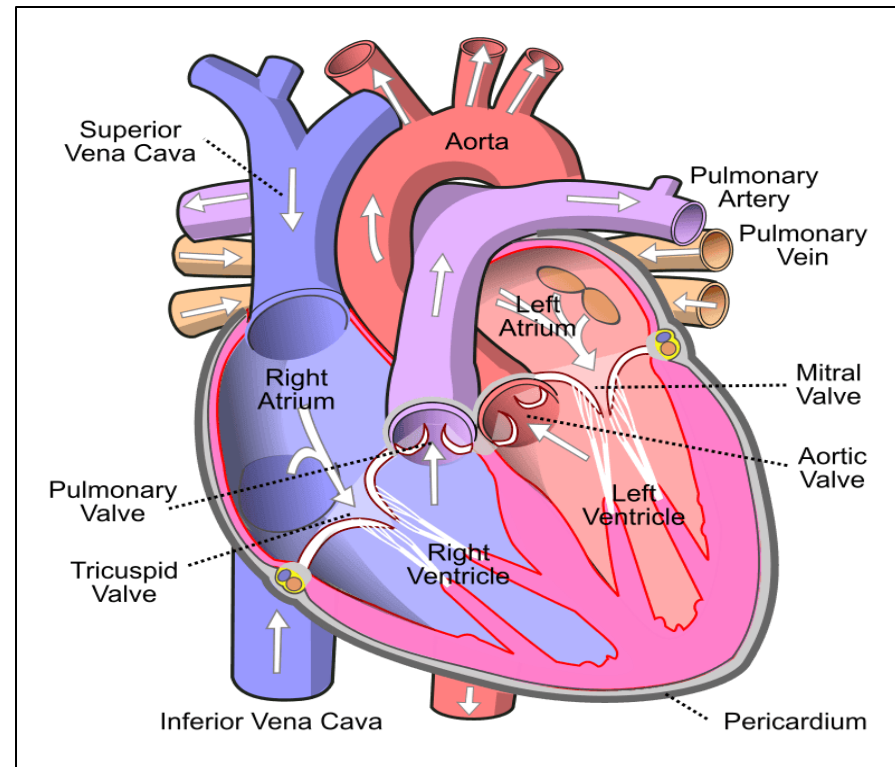


The cardio-vascular system

Third Year



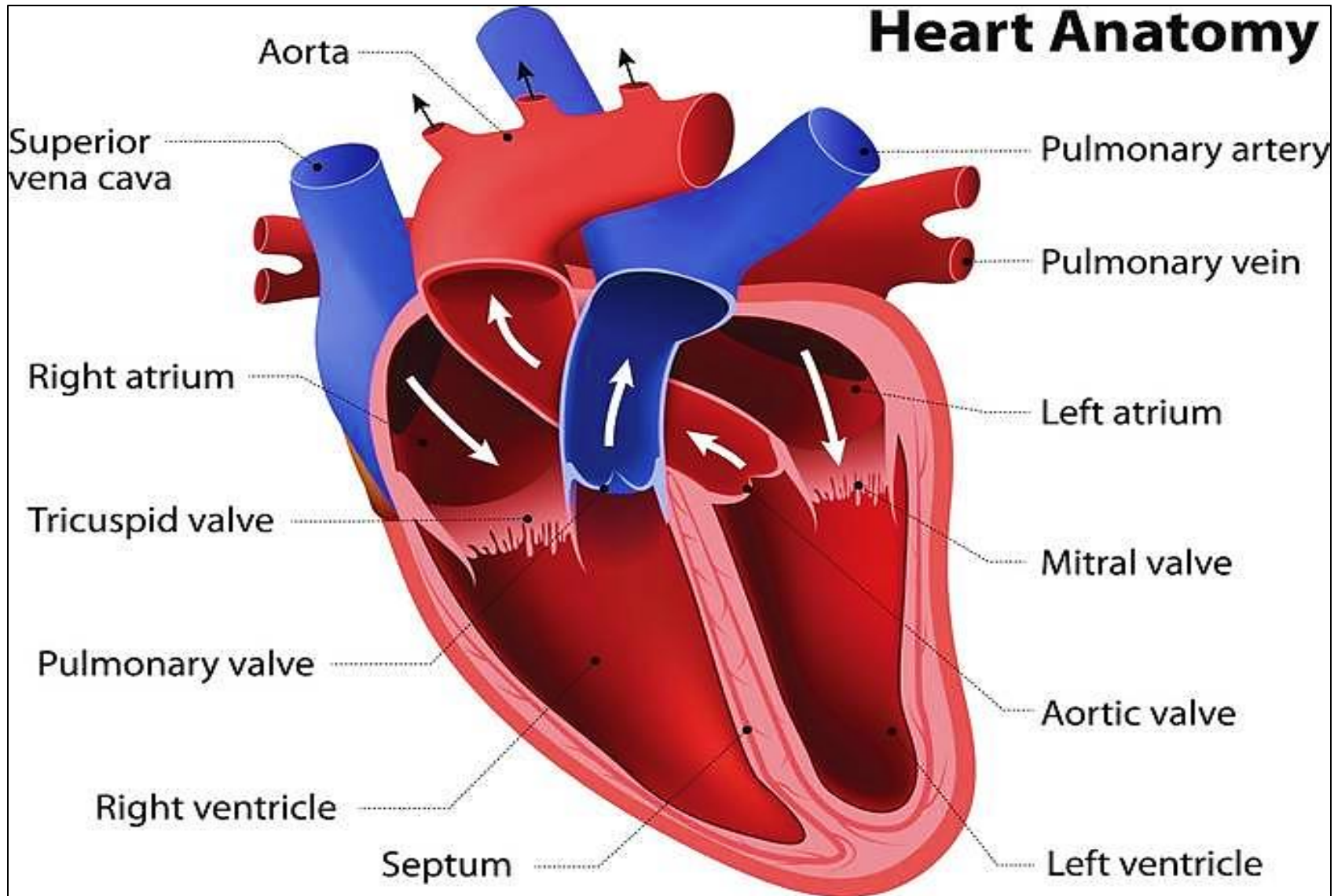
Heart

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graph TD; Heart[Heart] --- Cardiac[Cardiac muscles]; Heart --- Conducting[Conducting system]; Heart --- Fibrous[Fibrous skeleton];
```

**Cardiac
muscles**

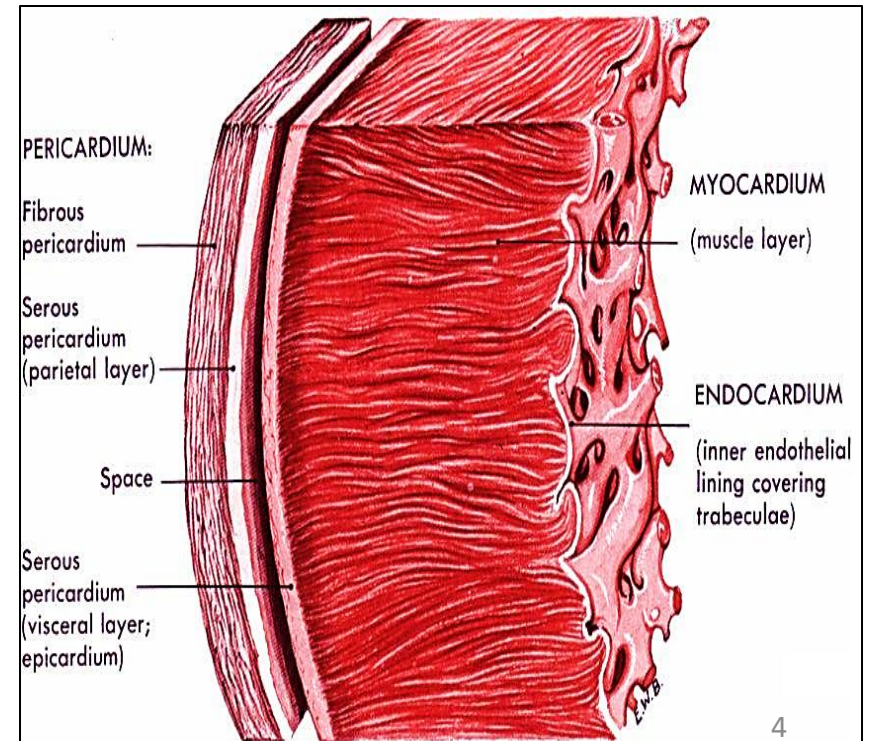
**Conducting
system**

**Fibrous
skeleton**

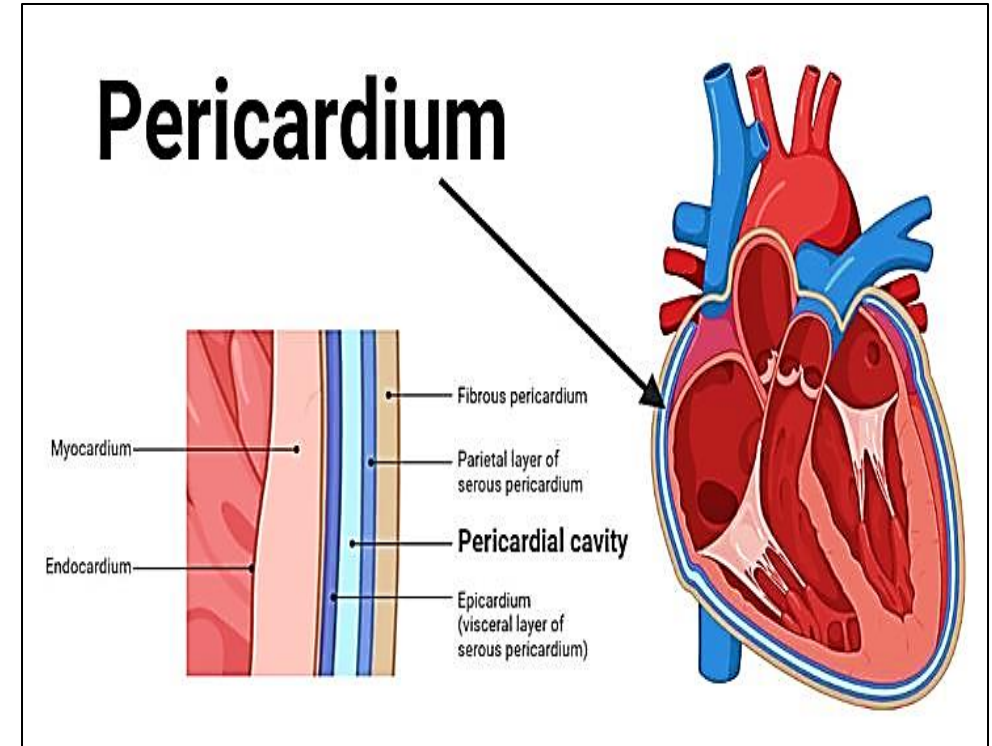
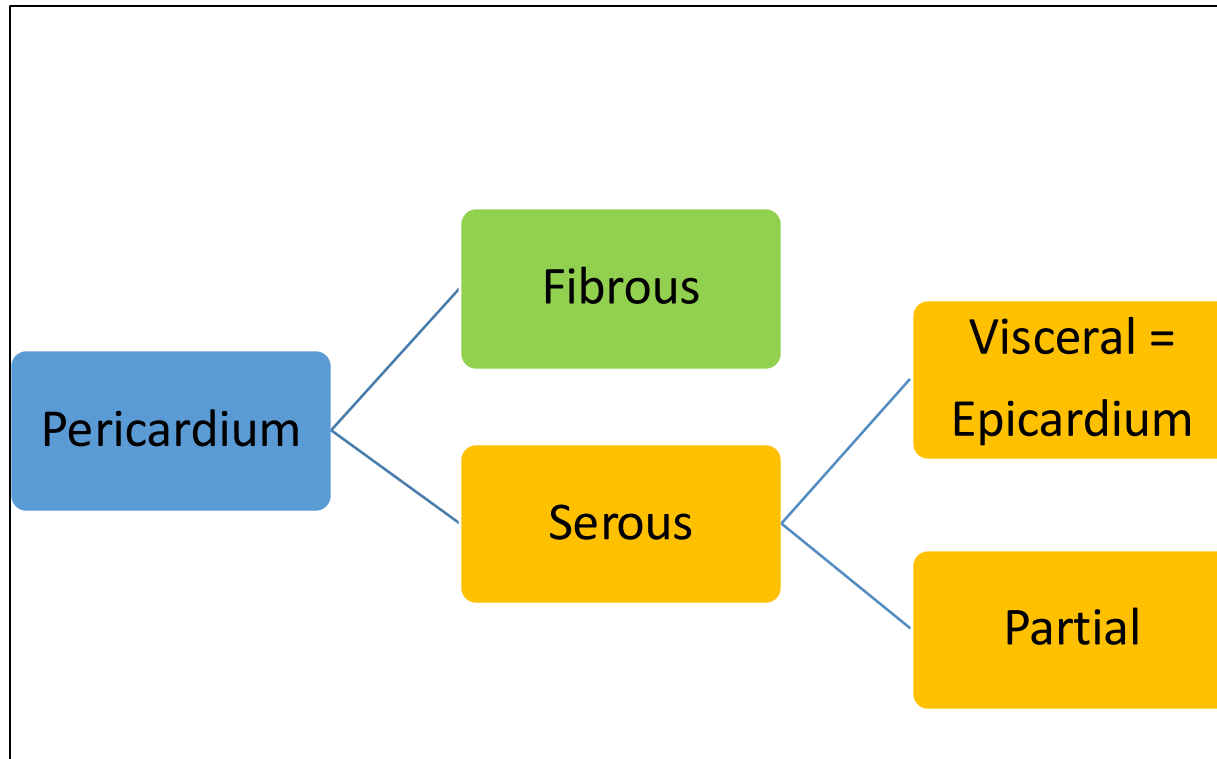


The Heart

- The heart is a 4 chambers pump composed of 2 atria & 2 ventricles
- The heart push the blood to the body through a network of blood vessels
- The wall of heart consists of 3 layers:
 - Endocardium
 - Myocardium
 - Epicardium
- Heart is surrounded by a fibro-serous sac called the pericardium



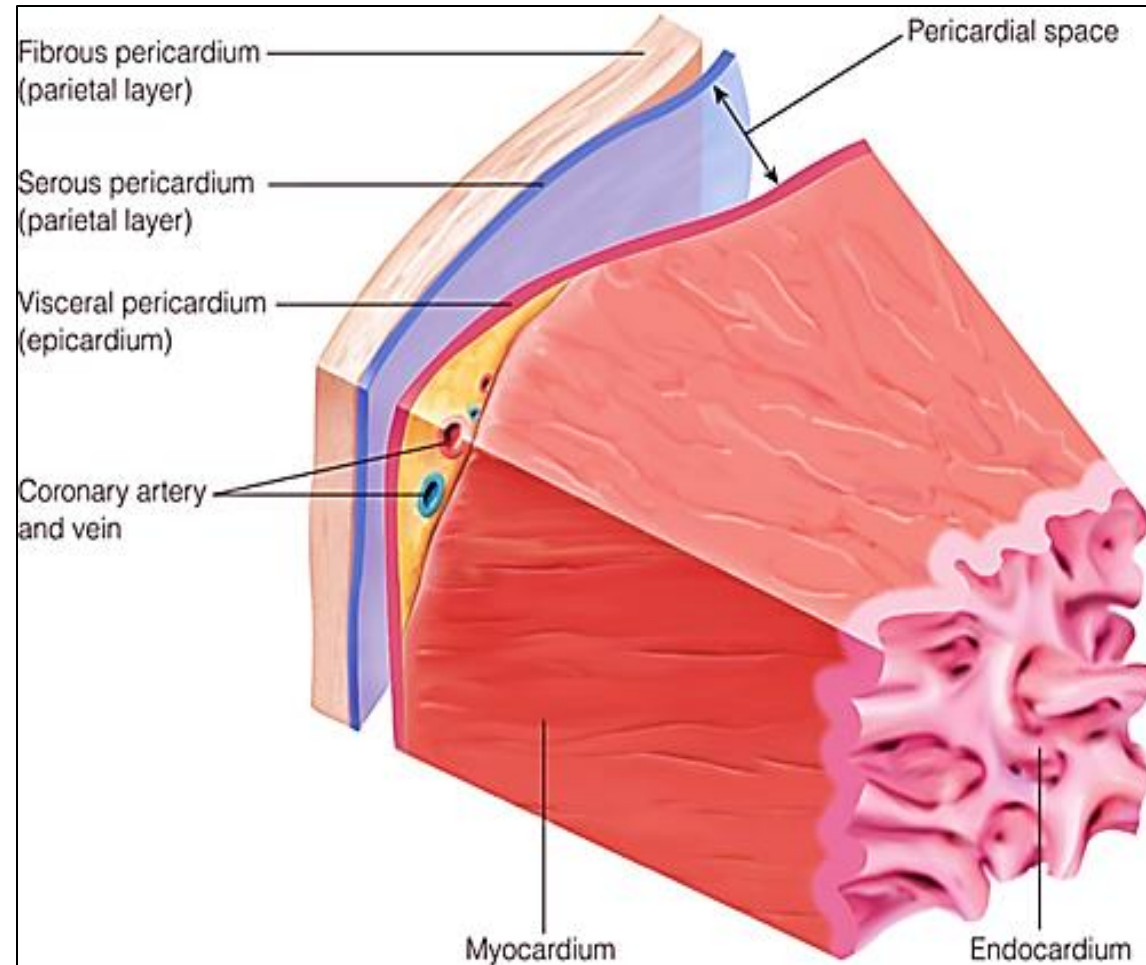
The pericardium composed of 2 layers:



Between the 2 layers of the serous pericardium (**the visceral & the partial**)
There is **a thin space that contain a thin film of fluid** that allows smooth movement of the heart during contraction and relaxation

Clinical hint: Pericarditis

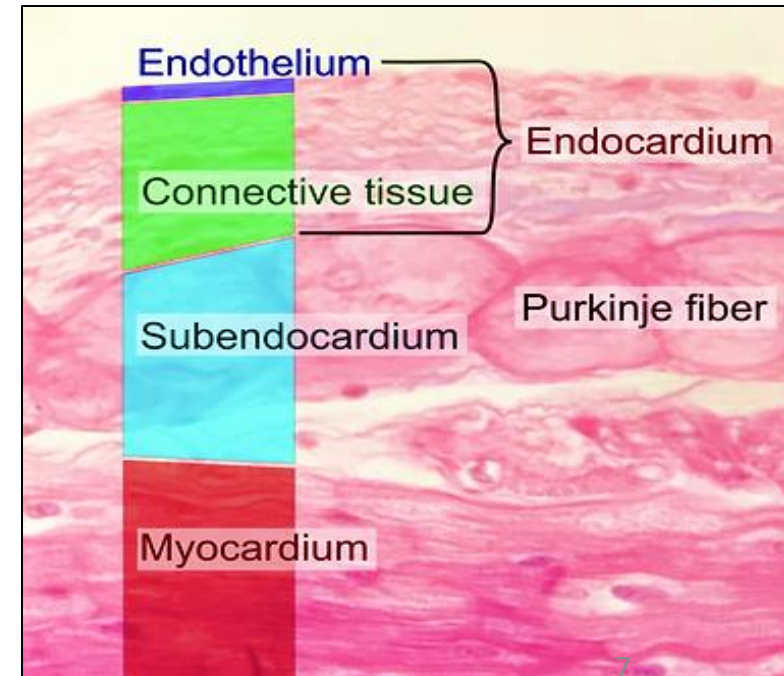
- **The epicardium** = the visceral layer of the pericardium consists of simple squamous mesothelium supported by loose C.T containing the coronary blood vessels , nerves & adipose tissue



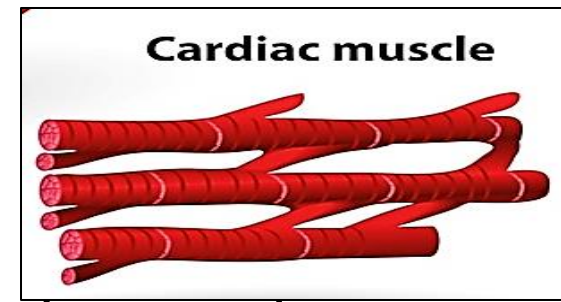
Endocardium

Lines the lumen of the heart and composed of :

- **Endothelium** (simple squamous epithelium)
- **Sub-endothelial C.T**: continuous e the C.T of the blood vessels that enter and exit from the heart
- **Sub-endocardium**: C.T layer contain **veins, nerves, & PurKinje fibers** : modified cardiomyocytes that represent the impulse conducting system of the heart i.e. conduct waves of depolarization
→ contraction of the heart



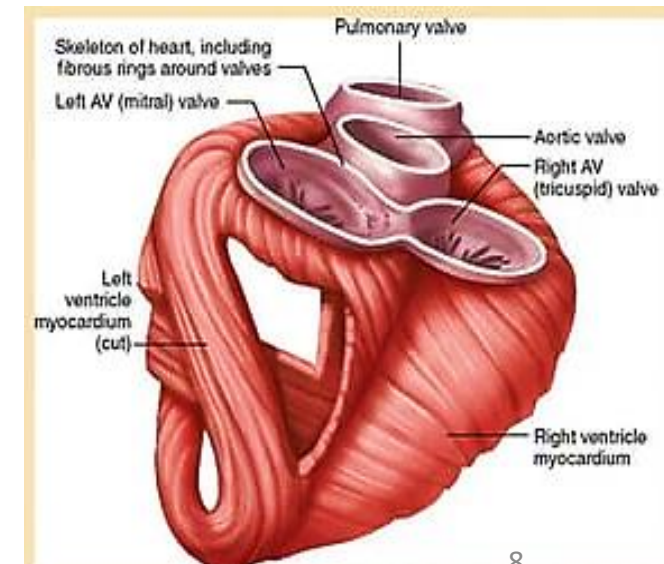
Myocardium



- Is the thickest part of the wall of the heart
- Composed of cardiac muscle fibers (striated, branched & involuntary)
- Muscle fibers are arranged in a spiral pattern around the chambers of the heart.
- It is thick in the ventricles than atria
- Cardiac muscle fibers are inserted into a dense collagenous C,T called

Fibrous skeleton of the heart:

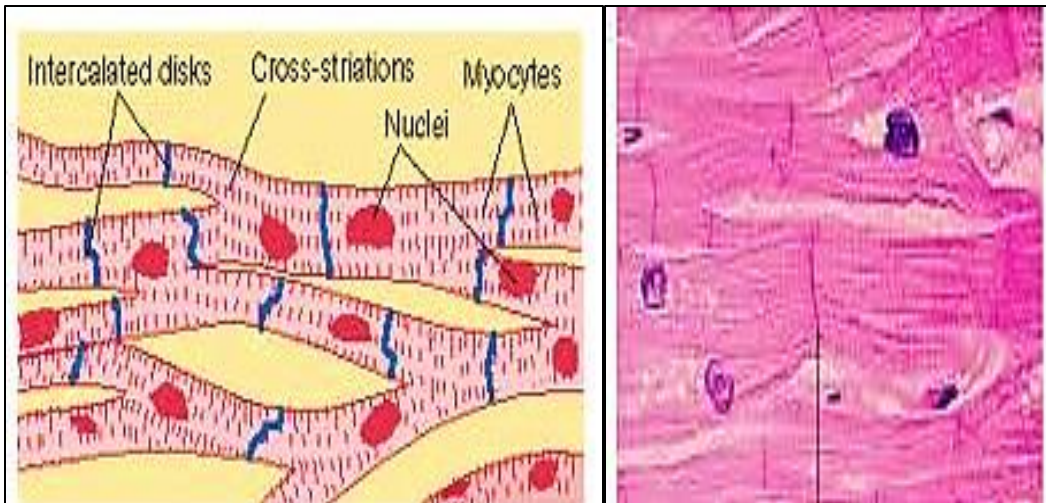
- Separate between atria & ventricles
- Form fibrous rings around the valves to support
- Attachment for the cardiac ms
- Serve as electric insulator between the atria & ventricles



1- cardiac muscle fiber

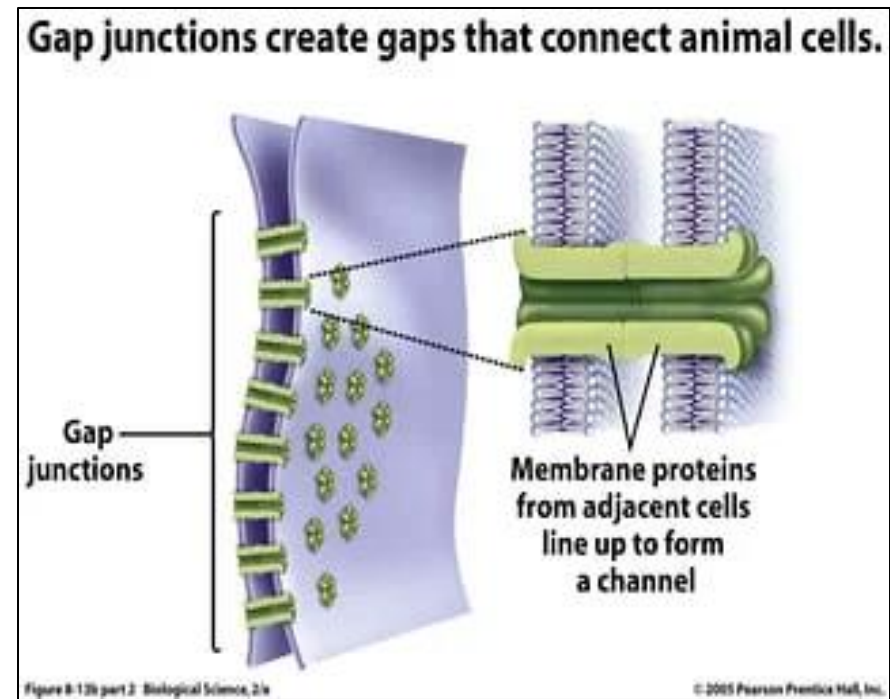
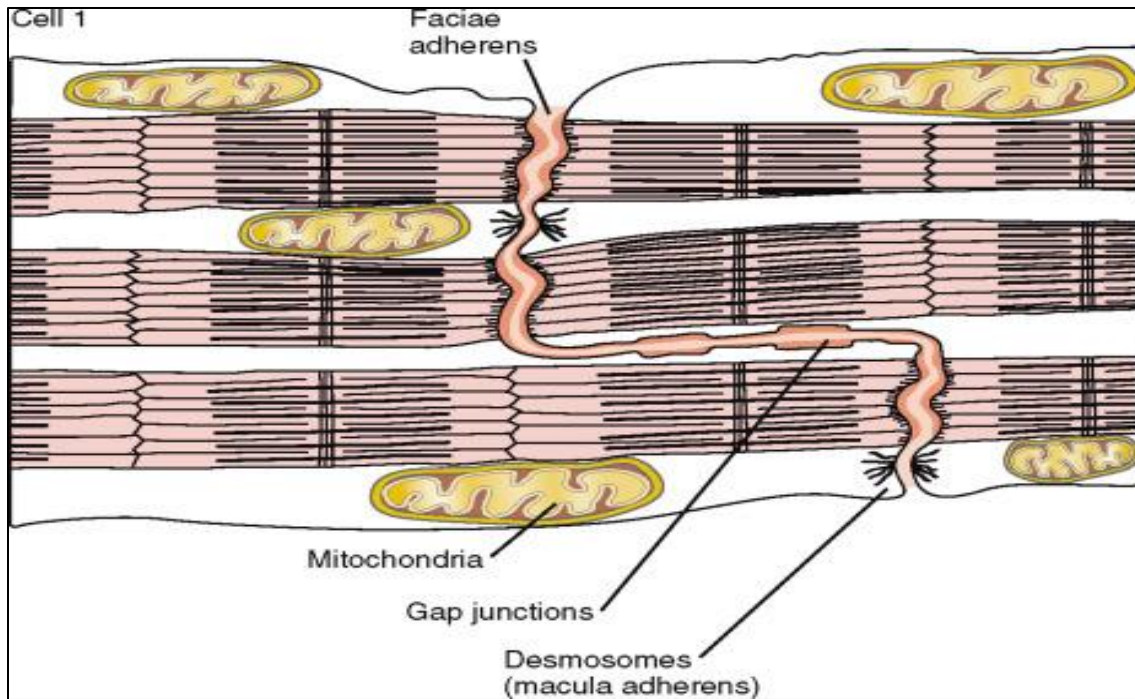
LM

- Each Muscle fiber is formed of group of cells called cardiac myocytes, the myocytes are connected end –to- end by intercalated discs
- Each myocyte has single central nucleus



EM

- Striation **not in perfect registration**
- Rich in mitochondria
- intercalated discs:
 - **Transverse Part:** **Fascia adherens & desmosomes** to prevent the cells from pulling apart
 - **Lateral Part:** **Gap junctions** for impulse transfer between adjacent myocytes → electrical communication between cardiac muscle cells
- T –Tubules
- Sarcoplasmic reticulum
- Others (glycogen , Lipid , Pigment)



Cardiac muscle cells are rectangular shaped cells connected by regions called **intercalated discs**.

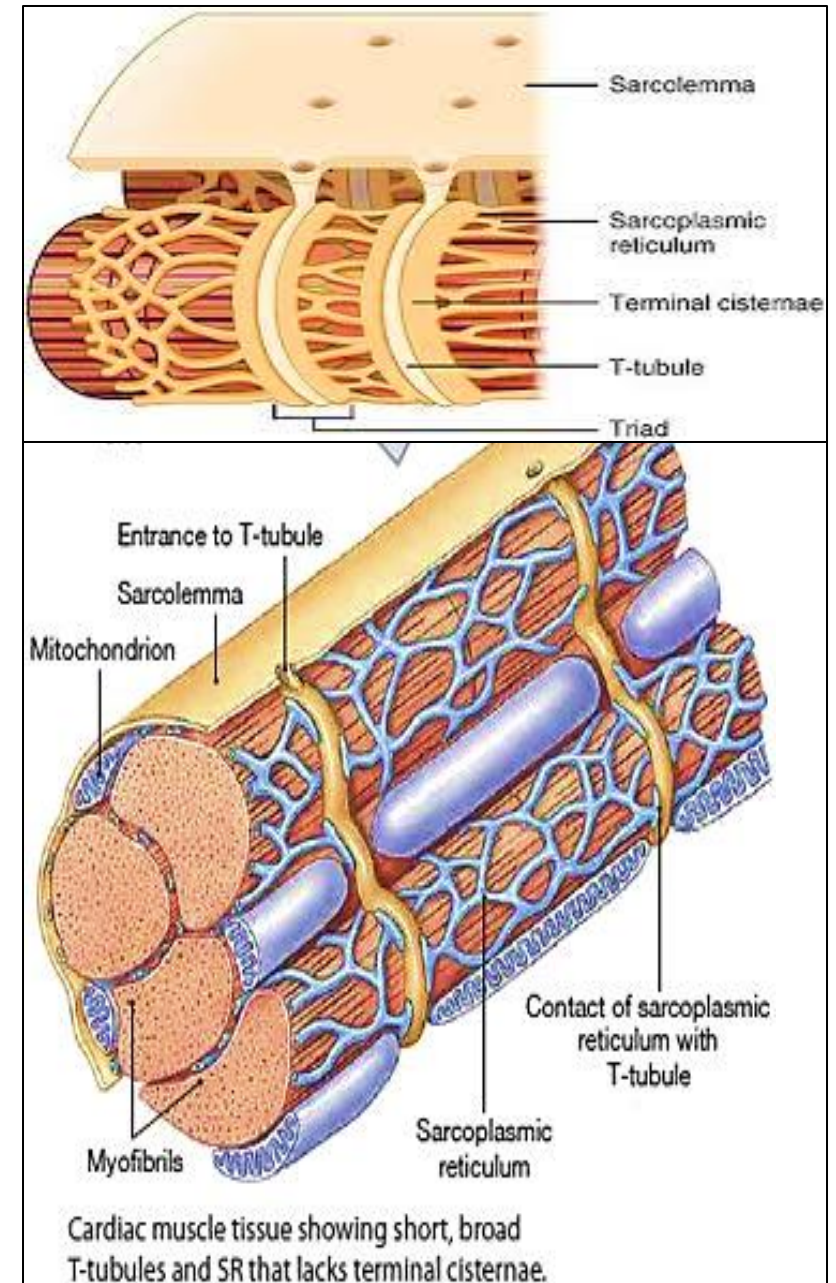
Intercalated discs contain **desmosomes & Fascia adherens**.

The desmosomes prevent adjacent cells from separating during contraction. **The fascia adherents** serve as anchoring sites for actin filaments of the terminal sarcomeres in each myocyte

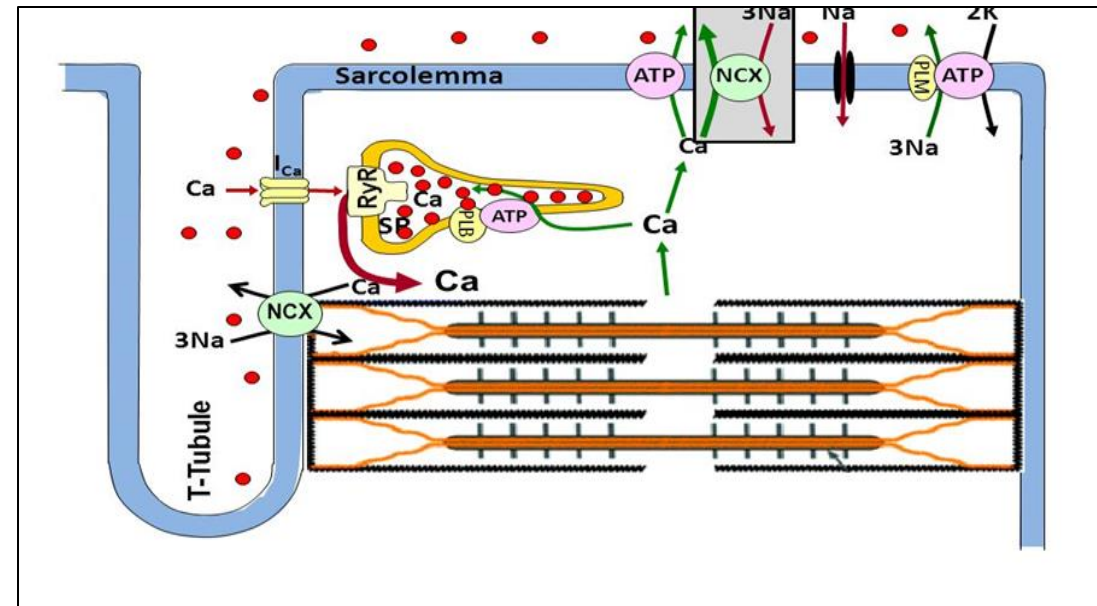
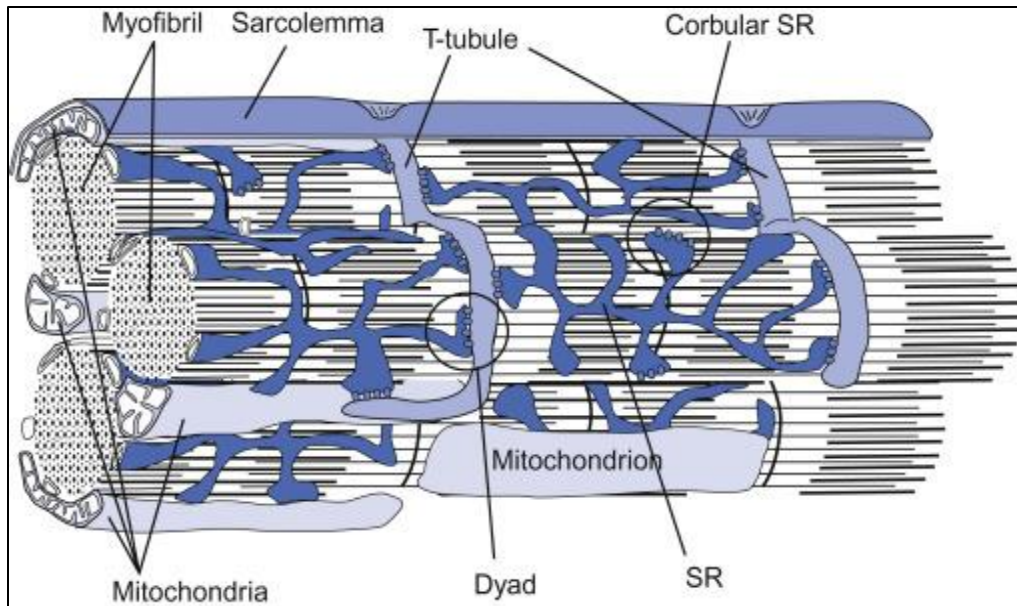
The gap junctions allow ions to pass from cell to cell, transmitting current across the entire heart.

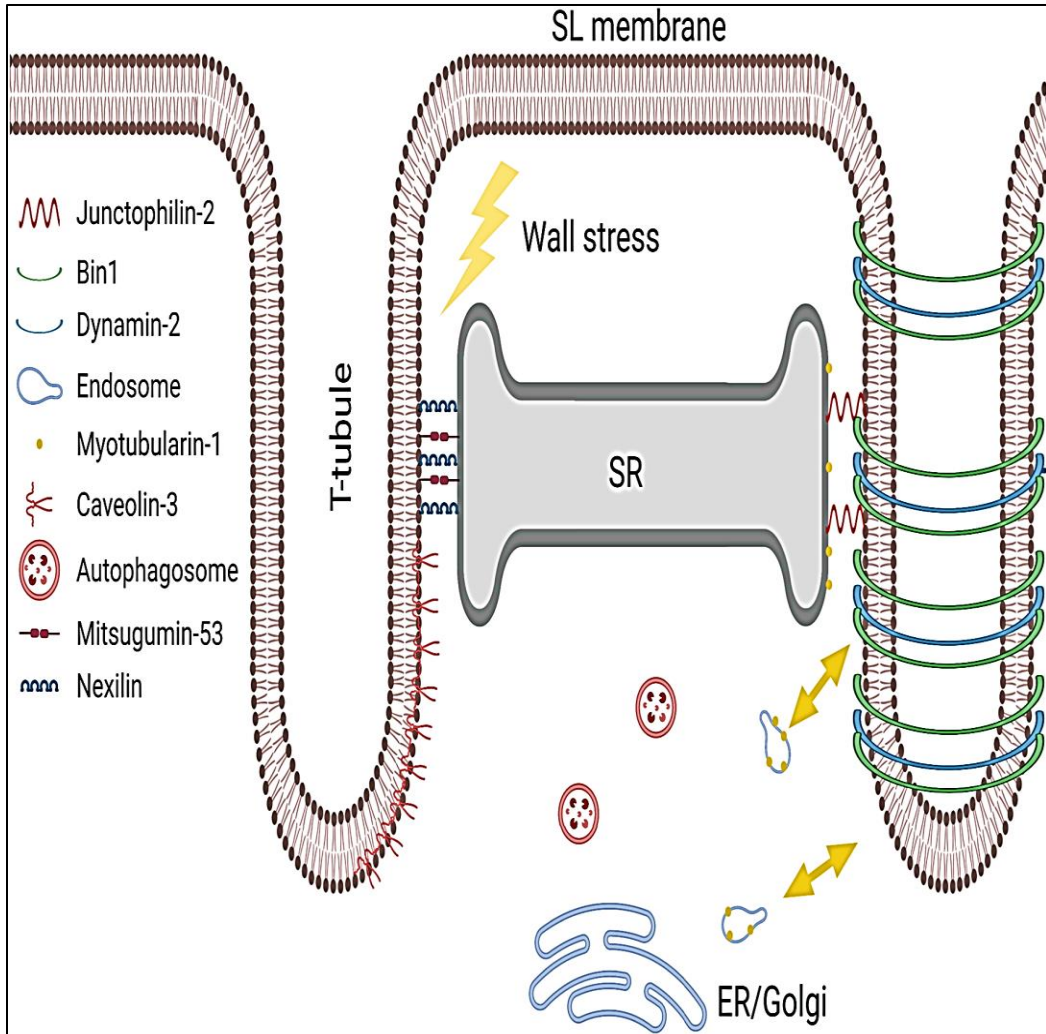
2-T-tubules (Transverse tubules) :

- Are invaginations of cardiomyocytes sarcolemma **rich in ion channels/ GJ (allow extracellular Ca⁺)** which is important for excitation-contraction (EC) coupling
- T –tubules play crucial role in rapid transmission of action potential and facilitate communication with the **sarcoplasmic reticulum SR** which also contains Ca⁺ needed for contraction

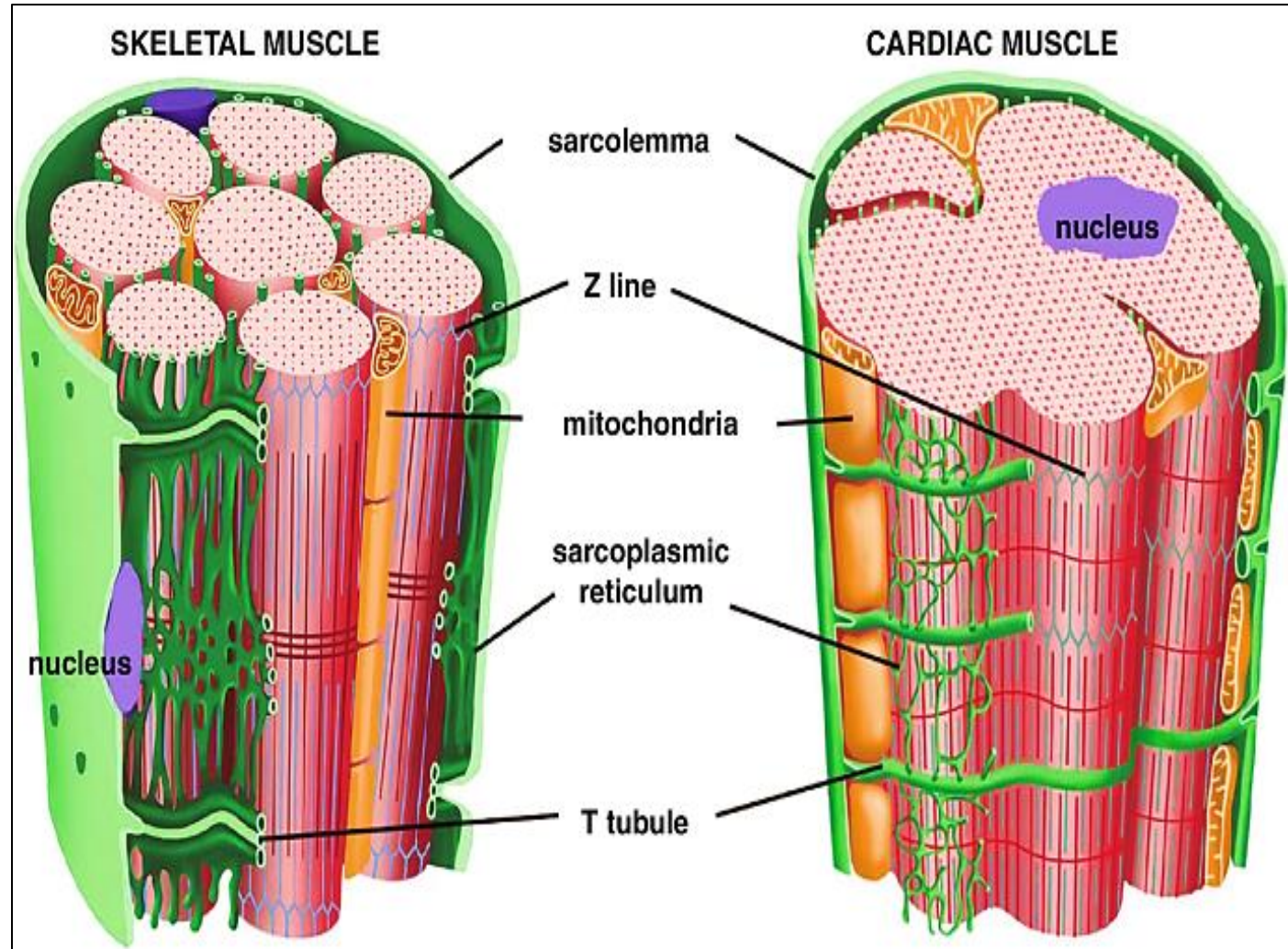


- T- tubules larger in size & numerous in the heart
- T –tubules Locate at Z –line where **actin myofilament** anchor within the cell (locate in skeletal ms. at A-I Junction)
- Only one T- tubule per sarcomere (in skeletal ms. 2 T-tubules / sarcomere)
- T- tubules to transmit the impulse from the sarcolemma to the interior of the cell→ Sarcoplasmic reticulum

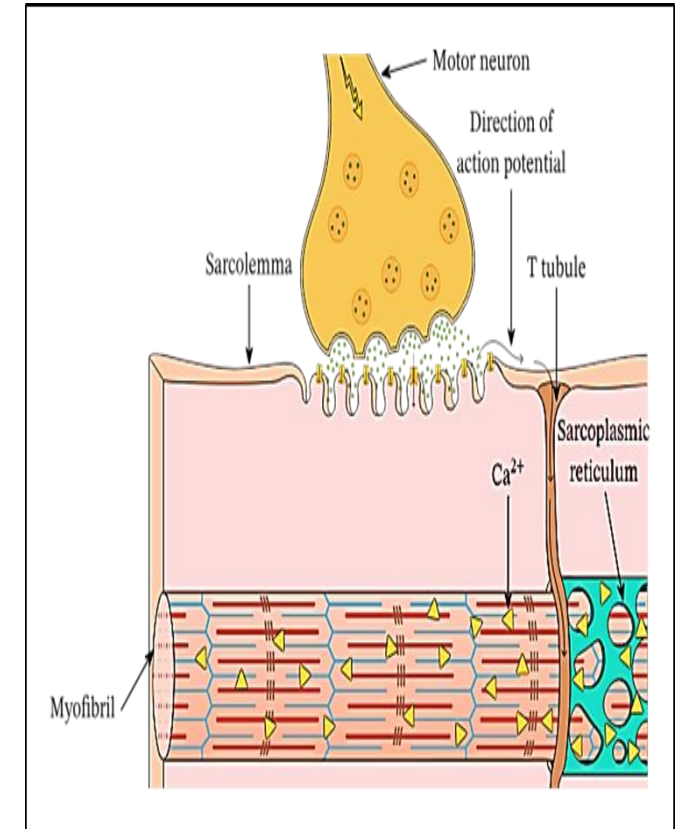
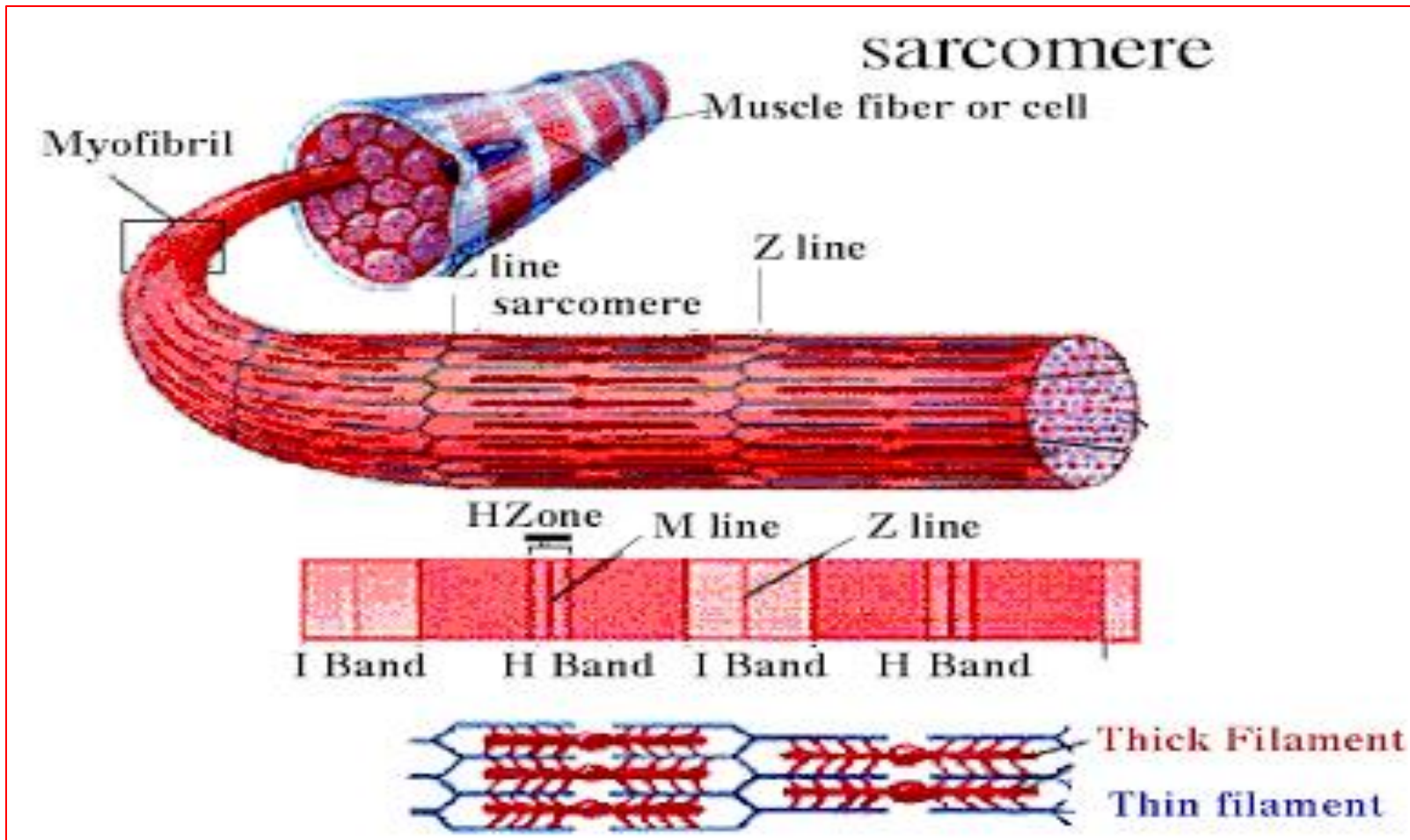




T- tubules to transmit the impulse from the sarcolemma to the interior of the cell



**2 t tubules / sarcomere in skeletal ms.
one T- tubule per sarcomere in cardiac ms.**

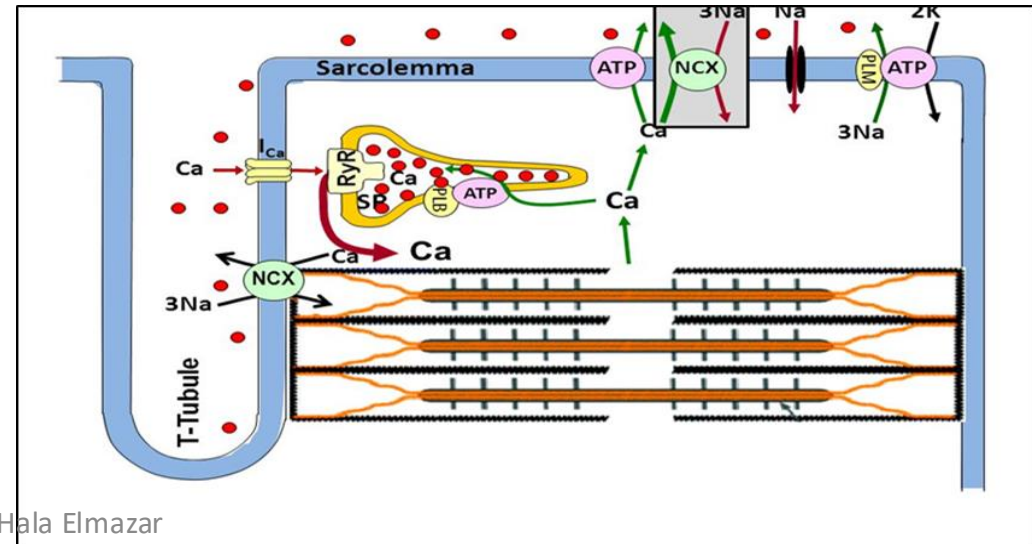
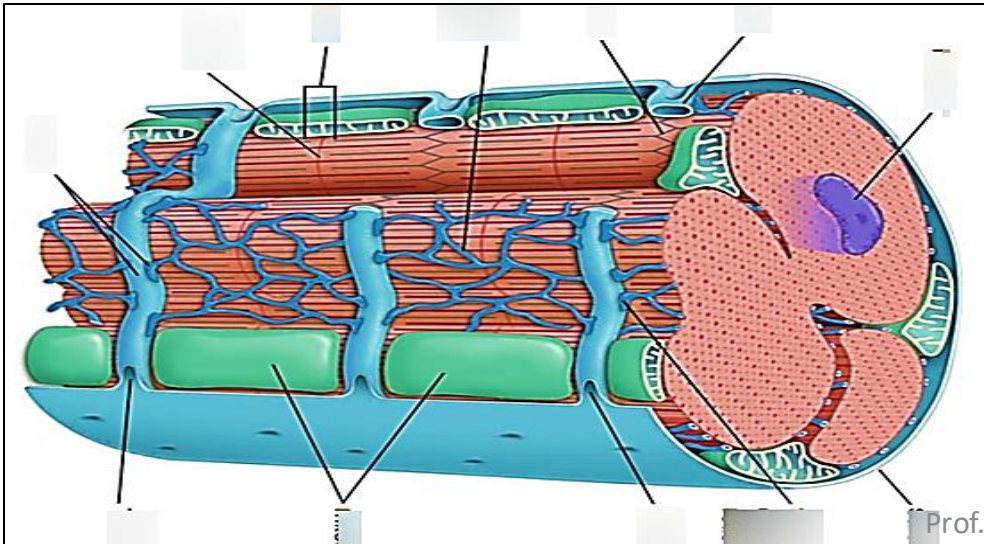


Cardiac muscle cells= Cardiomyocytes
 have **myofibrils** composed of **myofilaments** arranged in sarcomeres.

Ca⁺ is needed for contraction

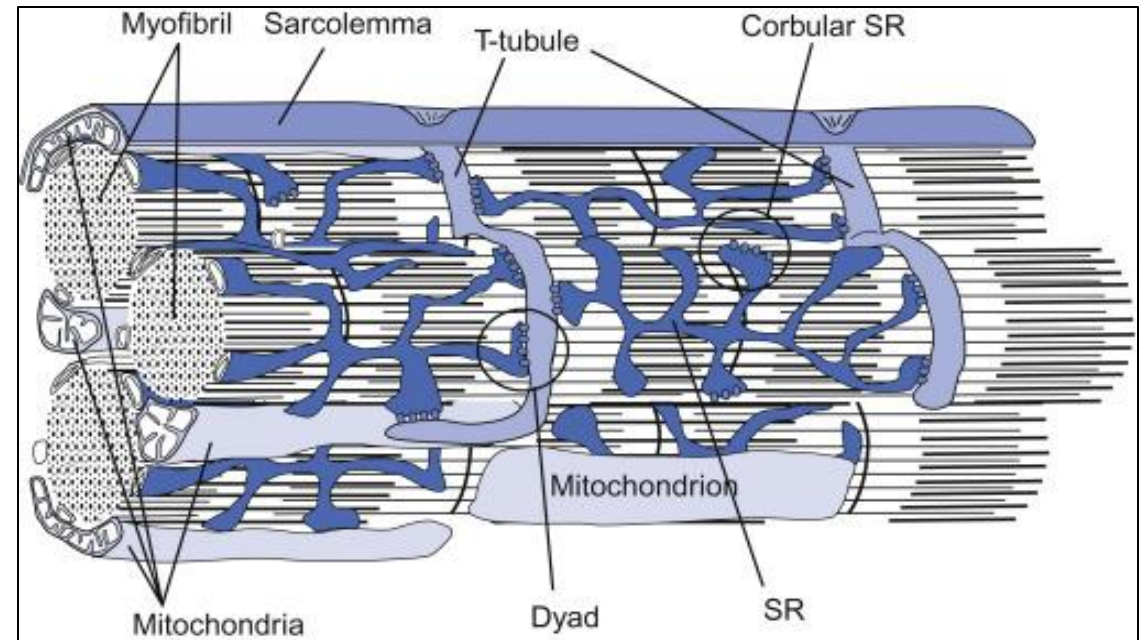
• 3- Sarcoplasmic Reticulum :

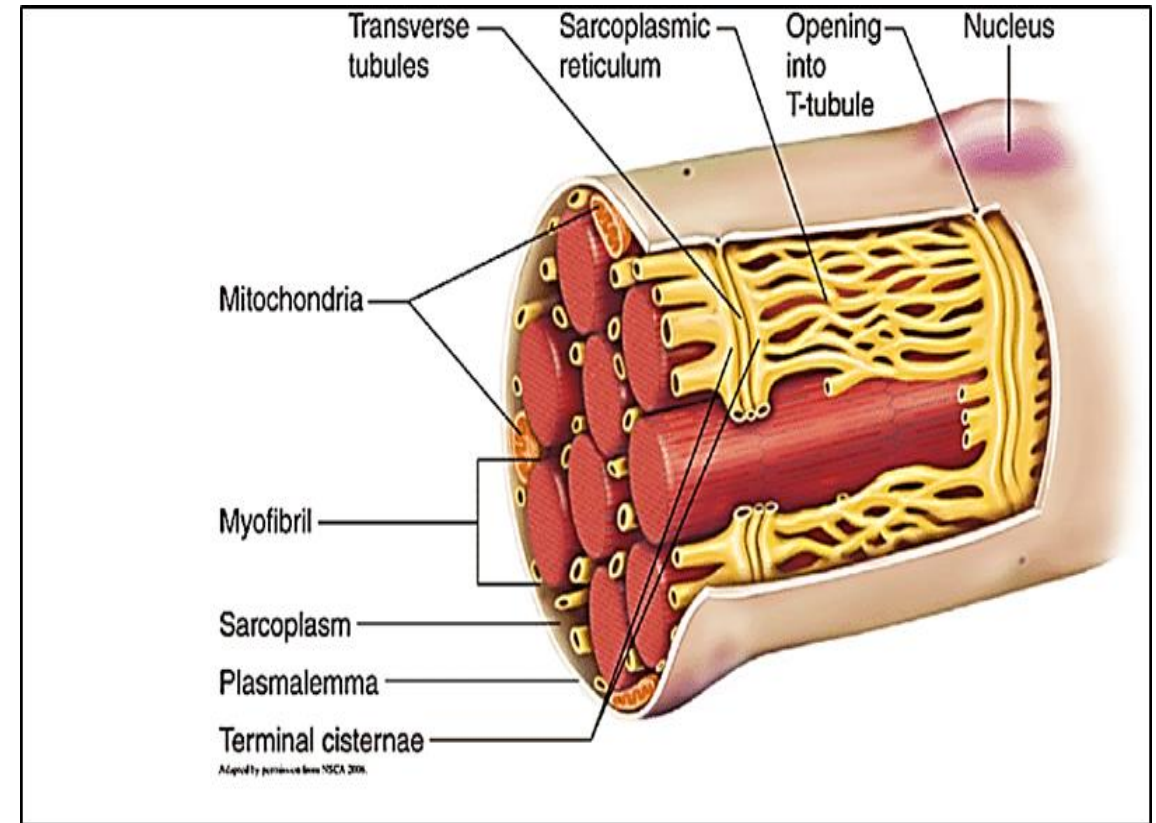
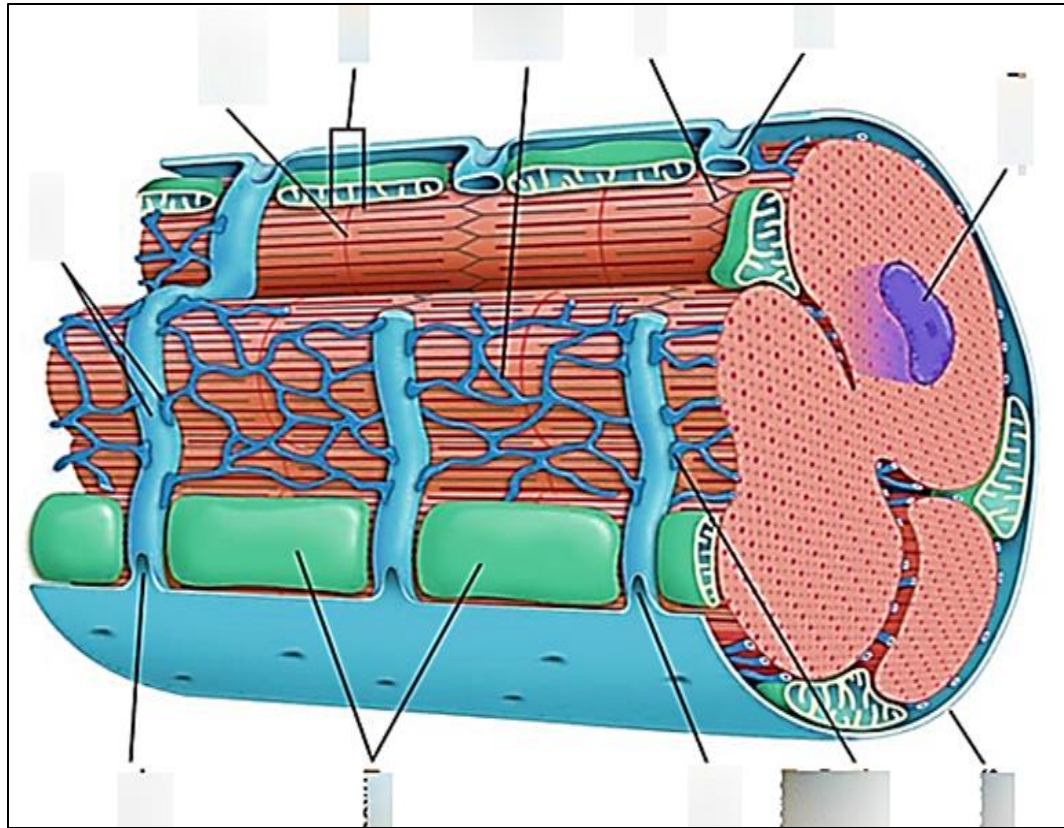
- a membranous intracellular organelle that spans the sarcomere and wraps up the contractile myofilaments in striated & cardiac muscles
- Cardiac SR is the major intracellular store of calcium and a central regulator of cardiac contractility
- Ca^{2+} is released through a specialized release channels known as the **ryanodine receptors (RyR)**
- **The T- tubules** lie in close apposition with the sarcoplasmic reticulum



- Ca^{2+} binds with the protein participating in muscle contraction (**troponin C**),
→ contraction and then Ca^{2+} is reabsorbed into the sarcoplasmic reticulum via **Ca^{2+} ATPase**
- SR irregular and narrow with one terminal cisternae
- Cisterna appear as scattered small expansions of **sacrotubules** which in close apposition with T tubules

- This arrangement is known as **dyads** (**diads**) (In skeletal m called Triad)





Terminal Cisternae of Sarcoplasmic Reticulum in **cardiac vs skeletal ms.
(Dyads vs Triads)**

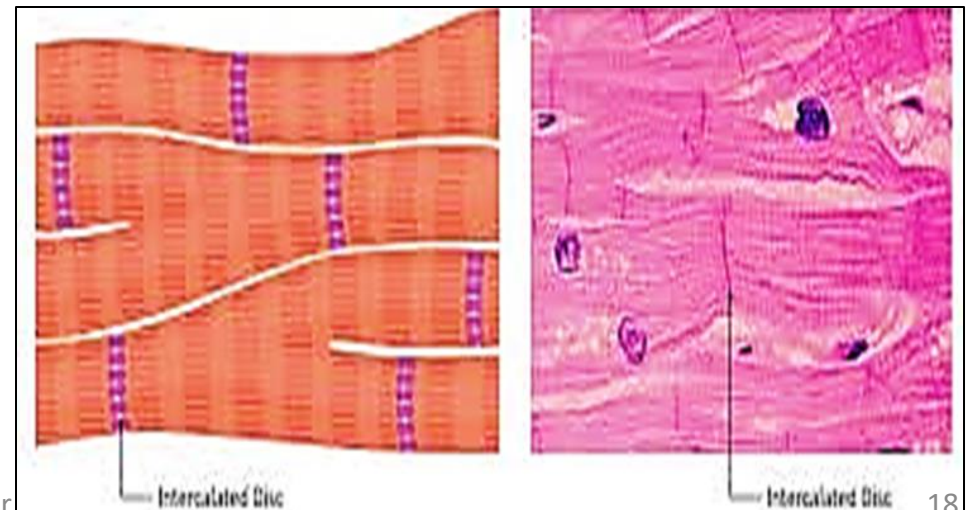
Types of Cardiomyocytes

- 1- Contractile cardiomyocytes
- 2- Endocrine cardiomyocytes
- 3- Cardiomyocytes of the conduction system
- 4- Purkinje fibers

1- Contractile cardiomyocytes

Structure : they are ordinary cardiomyocytes that form the mass / bulk of the myocardium of atria & ventricles

Function: Contraction



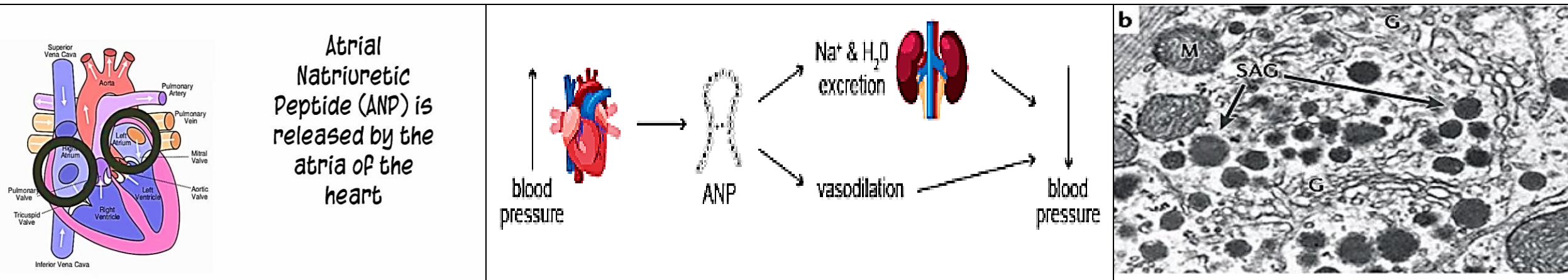
2- Endocrine cardiomyocytes

Structure: cardiomyocytes which have an **endocrine function**

Site : in the atria especially the **RT atrium**

Function: they differ from the contractile cardiomyocytes in the following :

- Have fewer myofibrils
- Have numerous electron dense granules contain **atrial natriuretic peptide / Factor (ANP)** which has role in control blood pressure & electrolyte balance
- ANP is secreted by these cells in response to increased atrial stretch resulting from higher blood volume



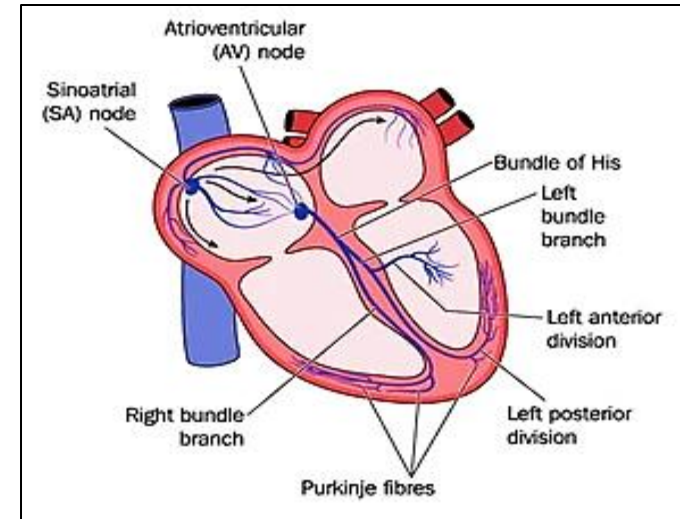
3- Cardiomyocytes of the conduction system

Structure : Modified cardiomyocytes are specialized in **initiation & propagation of depolarization** through the myocardium. Faster than the contractile ms. fibers

Types:

A- Sinoatrial node (SA node) = the pacemaker of the heart specialized cardiac cells located in the wall of the RT atrium, adjacent to the entry of SVC into the heart

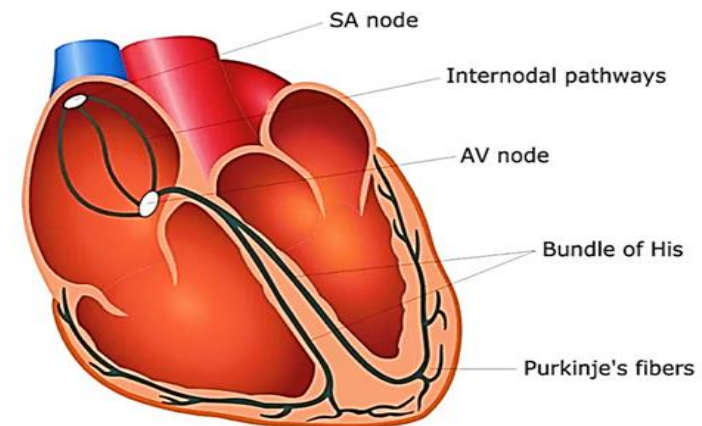
These cells **generates impulses** that initiate contraction of atrial ms. Cells, which are then conducted along internodal fibers to the Atrial- ventricular node (AV node)



B- The AV node: is located in the wall of the RT atrium adjacent to the tricuspid valve

C- bundle of His (A-V bundle): band of conducting tissue arise from AV node into the interventricular septum where **it divides** into **2 branches RT & LF bundle of His** and continue to branch as **Purkinje fibers**

- The nodal cells are smaller than the surrounding atrial cells
- Contain few myofibrils
- Lack typical intercalated disc



4- Purkinje fibers

Site : Sub-endocardium of ventricles

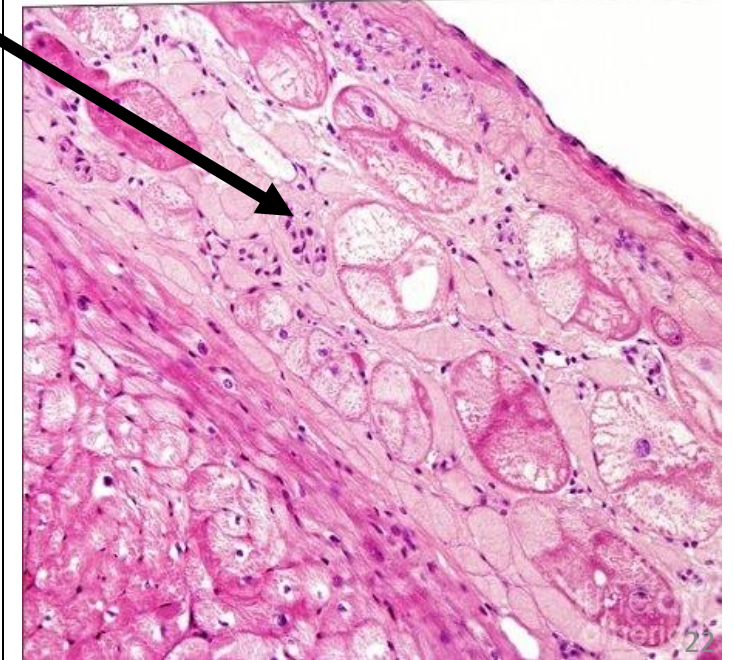
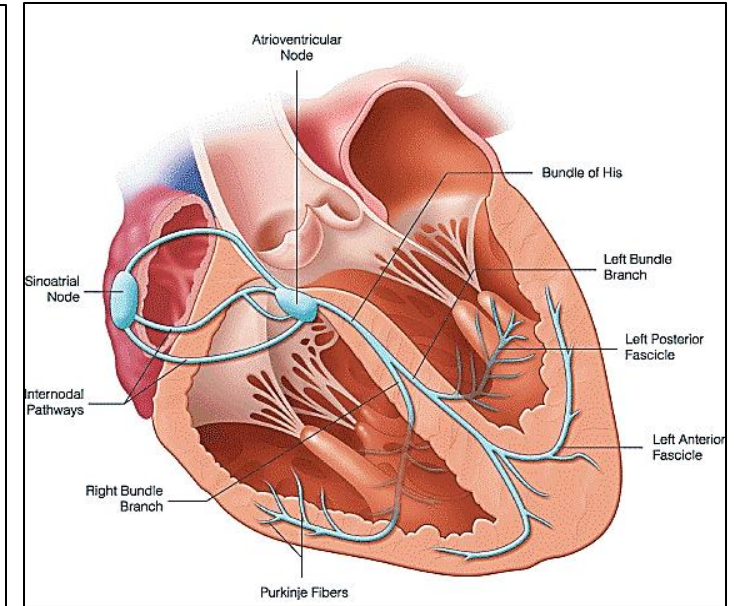
Structure: specialized conducting fibers composed of electrically excitable cells

present in groups of 2 or more & often bi-nucleated

They are larger than the ventricular ms fibers & contain fewer myofibrils

Their cytoplasm rich in **mitochondria** & **glycogen** (appear pale in H&E)

They don't have typical intercalated discs although they contain many gap junctions



Fibrous Skeleton of the Heart

Dense fibrous C.T, separate the atria from the ventricles . It provides electrical insulation for the flow of electrical impulses & fibrous support for the leaflets of the valves of the heart (mitral, and tricuspid, aortic & Pulmonary valves)

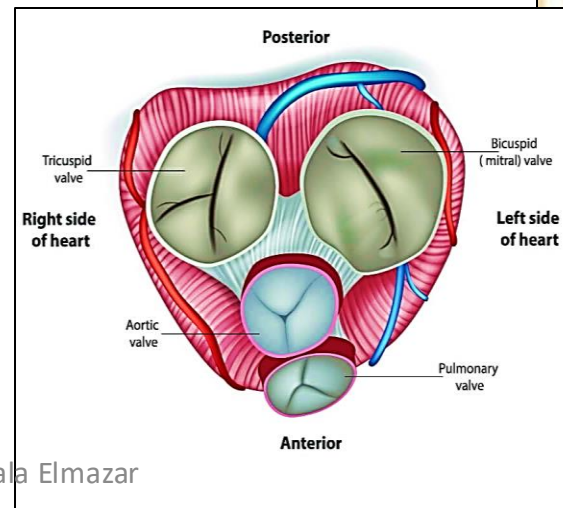
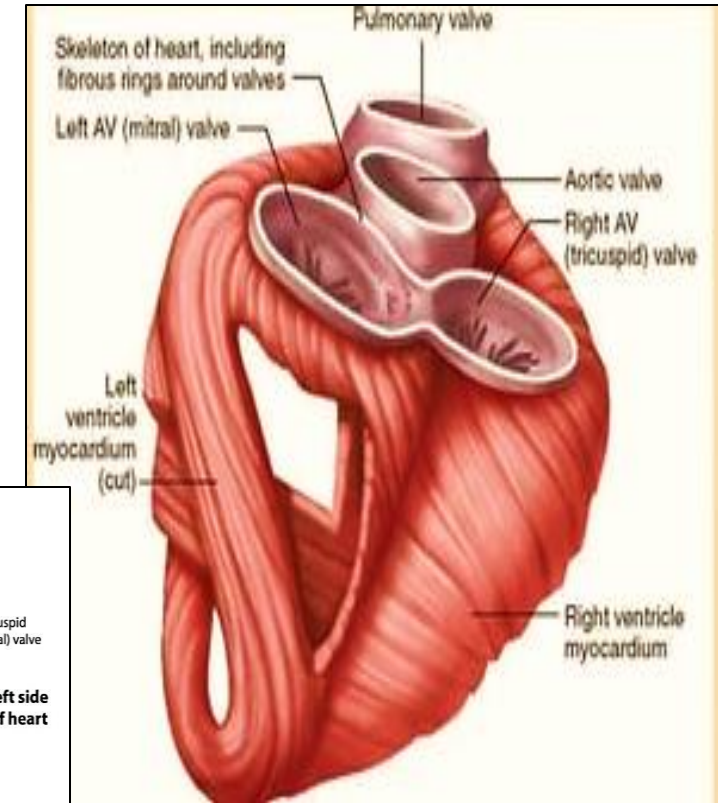
Consists of 4 regions :

1- 4 fibrous rings:

Encircle the origin of the Aorta, Pulmonary Trunk, Mitral & Tricuspid valves. To support & Give attachment to the leaflets (cusps) of these valves

The # of cusps/ valve = 3 in A,T,P valves & 2 in Mitral valve

The valves ensure unidirectional passage of blood



2- Fibrous Trigones:

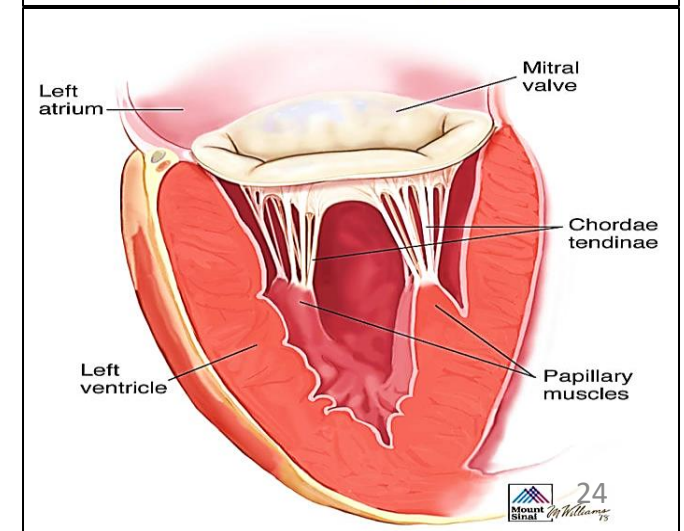
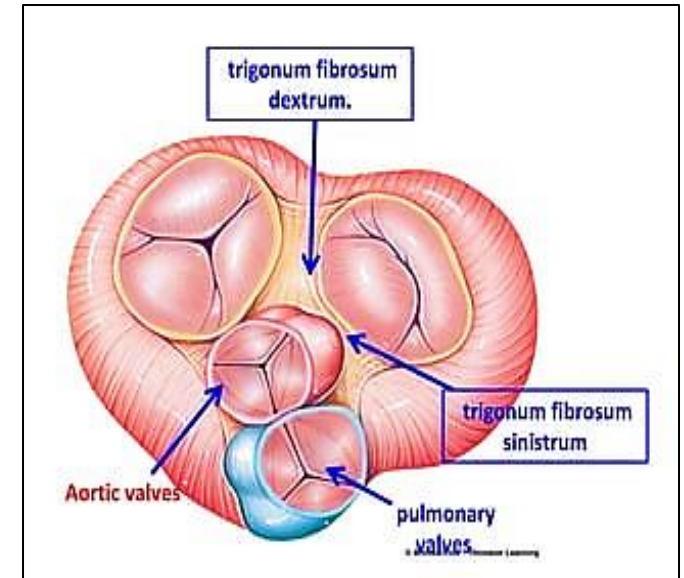
Triangular region Connecting the rings of the heart & represent the strongest portion of the cardiac skeleton

3- the membranous part of the inter-ventricular septum

contain short length of the A-V bundle of the conducting system, no cardiac ms. in that part
(common site for interventricular septal defect)

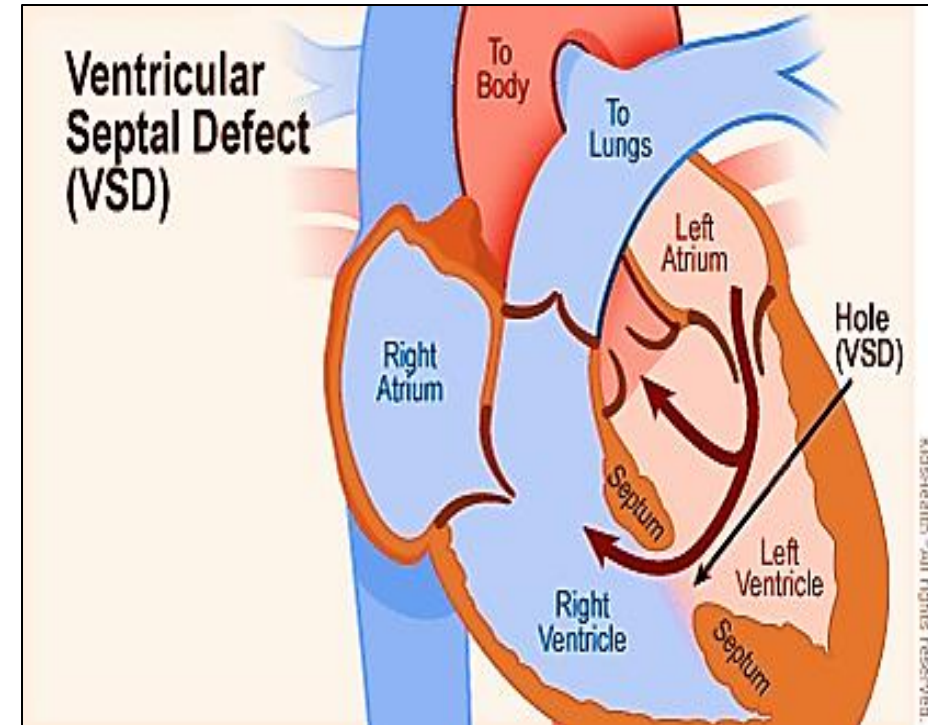
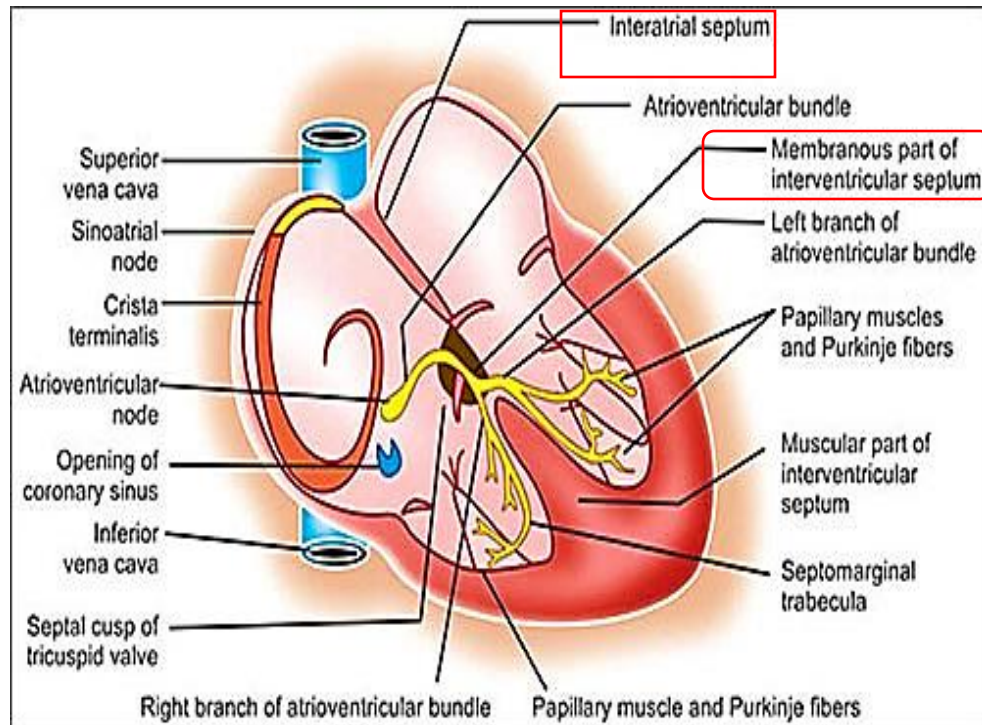
4- Chorda Tendinae (Fibrous cords of the heart) :

Fibrous connections between the papillary muscles of the ventricles and the cusps of atria-ventricular valves



Function of the fibrous skeleton

- Support the heart
- Attachment of the cardiac muscles
- Act as electrical insulator by preventing the flow of electrical impulses between the atria & ventricles

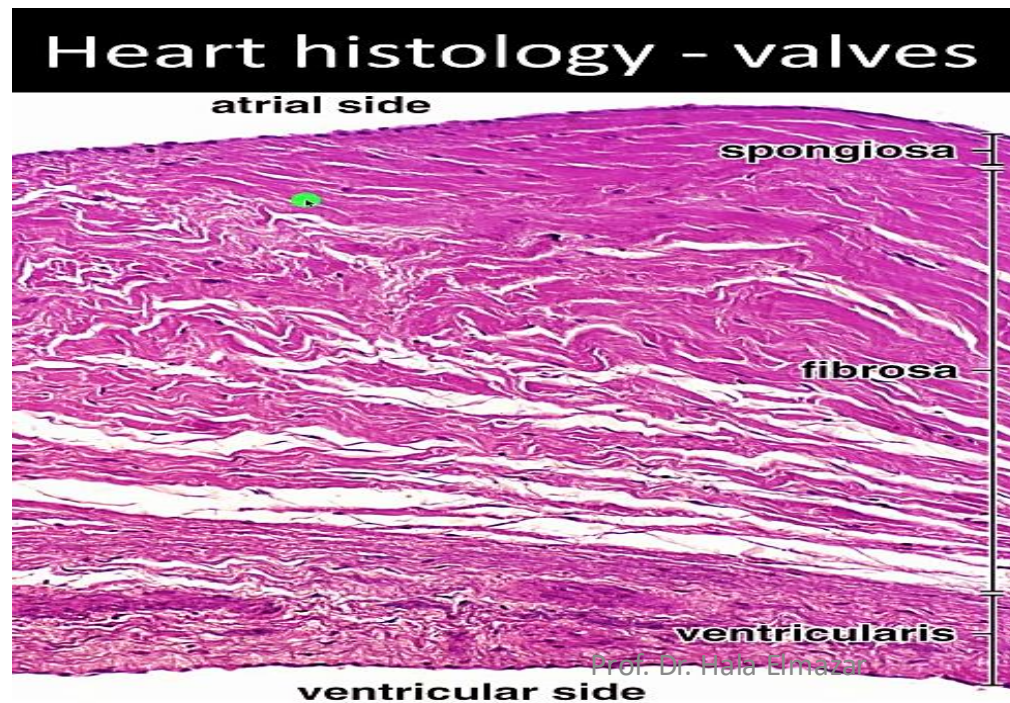


Heart valves

- The valves of the heart are attached to the dense C.T fibrous skeleton
- They are made of flaps of tissues called **cusps or leaflets** covered with endothelium on both sides of the valve

- **Histologically** Each valve composed of 3 layers:

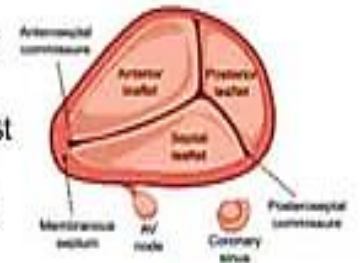
- 1- Fibrosa
- 2- Spongiosa
- 3- Ventricularis



Valve leaflets/cusps

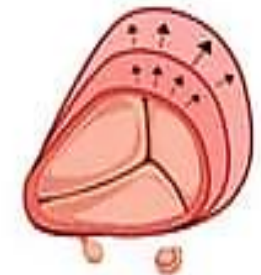
3 LEAFLETS :

- Anterior leaflet -largest & most mobile
- Septal leaflet-2nd largest & least mobile
- Posterior leaflet –triangular & smallest.



3 commissures

- Anteroseptal-
- Postero septal
- Anteroposterior



1- Fibrosa: (Center)

Site: forms the core of the valve

Structure: dense Irregular C.T. Extending from the fibrous ring

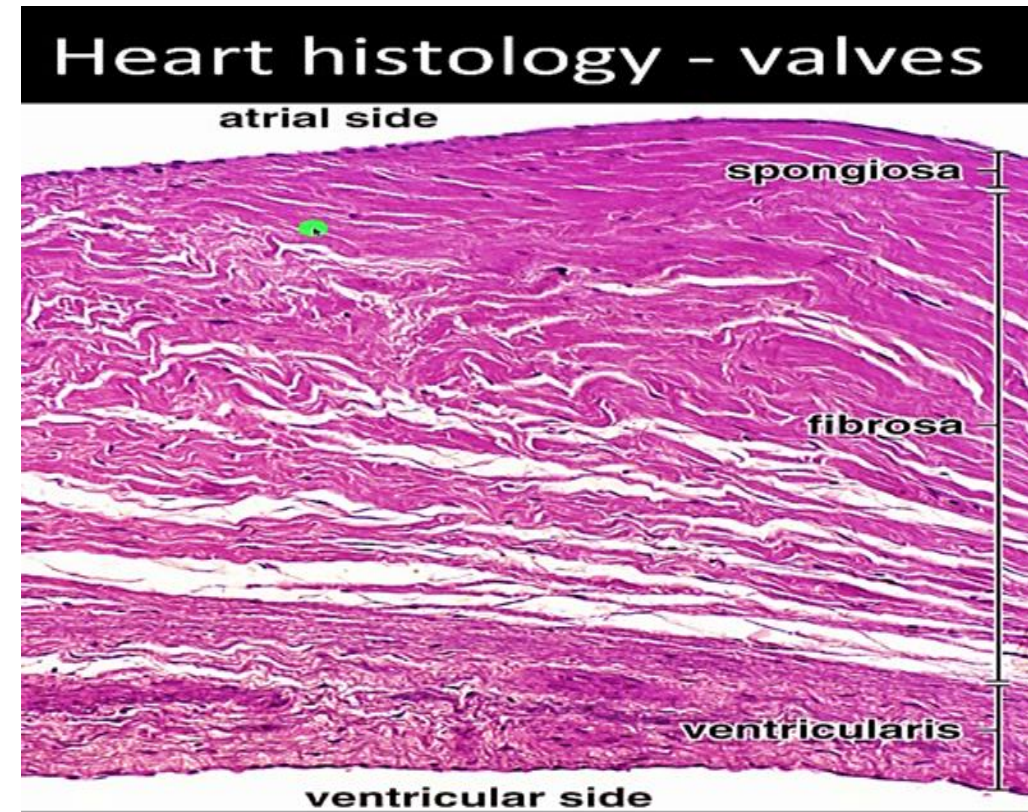
Function: load bearing that offers mechanical integrity to the cusps

2- Spongiosa:

Site: locate on the atrial side (M & T valves) or
The blood vessel side (A & P valves)

Structure: loose C.T

Function: shock absorber to reduce the
Strength of vibration associated with closure of
the valve



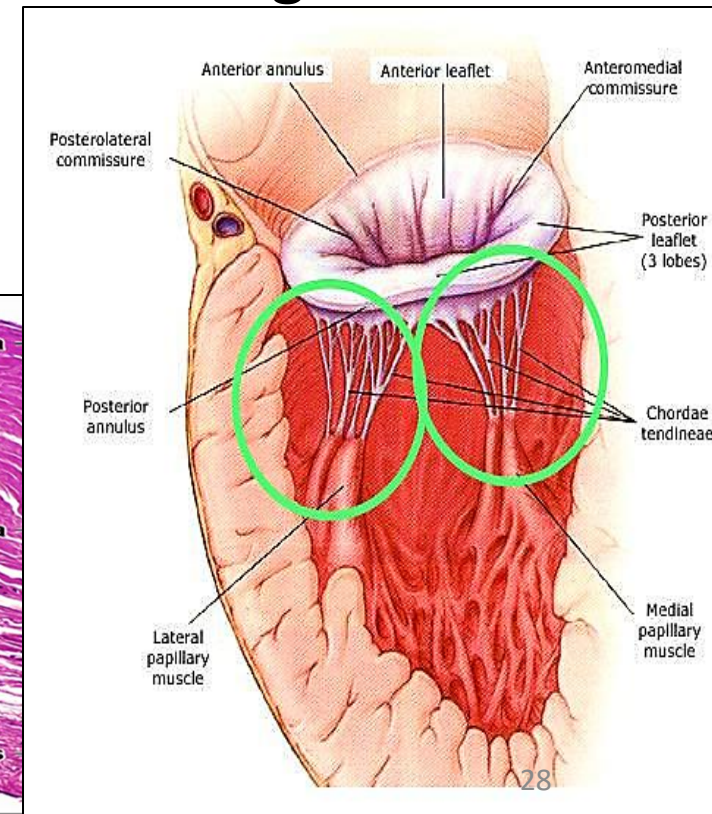
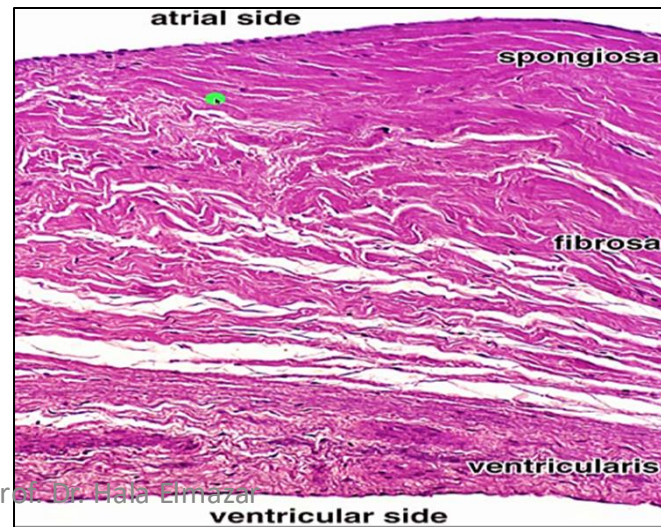
3- Ventricularis:

Site: immediately adjacent to the ventricular surface of each valve (4 valves)

Structure: dense C.T with many elastic fibers

In the A-V valves (M & T) the ventricles show **chorda tendineae** (fibrous cords covered with endothelium) extending from the edges of the valves to the papillary muscles

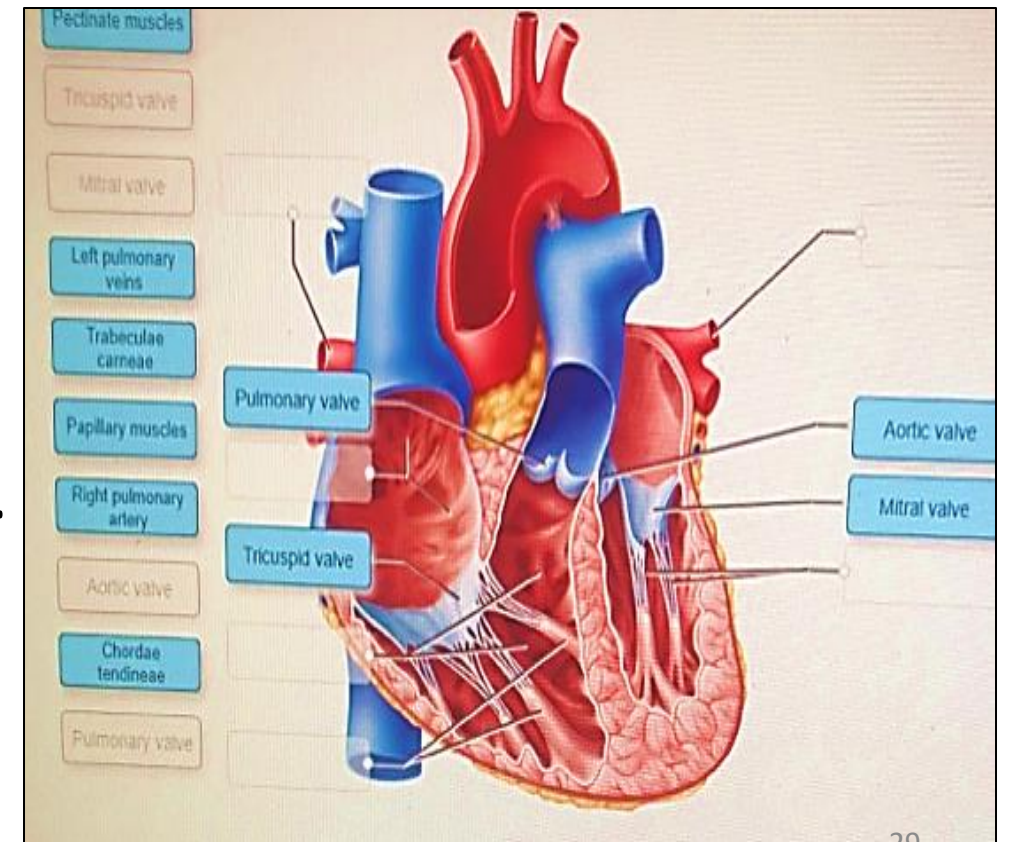
Papillary ms. + corda tendineae function to keep the valve in position & prevent its swinging during contraction of ventricles



The papillary muscles

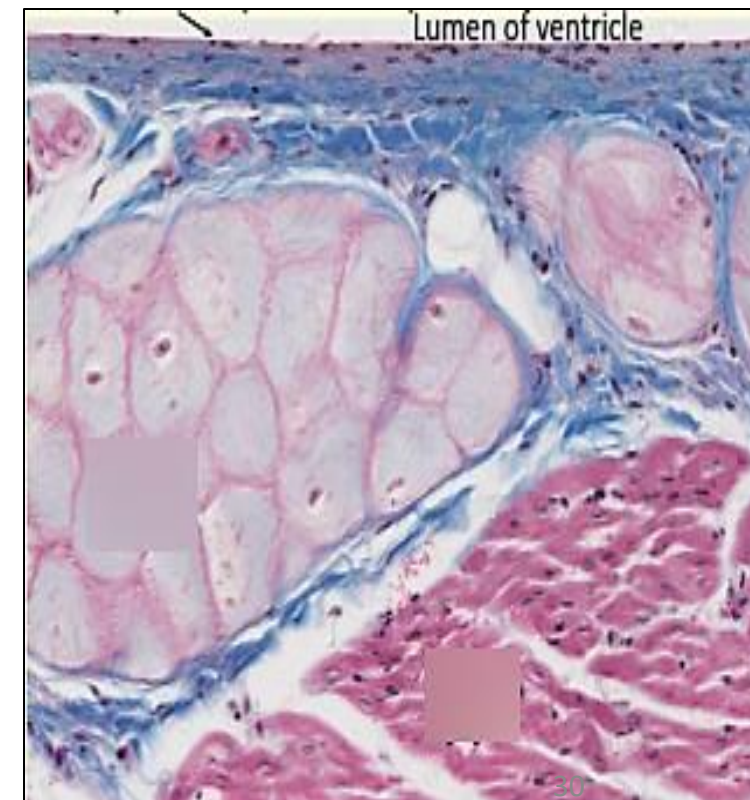
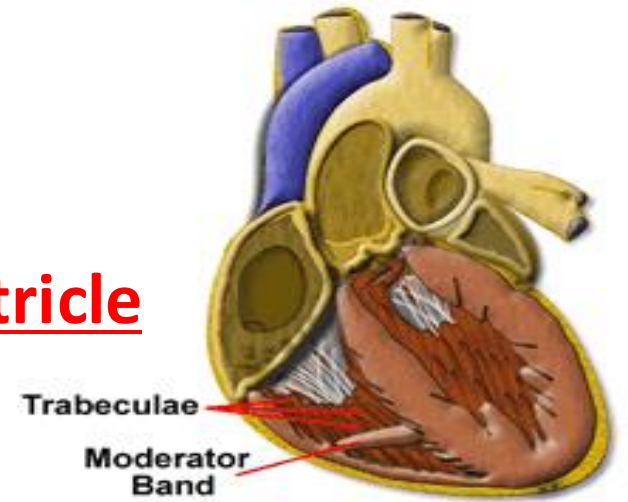
- There are 5 papillary muscles in the heart
- Originating from the ventricular wall to the chorda tendineae
- 3 in the right ventricle (anterior, posterior, septal) & 2 in the left ventricle (anterolateral & posteromedial)
- They prevent valvar inversion or prolapse
- Papillary muscle rupture can be caused by ischemia & myocardial infarction. Complications may lead mitral regurgitation.

Rupture of posteromedial one is more frequent cuz. it has single blood supply



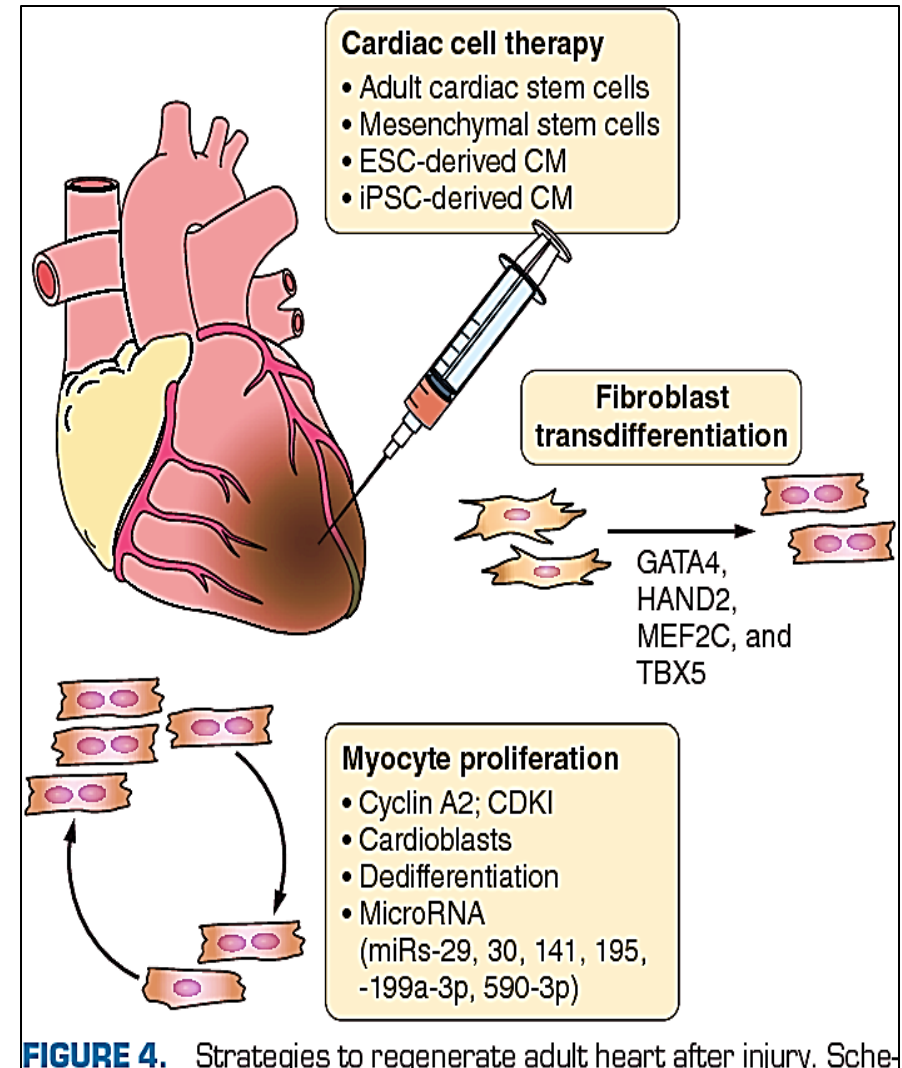
The moderator band

- * Also known as septo-marginal trabecula
- * is a band of cardiac muscle found in the Only in right ventricle
- * It extends from the ventricular septum to the base of the anterior papillary muscle
- Its main function is to carry the right branch of the A-V bundle (RT bundle of His)
- It prevent over distension of the RT ventricle of the heart.
(The RT ventricle wall is thinner than the LF ventricle)



Regeneration of the cardiac muscle

- Adult humans fail to regenerate their hearts following injury
- Dead cardiac muscle tissue is replaced by scar tissue, which cannot contract. As scar tissue accumulates, the heart loses its ability to pump because of the loss of contractile power.
- However, some minor regeneration may occur due to stem cells found in the blood that occasionally enter cardiac tissue



Thank you

