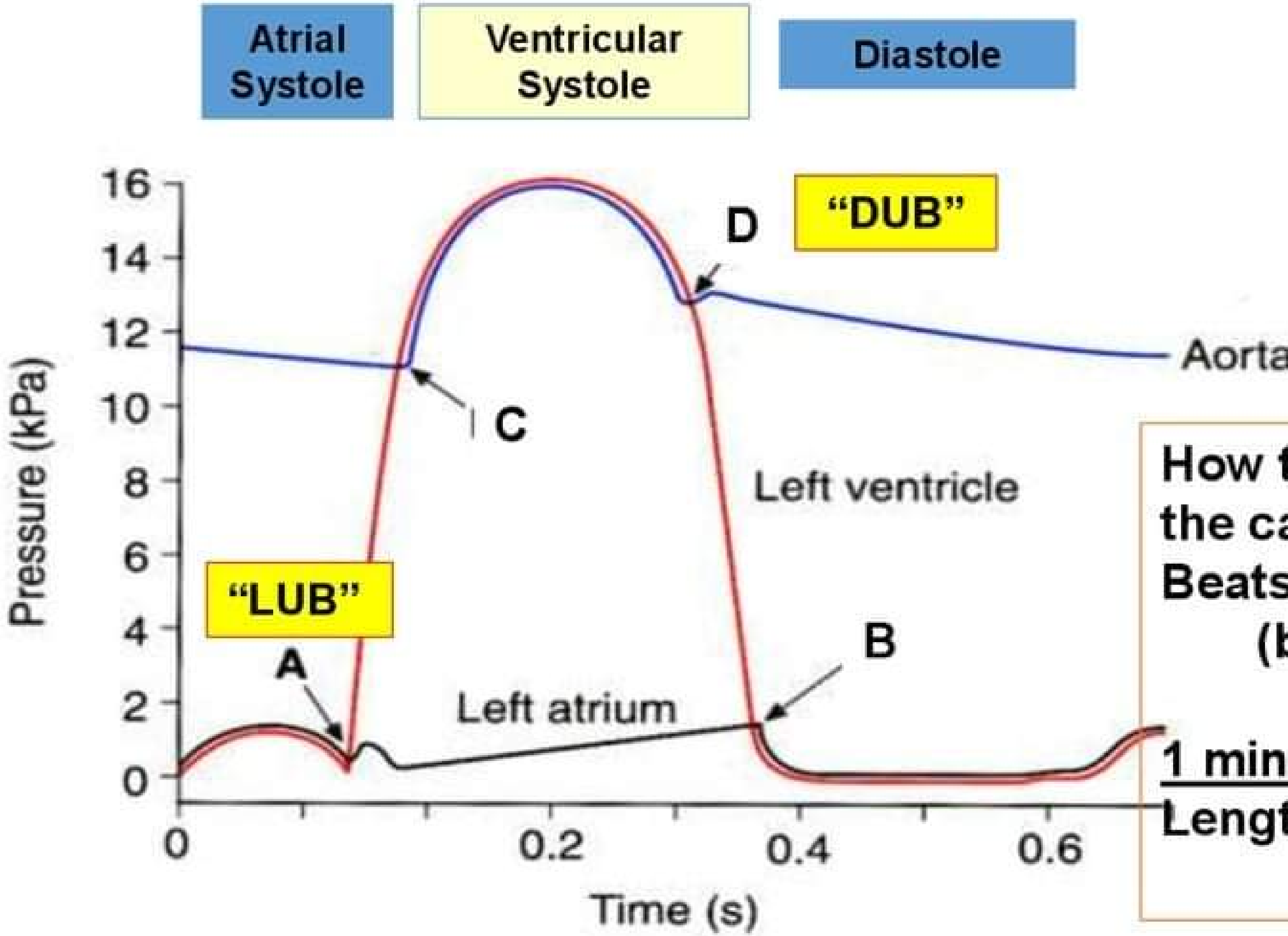
An extra electrical pathway between your heart's upper and lower chambers causes a rapid heartbeat. The extra pathway is present at birth and fairly rare.

WPW syndrome is **defined** as a congenital condition involving abnormal conductive cardiac tissue between the atria and the ventricles that provides a pathway for a reentrant tachycardia circuit

The accessory bridge is called the **bundle of Kent**. It runs along the wall of the the left ventricle.




P-Wave
Depolarization of atria in response to SA node triggering.
T-Wave
Ventricular repolarization
Voltage
Time
P
Q
R
S
T
PR Interval
Delay of AV node to allow filling of ventricles.
QRS Complex
Depolarization of ventricles, triggers main pumping contractions.
ST Segment
Beginning of ventricle repolarization, should be flat.



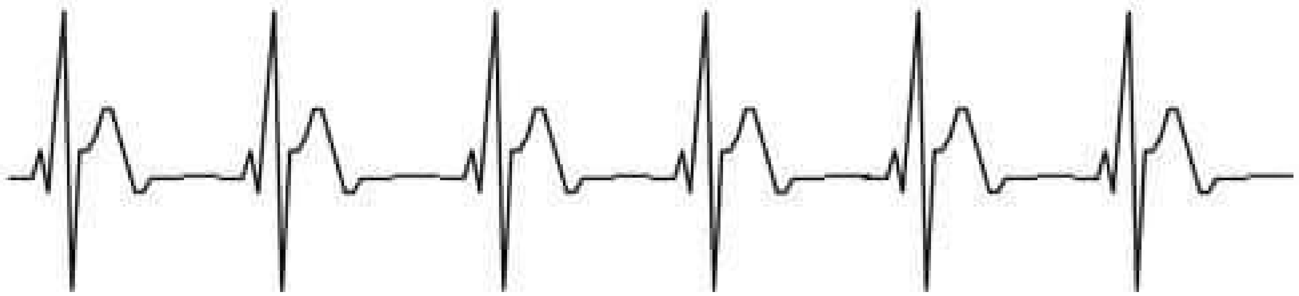
How to calculate the cardiac cycle Beats per minute (bpm).

$$\frac{\textbf{1 minute (60s)}}{\textbf{Length one cycle}}$$

A	Atrioventricular (bicuspid / mitral) valve(s) closes ("snaps shut"– makes 1st louder heart sound "LUB"
B	Semilunar valve(s) (aortic valve) opens
C	Semilunar valve(s) closes – makes second softer heart sound "DUB"- shut due to blood accumulating in their pockets
D	Atriioventricular (bicuspid) valve(s) opens

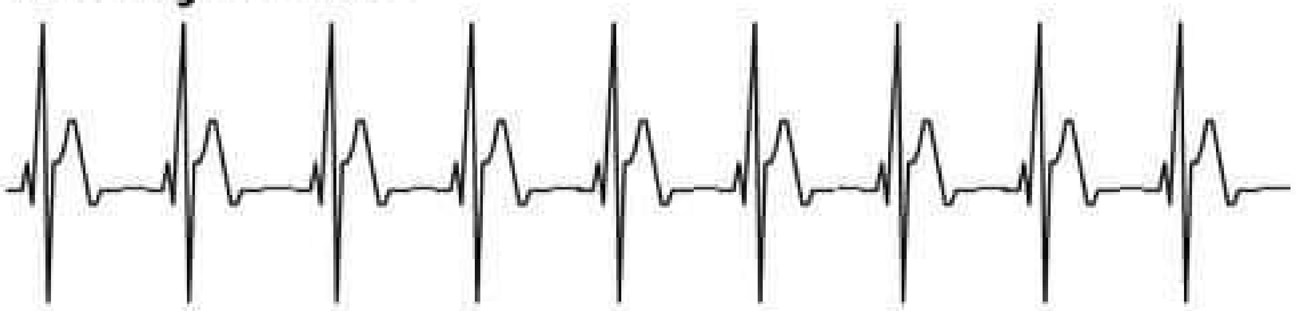
Tachycardia

Normal – for reference



6 beats per 5 seconds = 72 bpm

Tachycardic

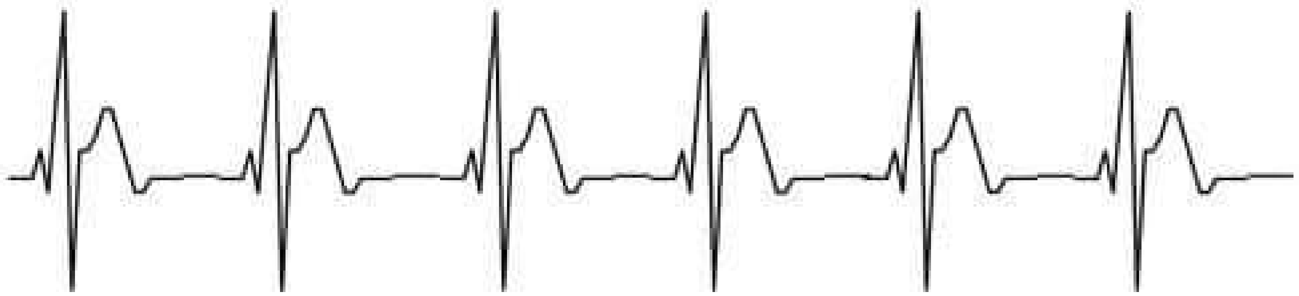


9 beats per 5 seconds =108 bpm

- Increased heart rate is a normal response to:
  - exercise
  - excitement
  - stress
  - drugs e.g. caffeine, nicotine, amphetamine (speed).
- Tachycardia is elevated heart rate for no reason.
- Sometimes heart rate is so high that little blood is actually pumped:
  - filling time too short.
- Treatment might involve:
  - relaxation therapy
  - β-blocker.

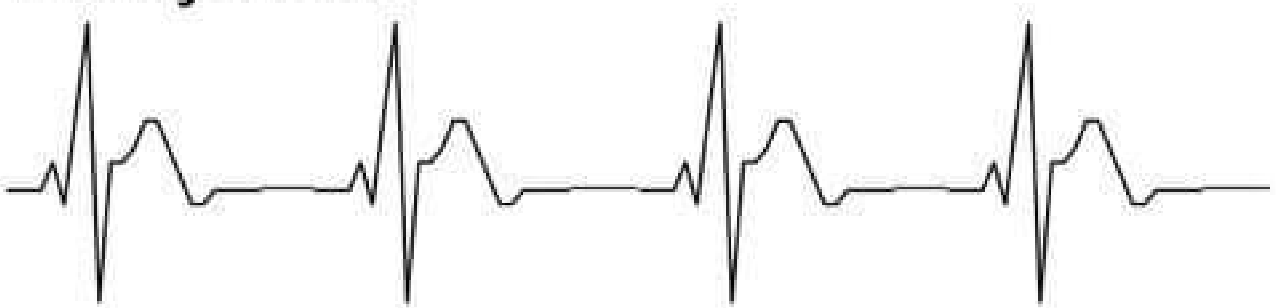
Bradycardia

Normal – for reference



6 beats per 5 seconds = 72 bpm

Bradycardic

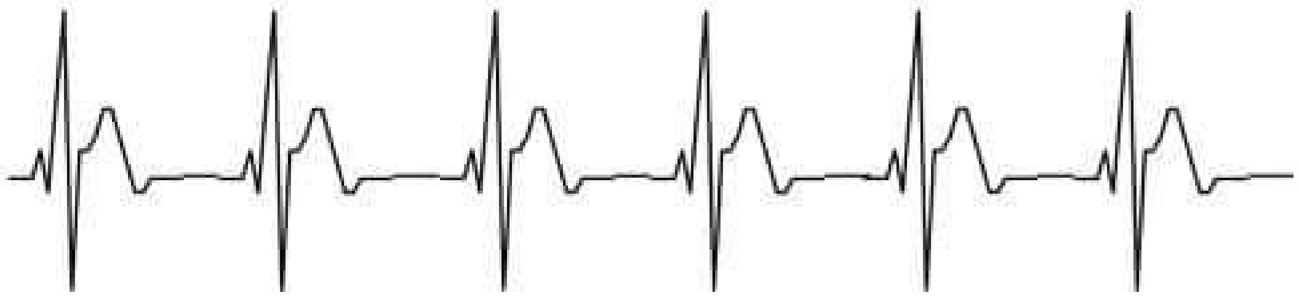


4 beats per 5 seconds = 48 bpm

- Pattern of electrical activity is normal but slow.
- Reduced heart rate could indicate:
  - good aerobic fitness (elite athletes like Steve Redgrave have resting heart of ca. 45 bpm).
  - Alternatively might be caused by drugs:
    - tranquilisers
    - β-blocker.
- Cause may need investigation:
  - stagnation
  - risk of blood clots.

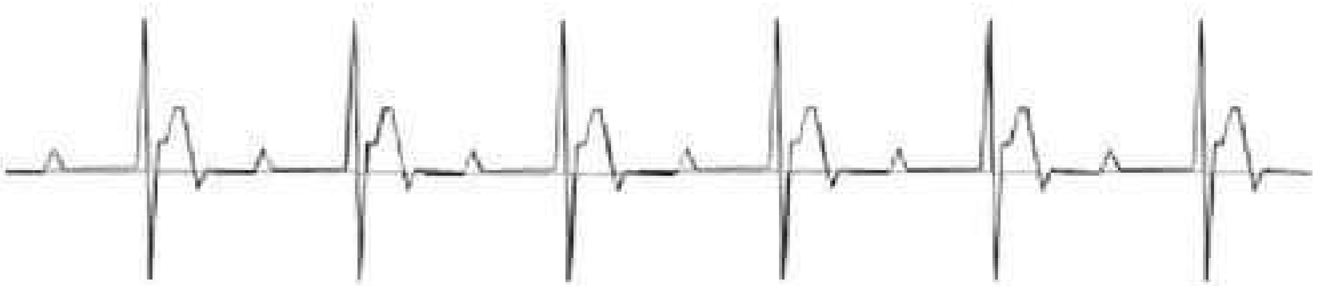
Heart block

Normal – for reference



6 beats per 5 seconds = 72 bpm

Heart block

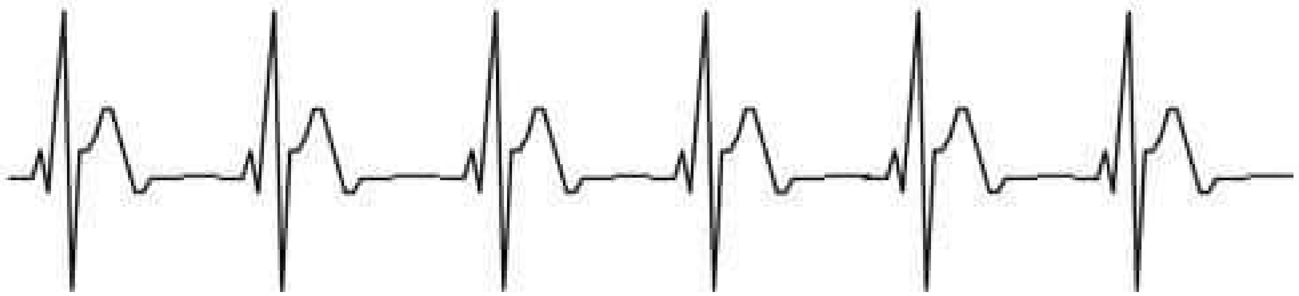


Dissociated P and QRS complex

- There is separation of the P wave and the QRS complex.
- Pacemaker activity and atrial contraction is normal.
- Delay in conduction between atria and ventricles.

Fibrillation

Normal – for reference

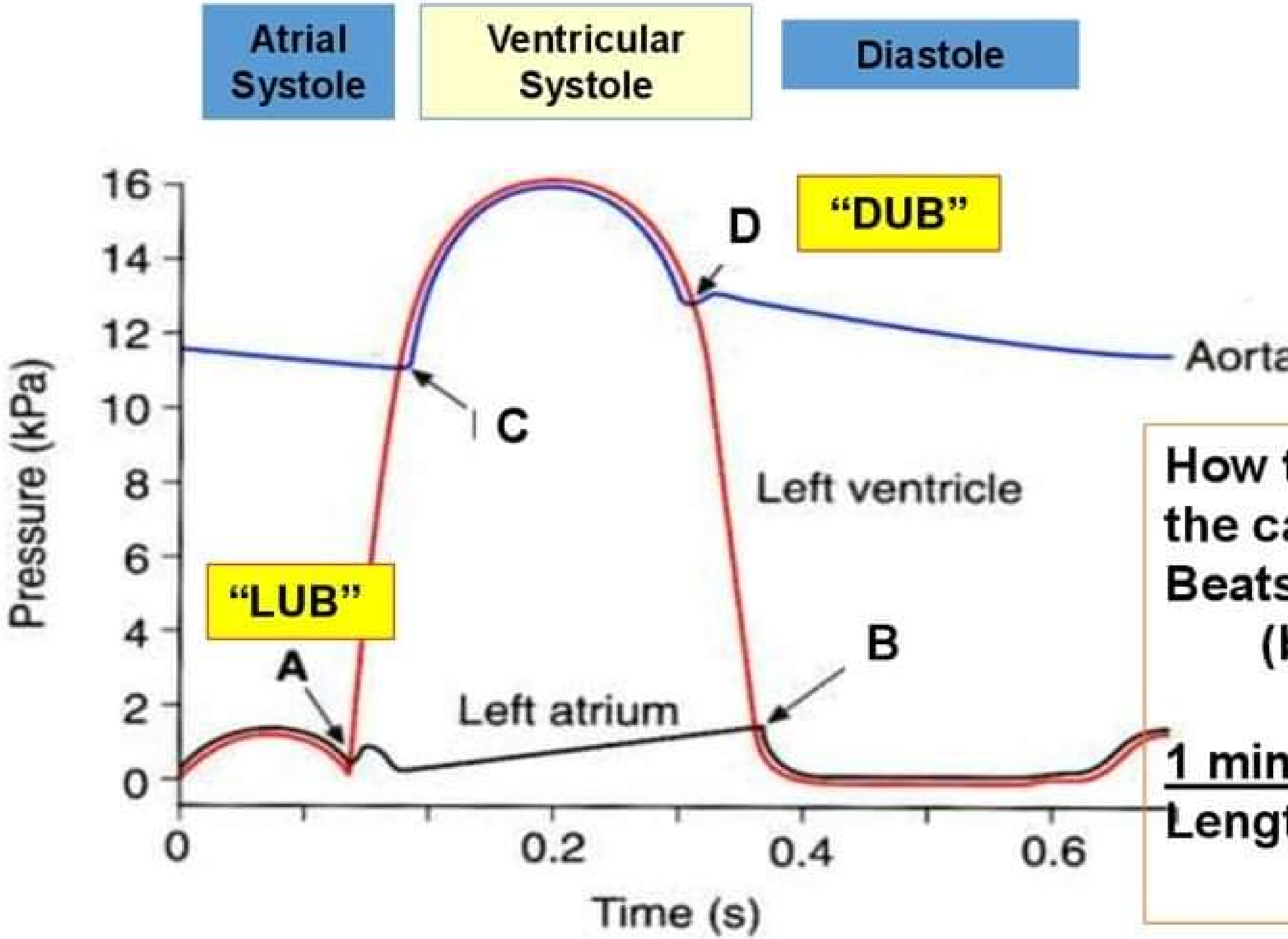


6 beats per 5 seconds = 72 bpm

Ventricular fibrillation (VF)

Uncoordinated and weak contraction

- Contraction of cardiac muscle is normally coordinated.
- In VF the ventricles contract, but it is not coordinated:
  - fluttering
  - little blood is pumped.
- Defibrillation may work:
  - heart is shocked
  - heart stops
  - when it restarts, it may do so with a normal rhythm.



How to calculate the cardiac cycle Beats per minute (bpm).

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D	Atriioventricular (bicuspid) valve(s) opens

What is the maximum pressure reached in the left ventricle?

- 16 kPa. Corresponds to ventricular systole – contraction of the left ventricle reduces ventricle volume and so increases pressure.

Why is the maximum pressure in the left atrium lower?

- Left atrium muscle is much thinner, so cannot generate as much pressure. Does not need to pump the blood very far.

What is the length of one cardiac cycle?

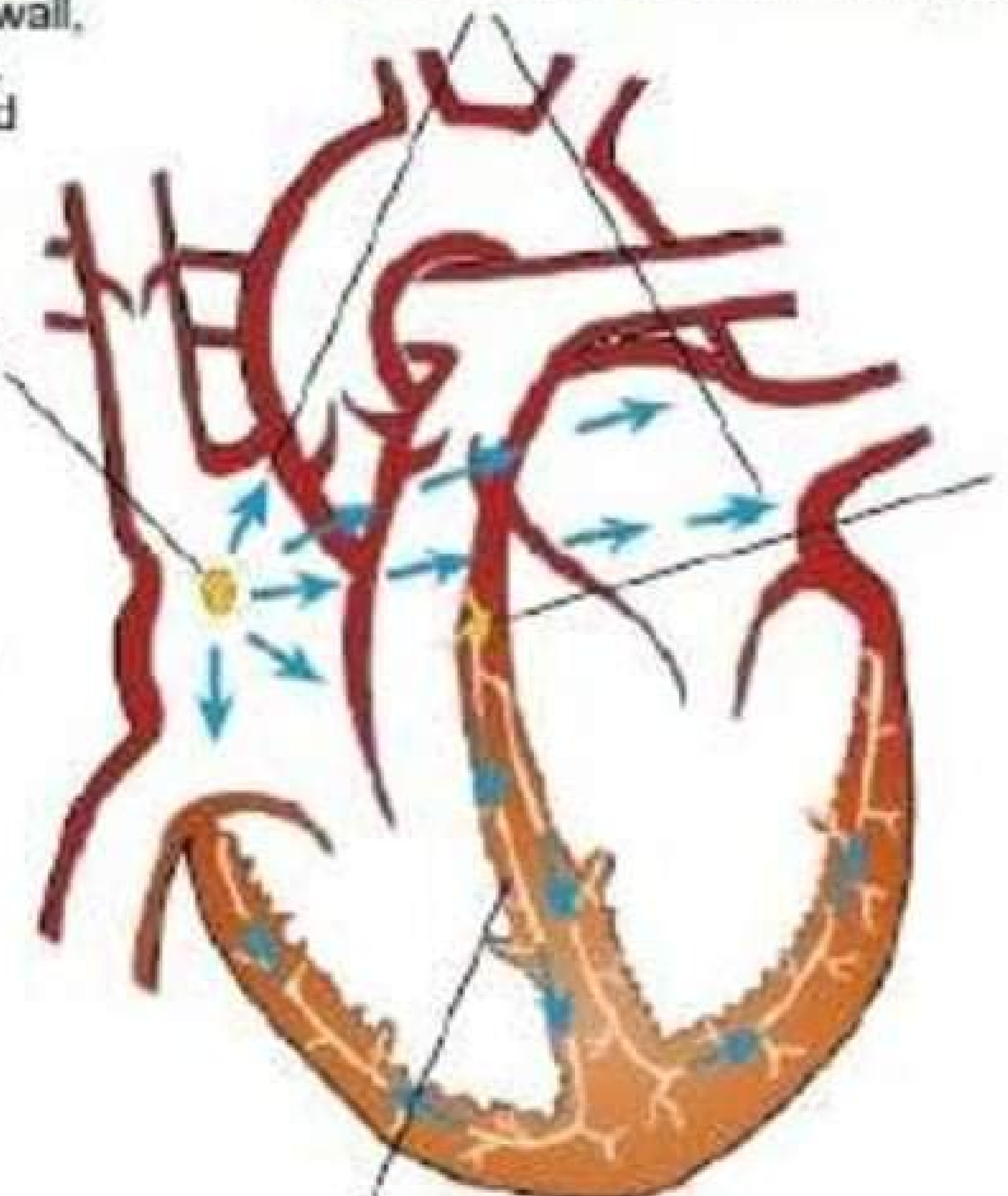
- Approximately 0.75 s

Using the length of cardiac cycle, what is the pulse rate in bpm? Show your work!

- 60/0.75 = 80 bpm

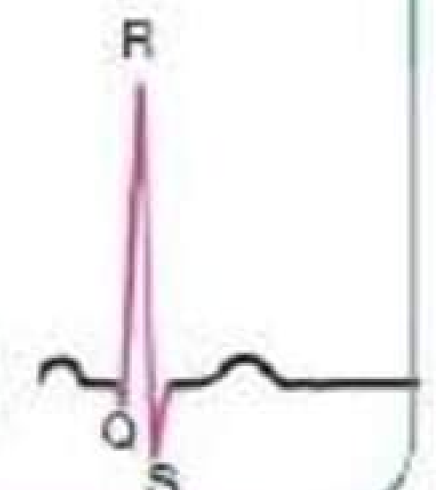
1 Each cardiac cycle begins in the right atrium. There is a small patch of muscle tissue in the right atrium wall, called the sino-atrial node (SAN), which automatically contracts and relaxes all the time. It doesn't need a nerve impulse to start it off, so it is said to be myogenic – that is, 'started by the muscle'. The SAN is often called the pacemaker, because it sets the pace at which the whole heart beats. However, the pacemaker's rate can be adjusted by nerves transmitting impulses to the pacemaker from the brain.

2 As the muscle in the SAN contracts, it produces an electrical impulse which sweeps through all of the muscle in the atria of the heart. This impulse makes the muscle in the atrial walls contract. The impulse shows up on the ECG as the P wave. So the P wave represents the electrical activity just before atrial systole.



3 The impulse sweeps onwards and reaches another patch of cells called the atrio-ventricular node (AVN). This node is the only way in which the electrical impulse can get down to the ventricles. The AVN delays the impulse for a fraction of a second, before it travels down into the ventricles. This delay means that the ventricles receive the signal to contract after the atria.

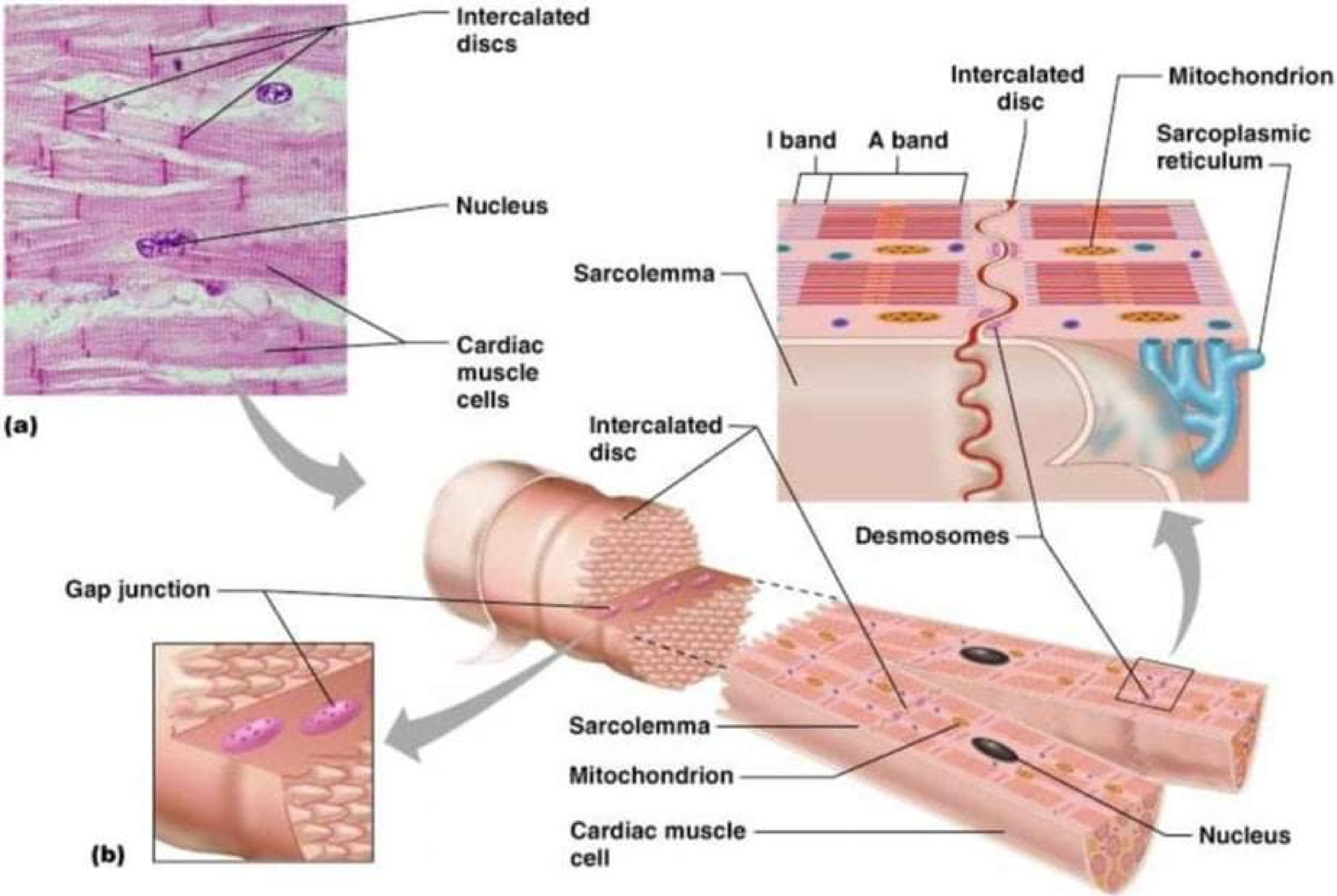
4 The impulse moves swiftly down through the septum of the heart, along fibres known as Purkyne tissue. Once the impulse arrives at the base of the ventricles it sweeps upwards, through the ventricle walls. This is shown by the Q, R and S part of the ECG. The ventricles then contract.



5 The ventricles then relax, indicated by the T wave. Then the muscle in the SAN contracts again, and the whole sequence runs through once more.

Microscopic Anatomy of Heart Muscle

Only know (a)



How does the structure of cardiac muscle differ from cardiac muscle?