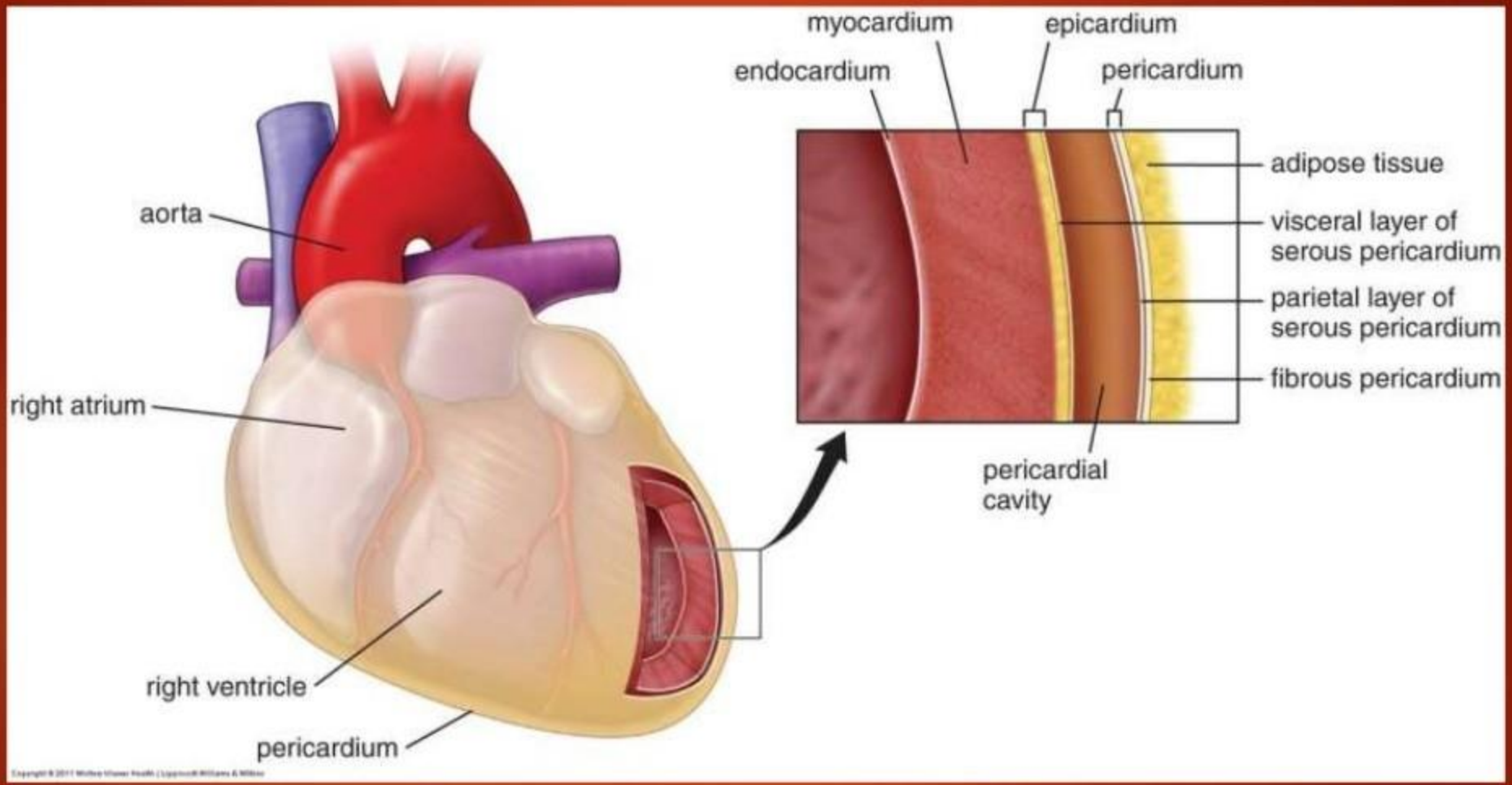
THE MYOCARDIUM

DR SHAHAB

- The myocardium is the muscular wall of the heart, or the heart muscle. It contracts to pump blood out of the heart and then relaxes as the heart refills with returning blood.

- The myocardium's smooth outer membrane is called the epicardium. Its inner lining is called the endocardium.


myocardium
epicardium
endocardium
pericardium
adipose tissue
visceral layer of serous pericardium
parietal layer of serous pericardium
fibrous pericardium
pericardial cavity
aorta
right atrium
right ventricle
pericardium

WORD Origin

- *Myo* – Muscle
- *Cardio* – Heart
- '*-ium*' – Tissue, Structure
- **Myocardium** – muscular tissue of the heart

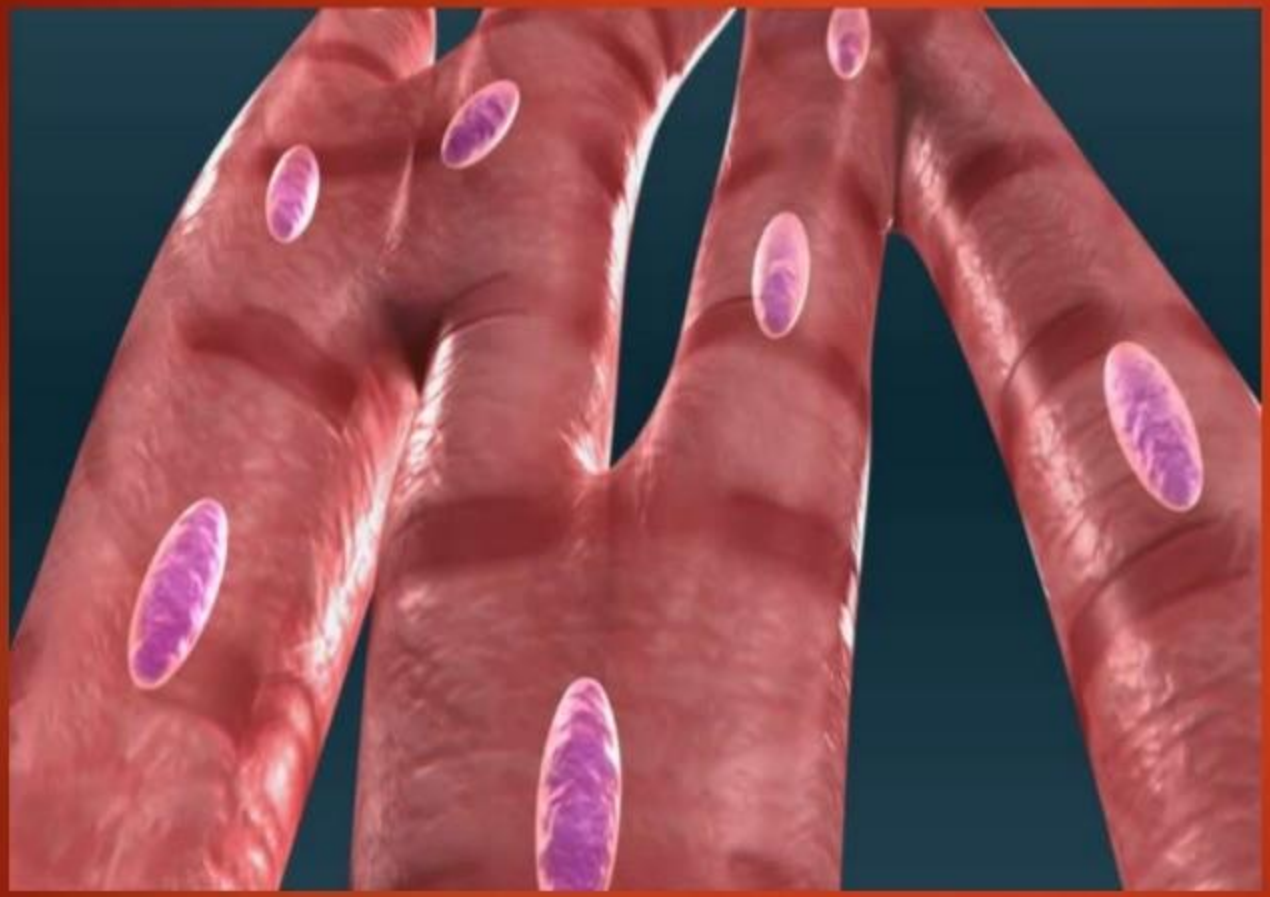
- *Myo* – Muscle
- *Cardio* – Heart
- '*-cyte*' – cell
- **Cardiomyocyte** – Cardiac Muscle Cell
- *'pathy'* – disease
- **Cardiomyopathy** – disease (chronic) of the heart muscle

THE HEART MUSCLE

- The MYOCARDIUM, or cardiac muscle, is the thickest section of the heart wall and contains CARDIOMYOCYTES, which are the contractile cells of the heart.

- The thickness of the myocardium determines the strength of the heart's ability to pump blood.

PROPERTIES OF CARDIAC MUSCLE



- Striations
- T-tubules
- Intercalated disks

MYOCYTE

- A **myocyte** (also known as a muscle cell) is the type of cell found in muscle tissue (myocardium).
- There are two types of cells within the heart: the **Cardiomyocytes** and the **Pacemaker cells**.
- Cardiomyocytes make up the atria and the ventricles.
- Pacemaker cells in the conduction system are specialized cardiomyocytes that generate and conduct electrical impulses.

CARDIOMYOCYTES

a) Make up the muscular walls of the atrium and ventricles of the heart

b) Possess specific properties

(1) **contractility** – the ability of the cell to shorten and lengthen its fibers

(2) **extensibility** – the ability of the cell to stretch

ELECTRICAL CELLS

a) Make up the conduction system of the heart

b) Are distributed in an orderly fashion through the heart

c) Possess specific properties

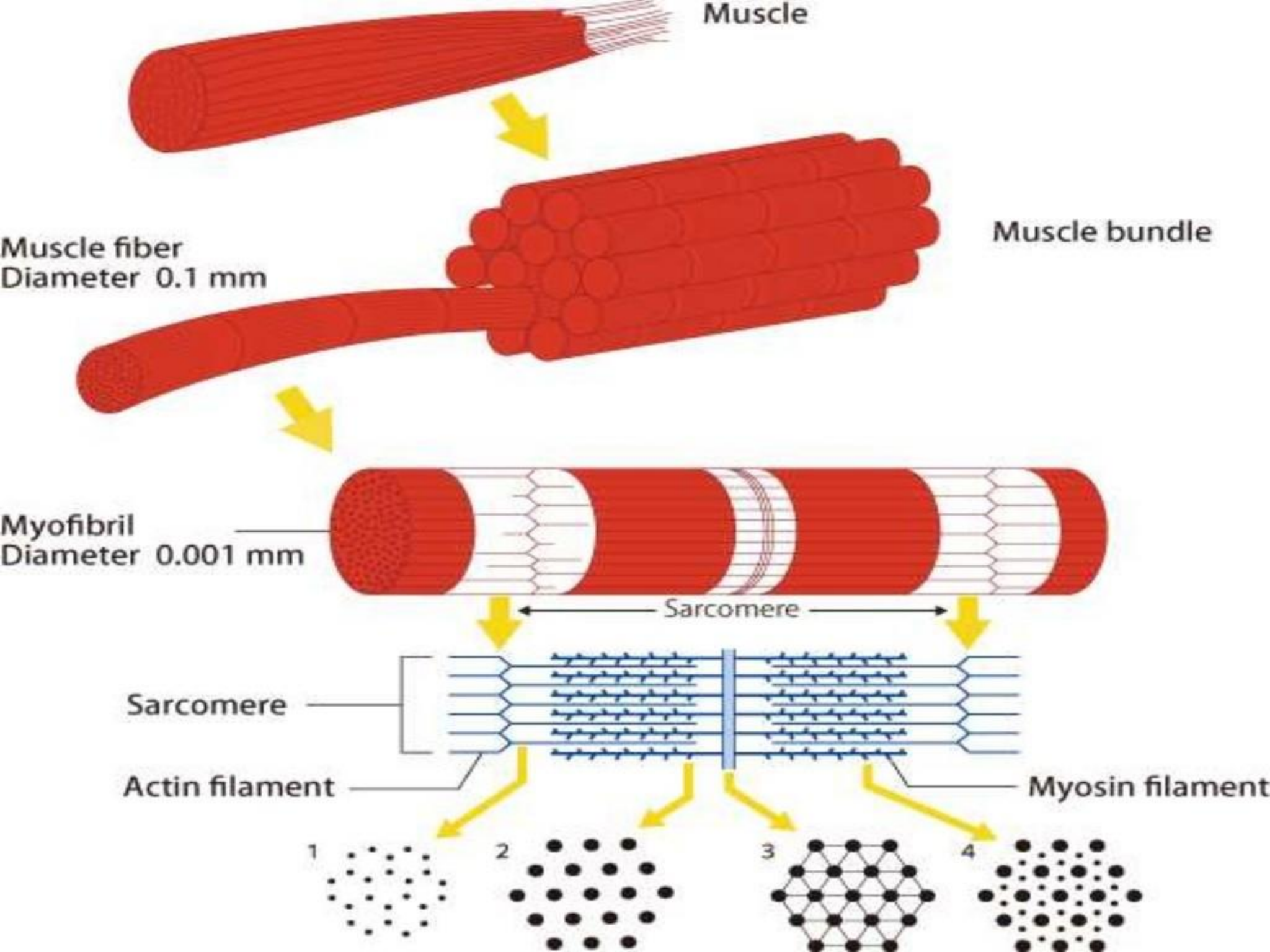
- **automaticity** – the ability to spontaneously generate and discharge an electrical impulse
- **excitability** – the ability of the cell to respond to an electrical impulse
- **conductivity** – the ability to transmit an electrical impulse from one cell to the next

MYOFIBRIL

- A **myofibril** (also known as a **muscle fibril**) is a basic rod-like unit of a muscle cell. Muscles are composed of tubular cells called myocytes, known as muscle fibers in striated muscle, and these cells in turn contain many chains of myofibrils.

- Myofibrils are composed of long proteins including actin, myosin, and titin, and other proteins that hold them together. These proteins are organized into thick and thin filaments called myofilaments, which repeat along the length of the myofibril in sections called SARCOMERES.

- Muscles contract by sliding the thick (MYOSIN) and thin (ACTIN) filaments along each other.


Muscle
Muscle bundle
Muscle fiber
Diameter 0.1 mm
Myofibril
Diameter 0.001 mm
Sarcomere
Sarcomere
Actin filament
Myosin filament
1
2
3
4

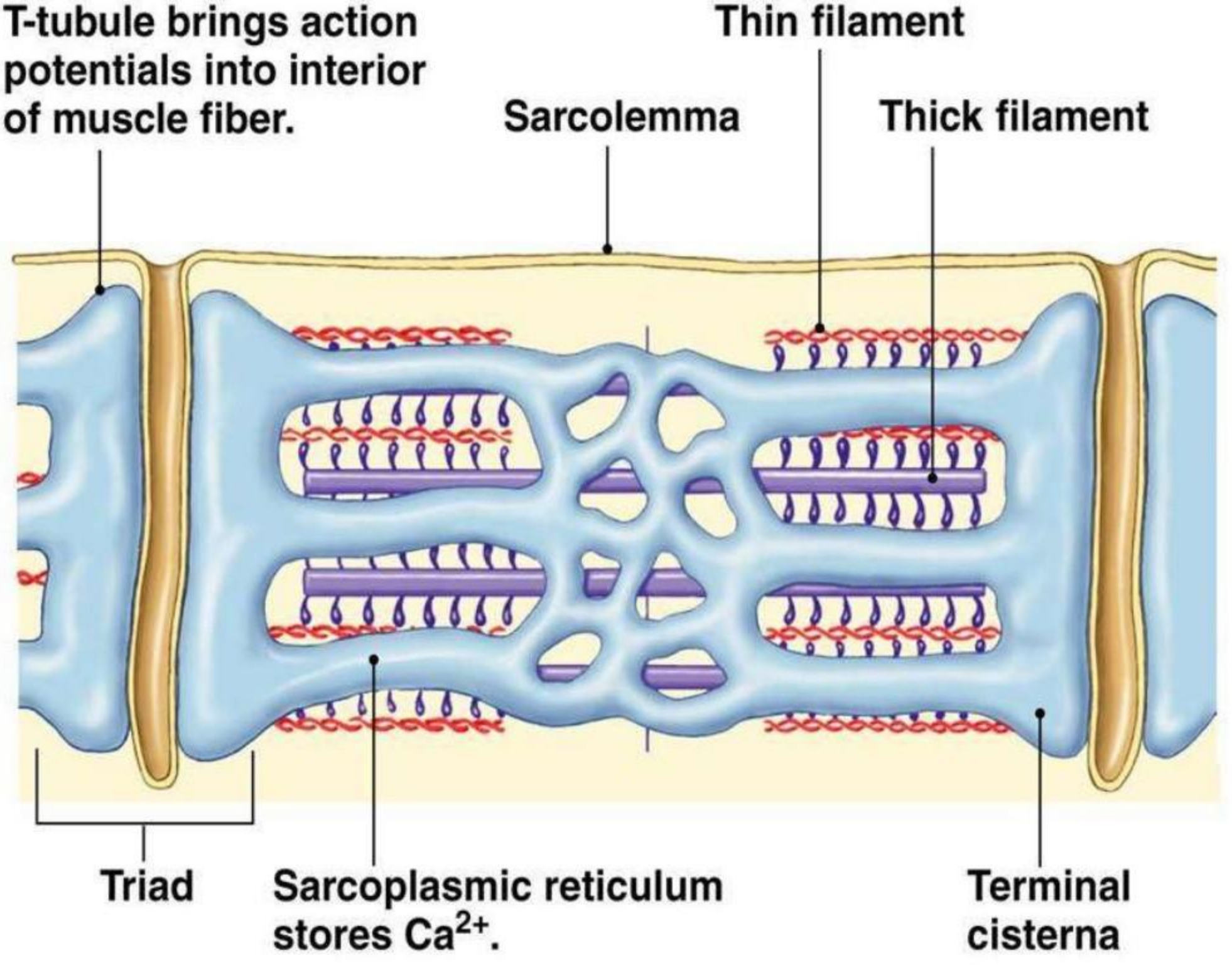
Skeletal muscle

Smooth muscle

Cardiac muscle

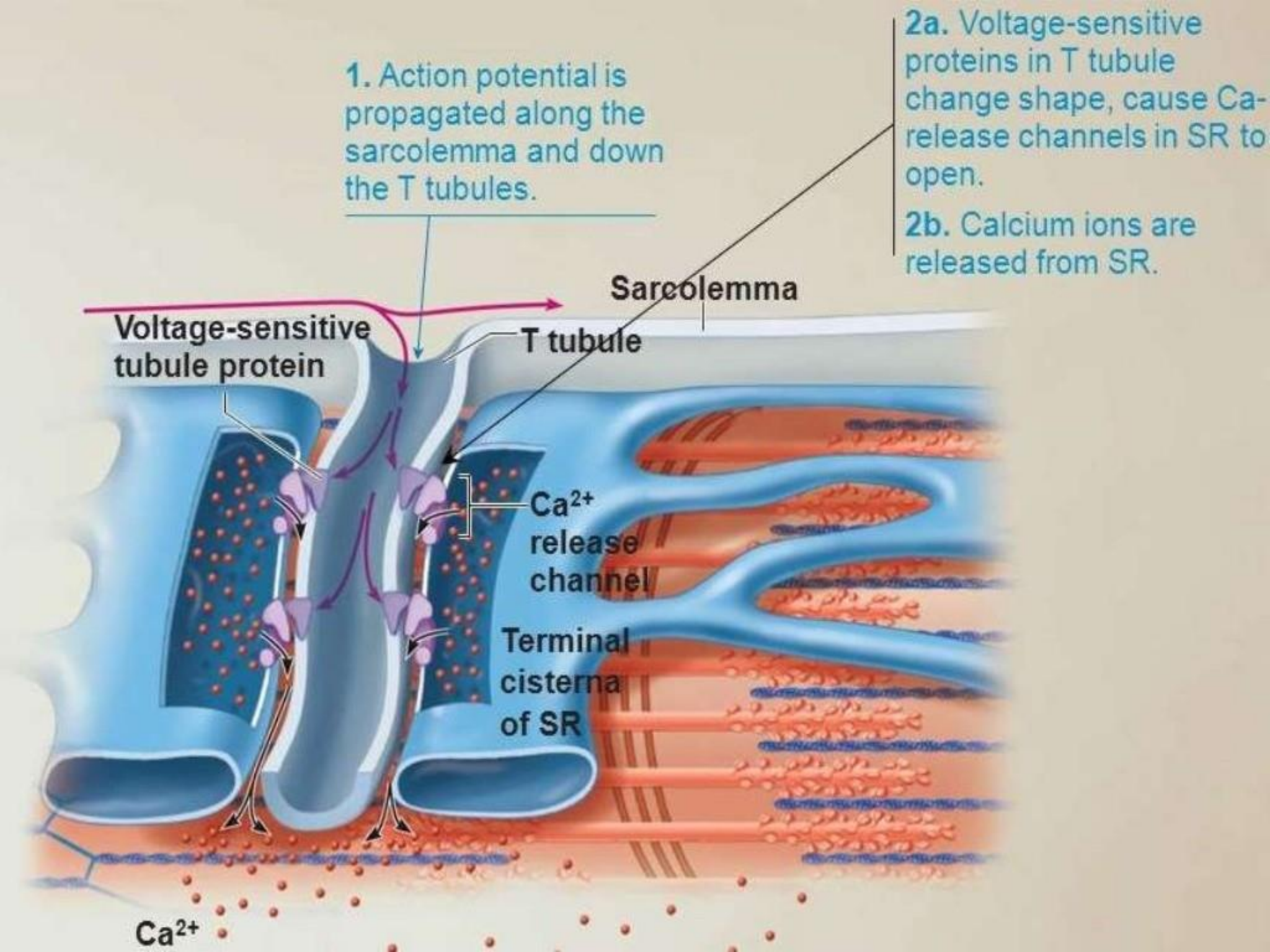
- Cardiac muscle fibres are essentially long, cylindrical cells with one (or sometimes two) nuclei. These are centrally located within the cell.

- Each muscle fiber connects to the plasma membrane (sarcolemma) with distinctive tubules (T-tubules).

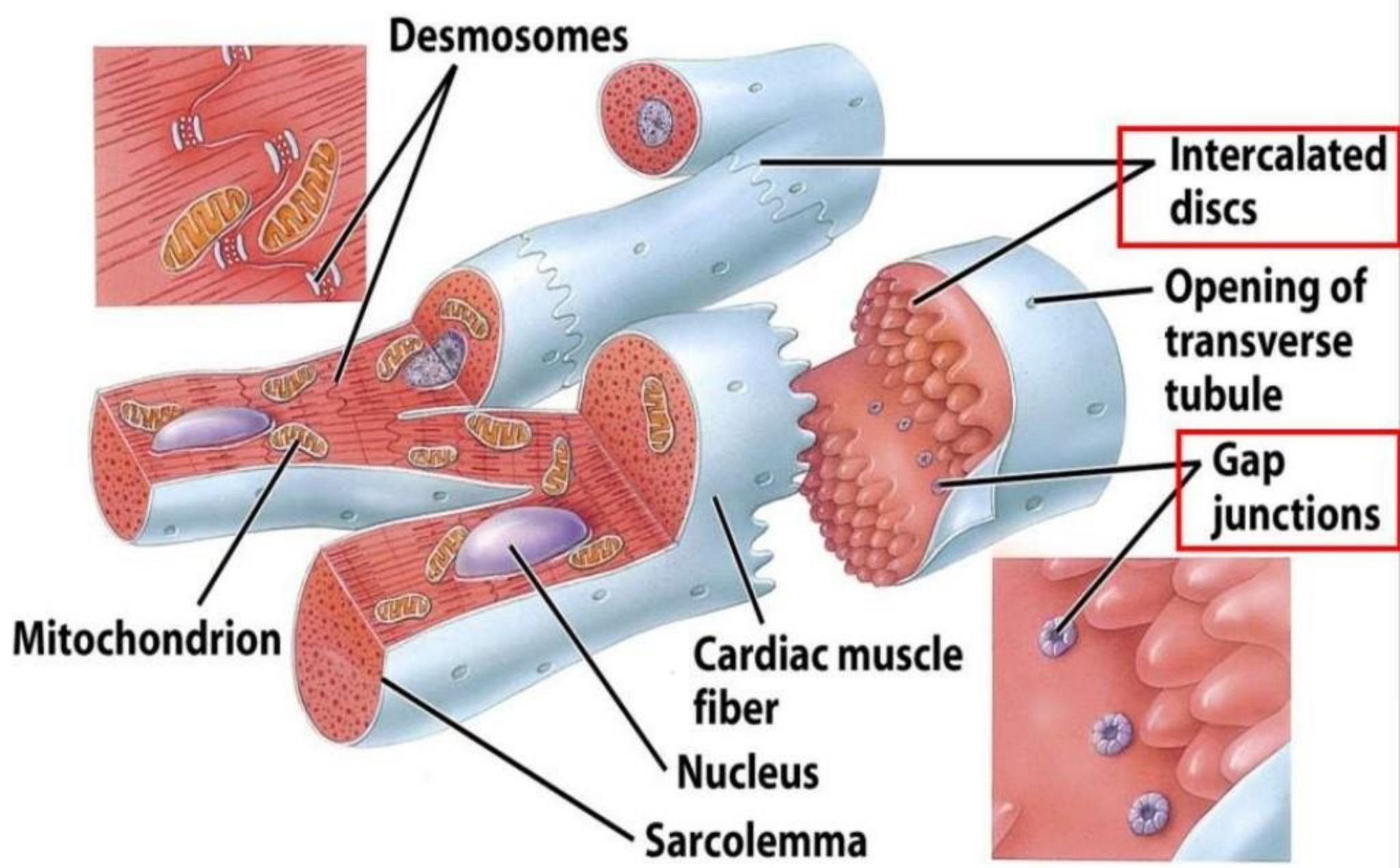

T-tubule brings action potentials into interior of muscle fiber.
Thin filament
Sarcolemma
Thick filament
Triad
Sarcoplasmic reticulum stores Ca^{2+}.
Terminal cisterna

- At these T-tubules, the sarcolemma is studded with a large number of calcium channels which allow calcium ion exchange.

- The flux of calcium ions into the muscle cells stimulates an ACTION POTENTIAL, which causes the cells to contract.


1. Action potential is propagated along the sarcolemma and down the T tubules.
2a. Voltage-sensitive proteins in T tubule change shape, cause Ca-release channels in SR to open.
2b. Calcium ions are released from SR.
Sarcolemma
Voltage-sensitive tubule protein
T tubule
Ca2+ release channel
Terminal cisterna of SR
Ca2+

- Between the ends of adjacent cardiac muscle cells are specialised intercellular junctions called INTERCALATED DISKS. These are irregular transverse thickenings of the sarcolemma that contain structures called DESMOSOMES. Desmosomes are like spot-rivets, that hold adjacent cardiac muscle fibres together.



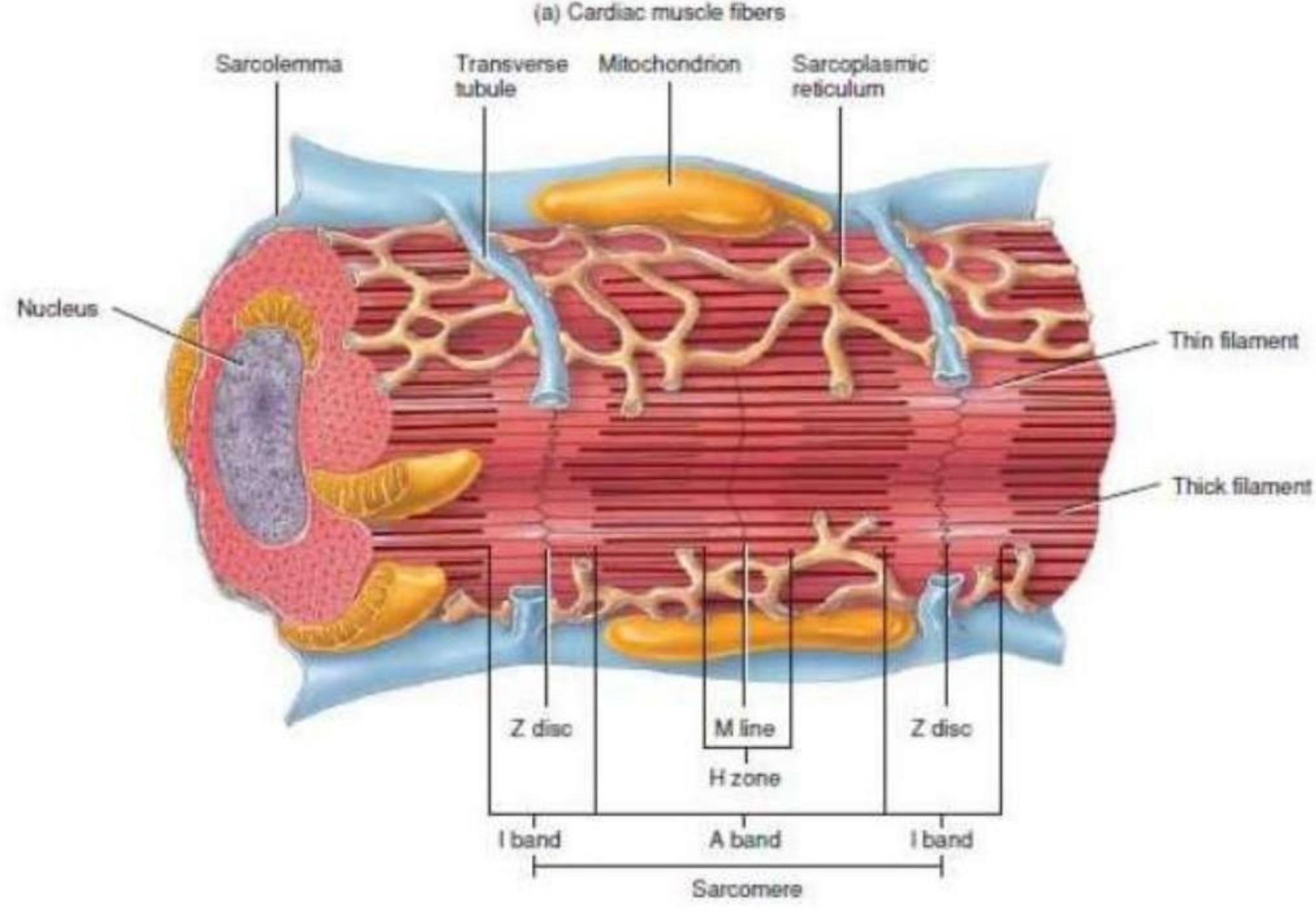
Cardiac muscle fibers

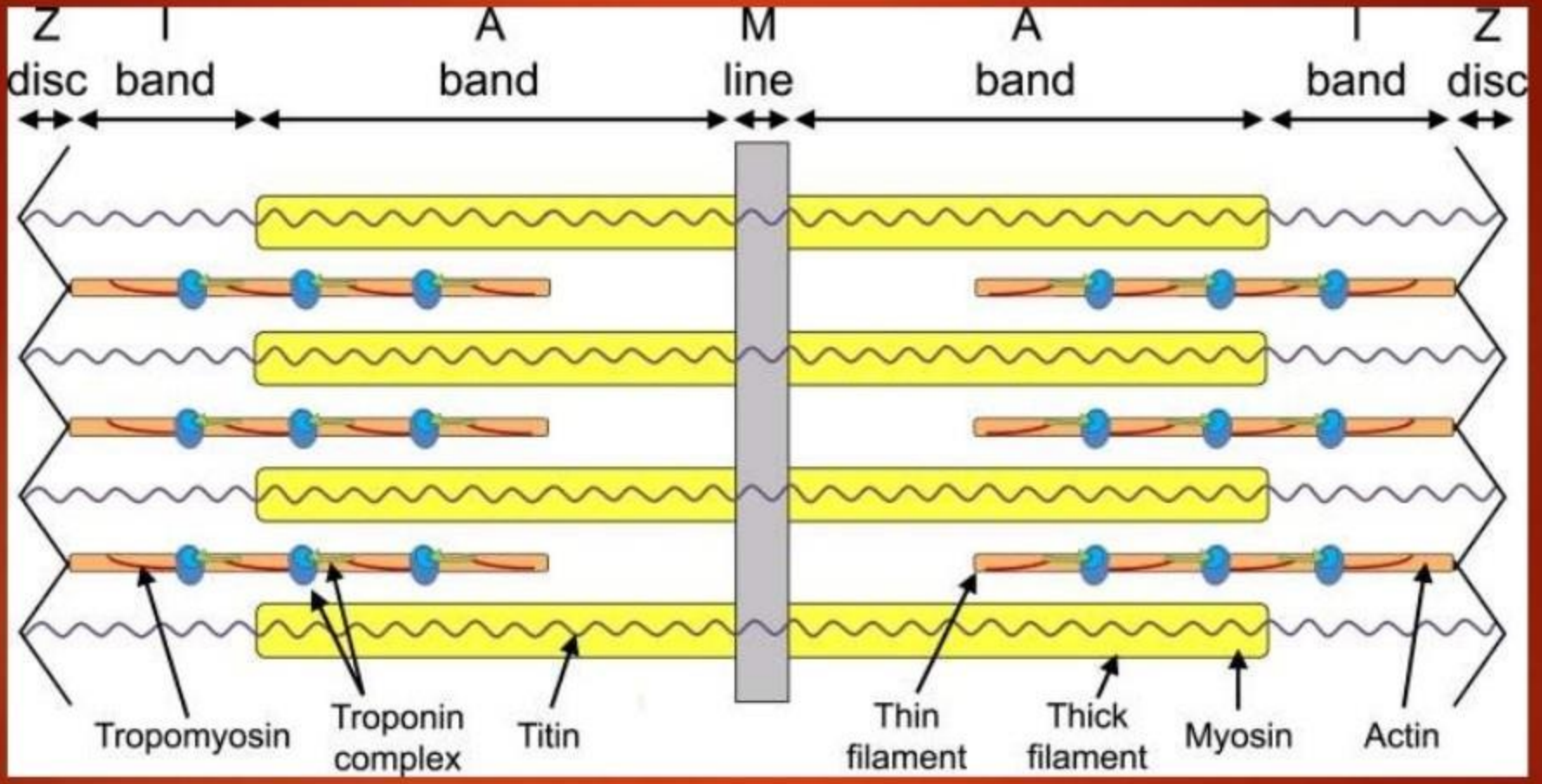
Figure 20-9a Principles of Anatomy and Physiology, 11/e

- The intercalated discs also act as points of anchorage for the contractile proteins, and they contain important channels called GAP JUNCTIONS. These connect the cytoplasm of adjacent cardiac muscle fibres and **permit the extremely rapid** low-resistance **spread of action potentials from one cell to another**.

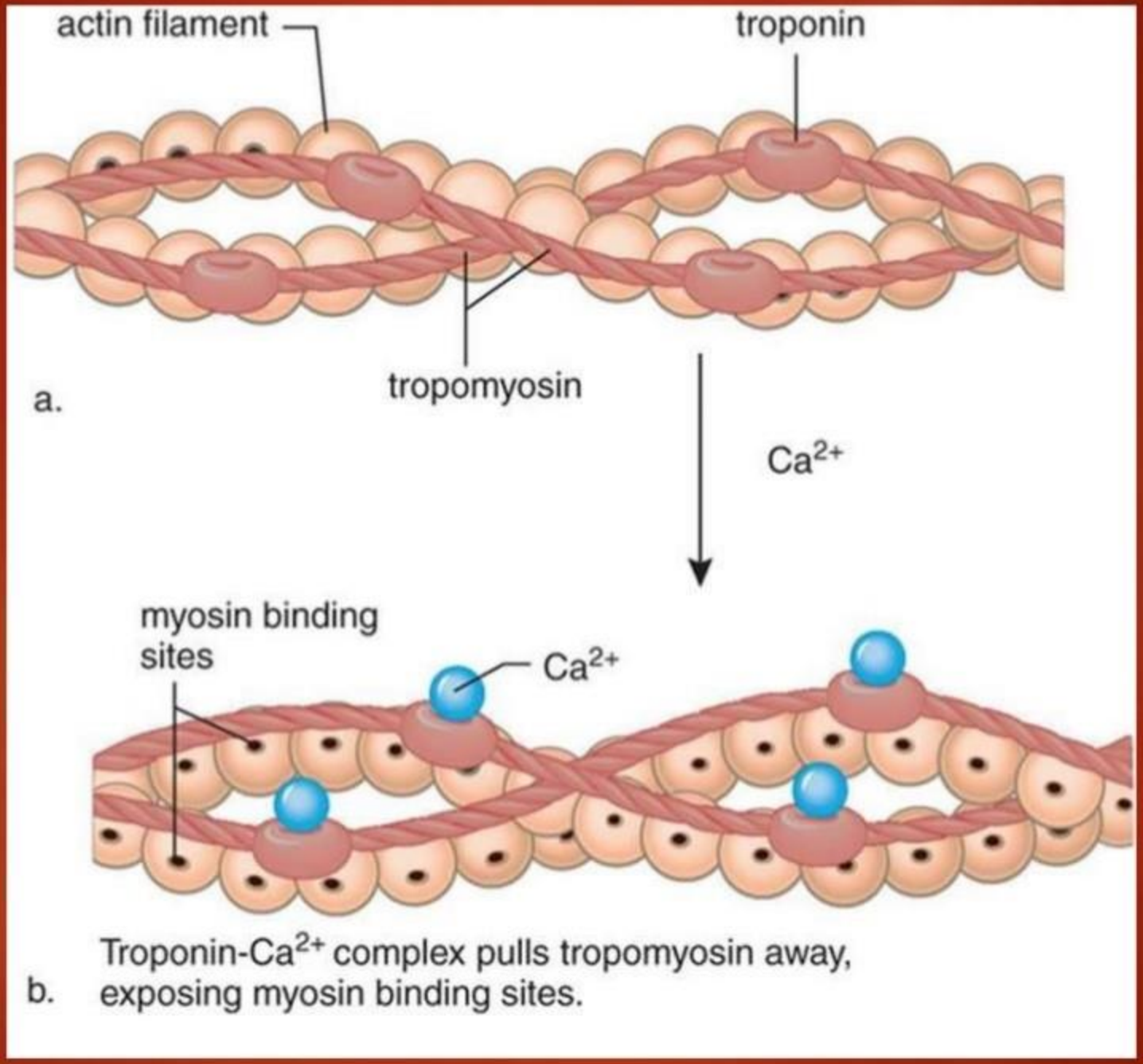
SARCOMERE

- SARCOMERE is the contractile unit of the myocardial cell. Sarcomeres are composed of long, fibrous proteins that slide past each other when the muscles contract and relax.
- Two of the important proteins found in sarcomeres are MYOSIN, which forms the thick filament, and ACTIN, which forms the thin filament. Myosin has a long, fibrous tail and a globular head, which binds to actin.
- Two other proteins present in sarcomeres are TROPONIN and TROPOMYOSIN.


(a) Cardiac muscle fibers
Sarcolemma
Transverse tubule
Mitochondrion
Sarcoplasmic reticulum
Nucleus
Thin filament
Thick filament
Z disc
M line
Z disc
H zone
I band
A band
I band
Sarcomere


Z disc
I band
A band
M line
A band
I band
Z disc
Tropomyosin
Troponin complex
Titin
Thin filament
Thick filament
Myosin
Actin

- TROPONIN is attached to the protein TROPOMYOSIN and lies within the groove between actin filaments in muscle tissue. In a relaxed
muscle, tropomyosin blocks the attachment site for the myosin cross-bridge, thus preventing contraction.


actin filament
troponin
tropomyosin
a.
Ca^{2+}
myosin binding sites
Ca^{2+}
b.
Troponin-Ca^{2+} complex pulls tropomyosin away, exposing myosin binding sites.

TROPONIN

- Troponin is a complex of three polypeptides found in striated muscle fibres.
- One polypeptide (**TnI**) binds to actin, another (**TnT**) binds to tropomyosin, and the third (**TnC**) binds to calcium ions.
- When calcium ions bind to troponin, the troponin changes shape, forcing tropomyosin away from the actin filaments. This allows myosin cross-bridges to attach onto the actin, enabling contractions to occur.

Cardiomyocyte Perfusion

- Contain the protein myoglobin, which stores oxygen.
- Adapted to be highly resistant to fatigue. Cardiomyocytes have a large number of mitochondria, enabling continuous aerobic respiration.
- Large blood supply relative to its size, which provides a continuous stream of nutrients and oxygen, while providing ample removal of metabolic waste.

Myocardial Thickness

- The myocardium has variable levels of thickness within the heart. Chambers of the heart with a thicker myocardium are able to pump blood with more pressure and force compared to chambers of the heart with a thinner myocardium. The myocardium is thinnest within the atria, as the atria fill largely through passive blood flow.

- The thickness of the myocardium may change in some individuals as a compensatory adaptation to disease. The myocardium may thicken and become stiff, or it may become thinner and flabby.

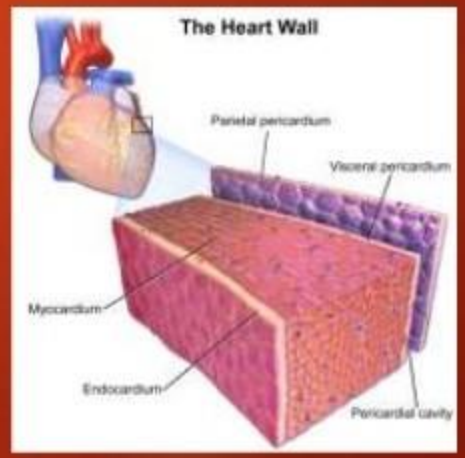
Myocardial Thickness and Disease

- Cardiac **hypertrophy** is a common result of hypertension (high blood pressure) in which the cells of the myocardium enlarge as an adaptive response to pumping against the higher pressure. Eventually it may become so severe that heart failure occurs when the heart becomes so stiff that it can no longer pump blood.

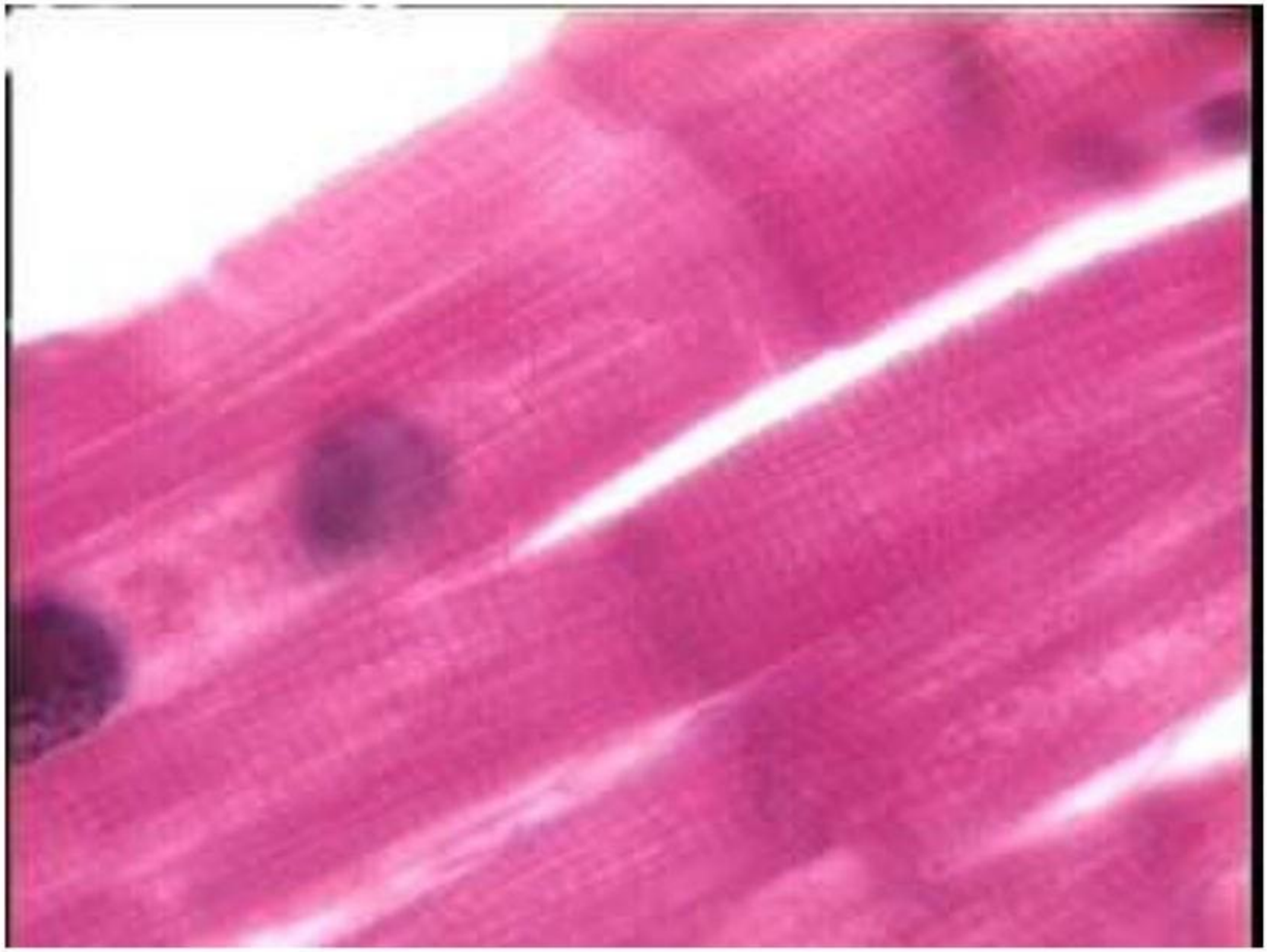
- A flabby heart is typically the result of myocardial infections (**myocarditis**), in which the heart muscle becomes so weak that it cannot efficiently pump blood, which also leads to heart failure.

Functions of the Myocardium

- Providing a scaffolding for the heart chambers
- Assisting in contraction and relaxation of the cardiac walls so that blood can pass between the chambers.
- Conducting electro-stimulation through its own tissues and into the epicardium (The Conducting system of the heart).

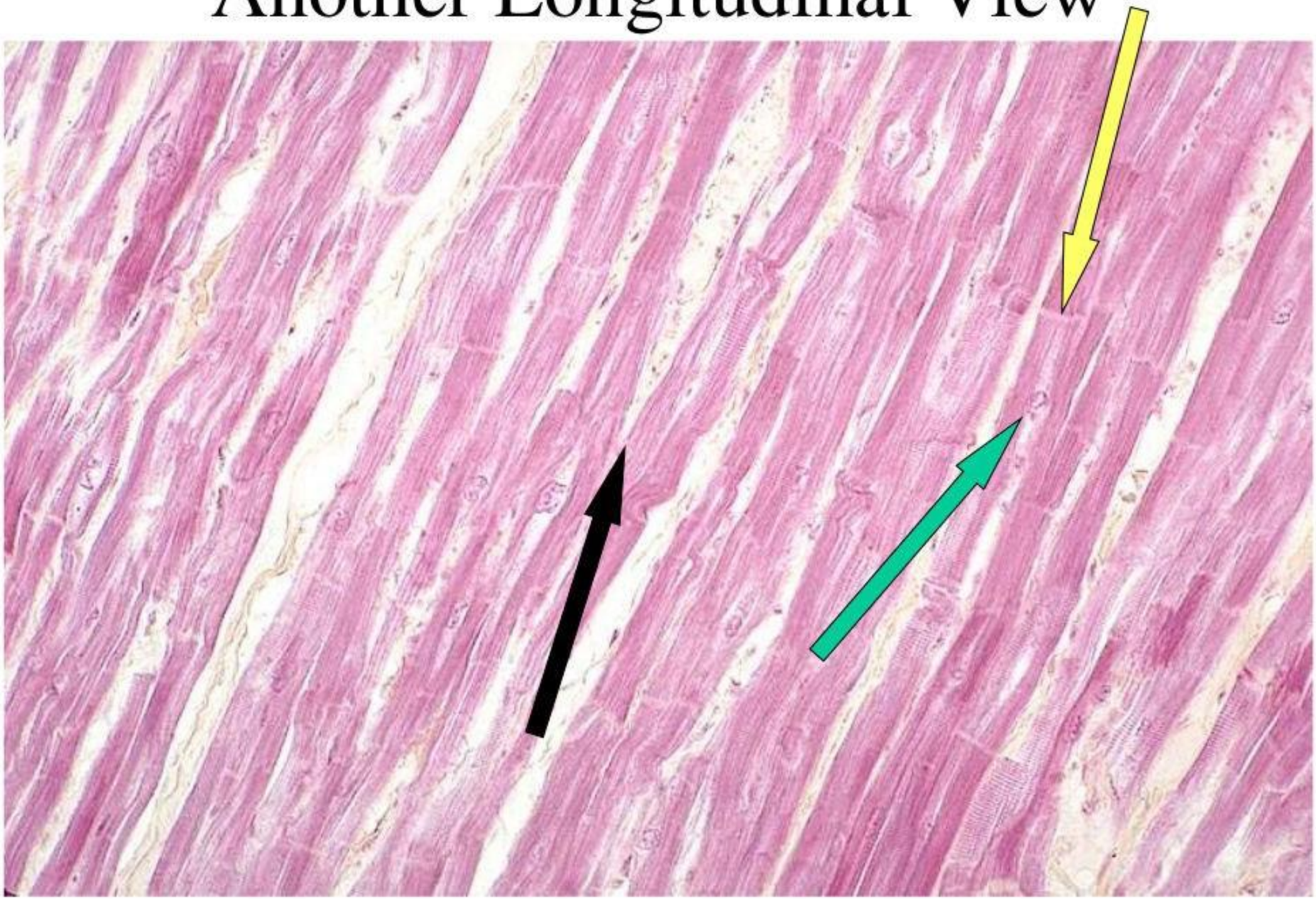


Longitudinal View (long Axis)



**(Note the light striations, centrally located nucleus, and intercalated discs)

Another Longitudinal View

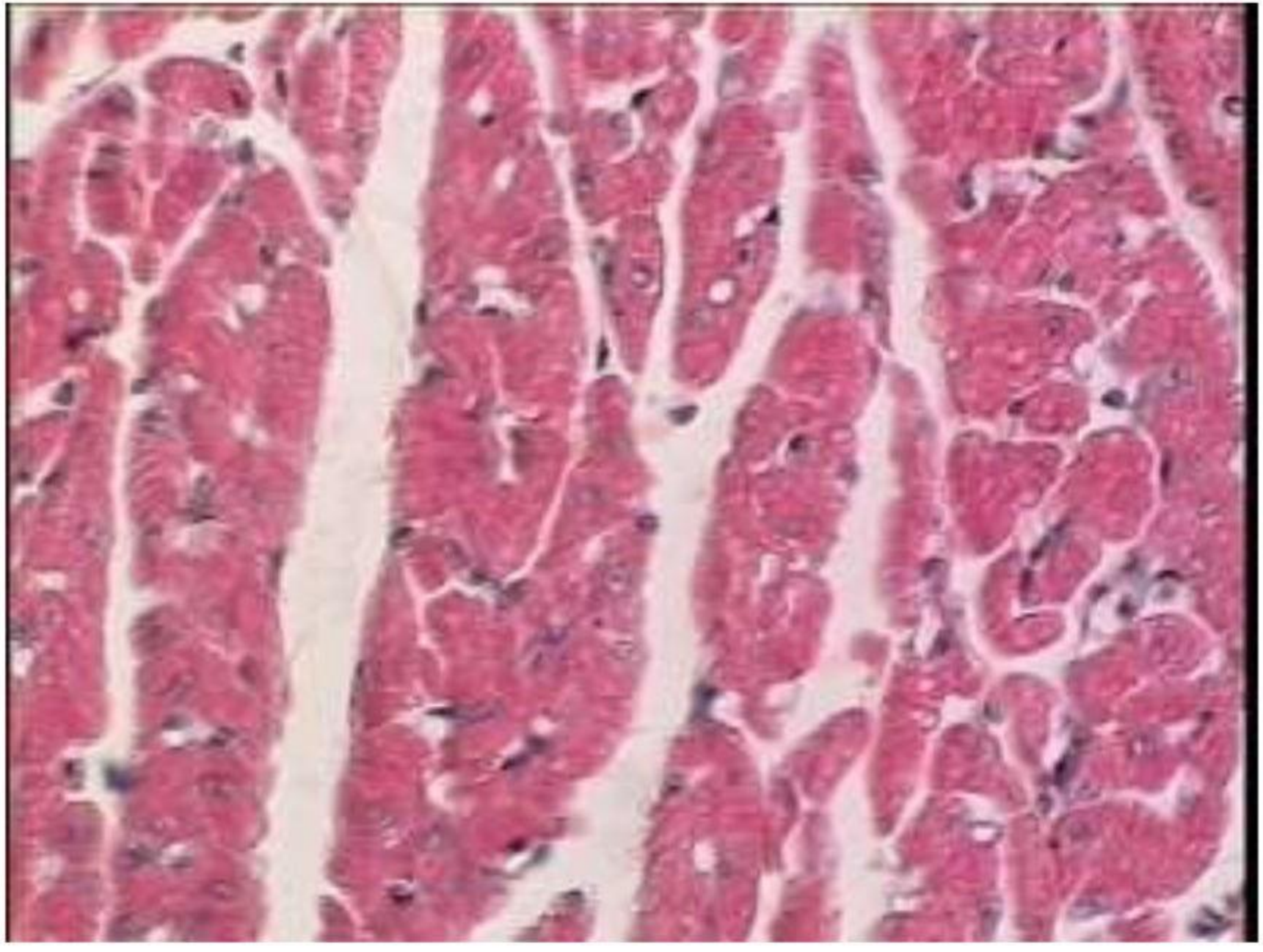


Note the branching, weaving network (black arrow), single, centered nucleus (green arrow), and the intercalated discs (yellow arrow).

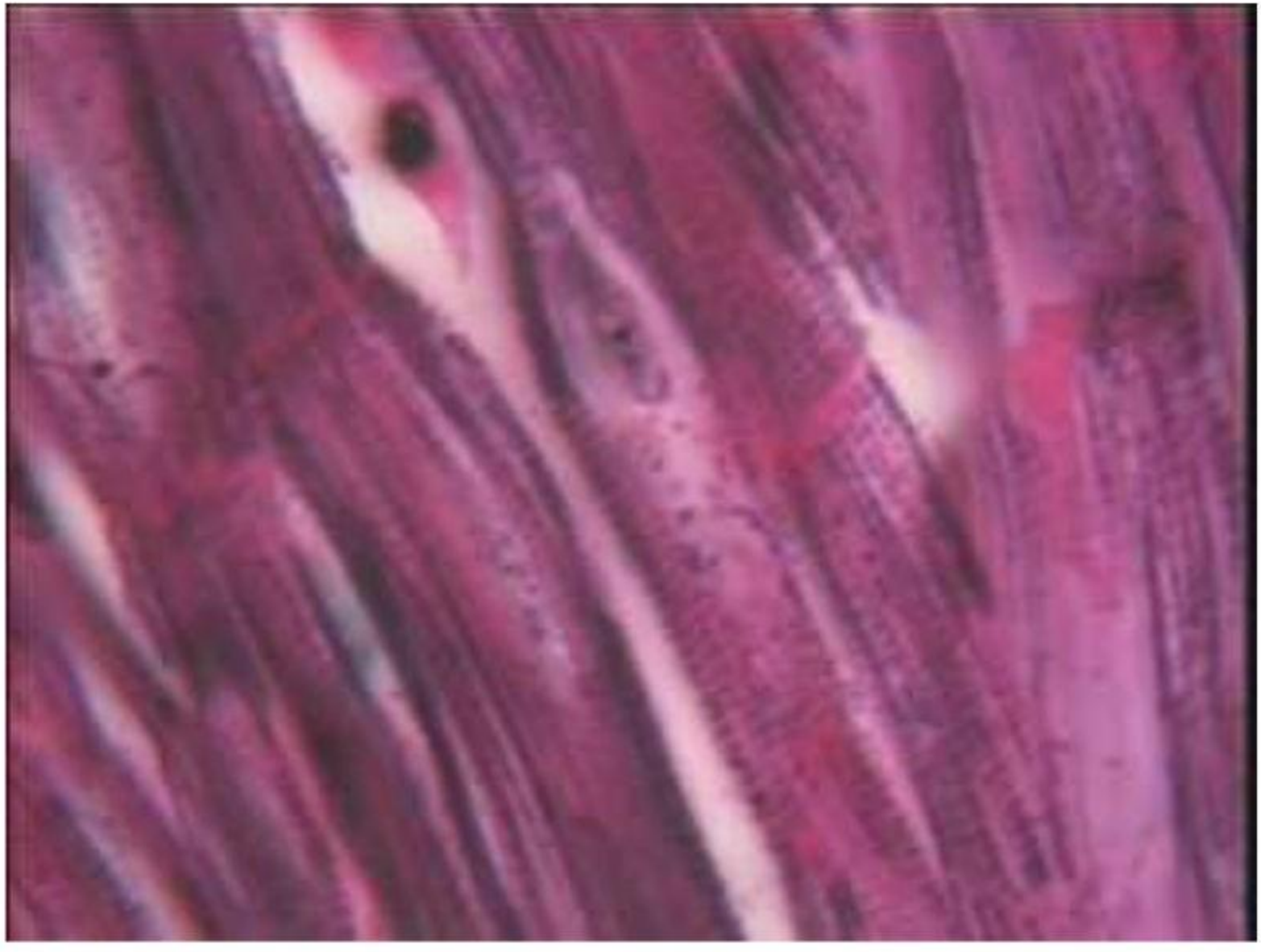
Cross-sectional View (short axis)

Note the single, centrally located nucleus

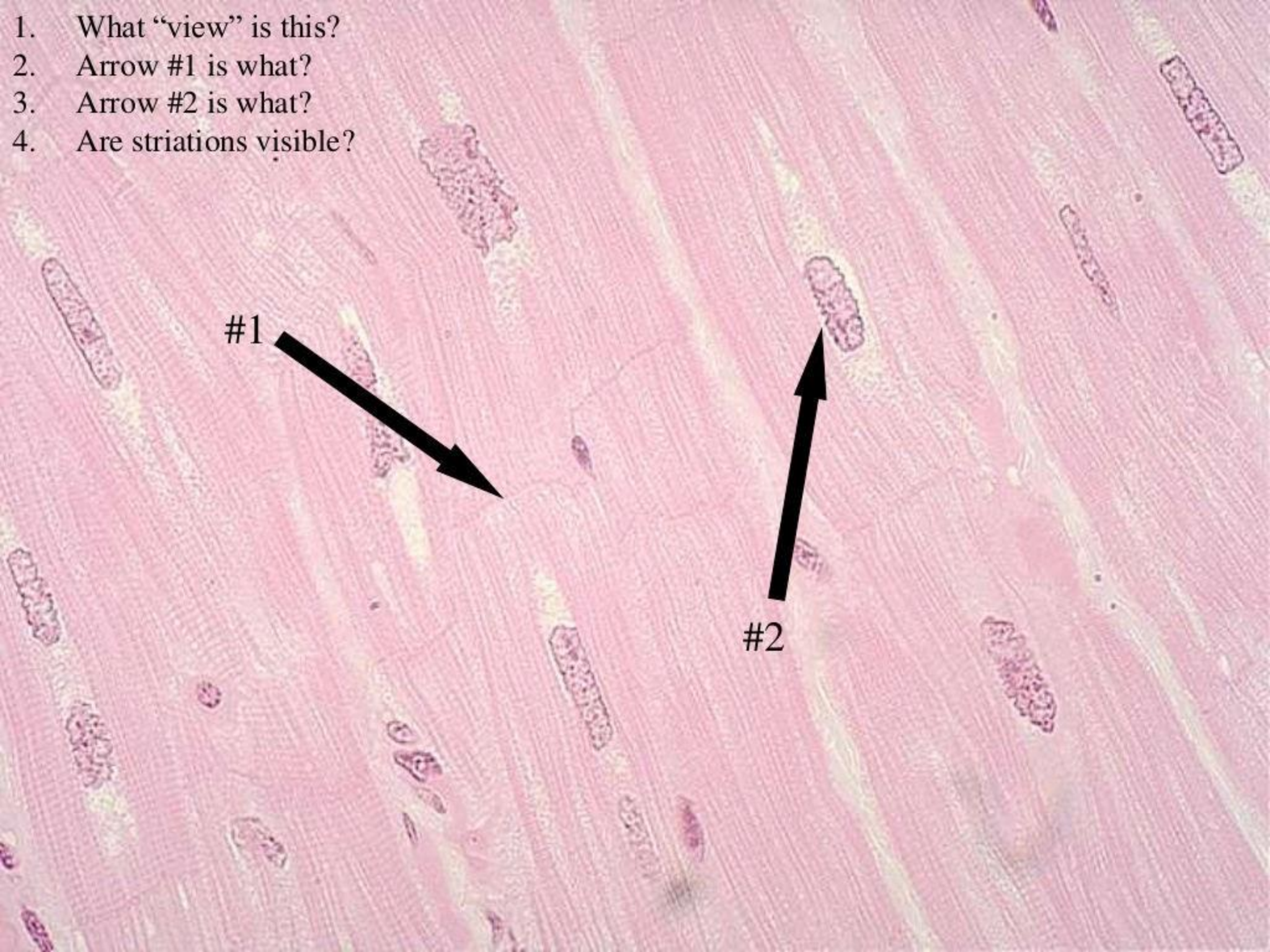
Another Cross-sectional View



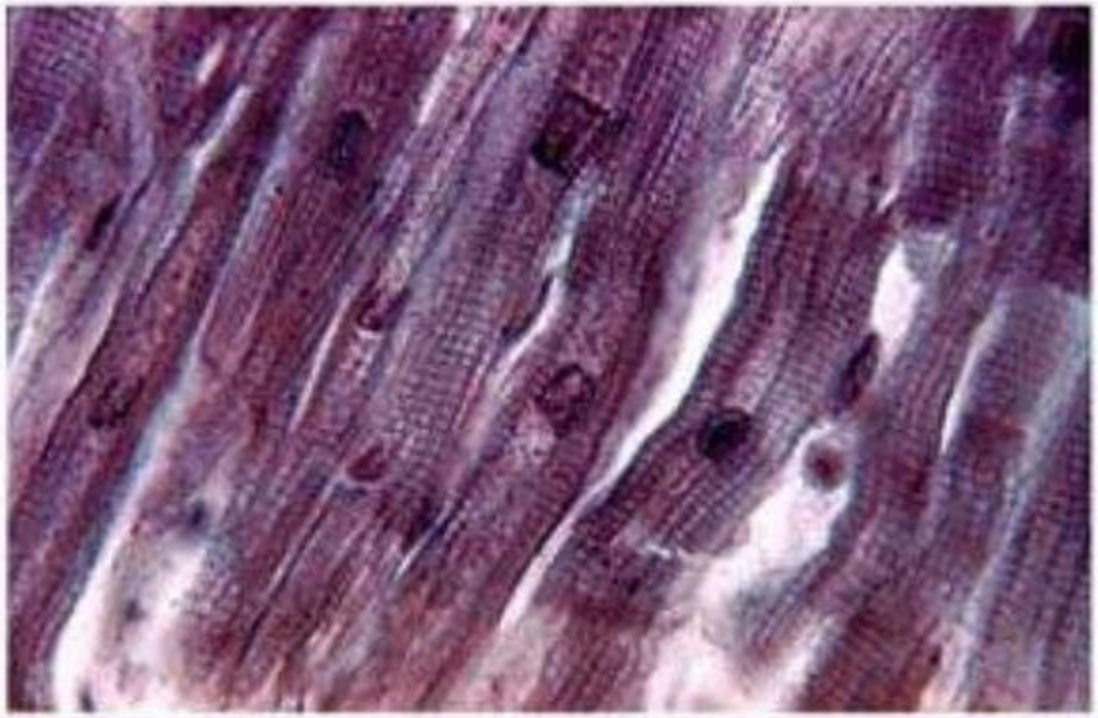
Additional Pictures of Cardiac Muscle

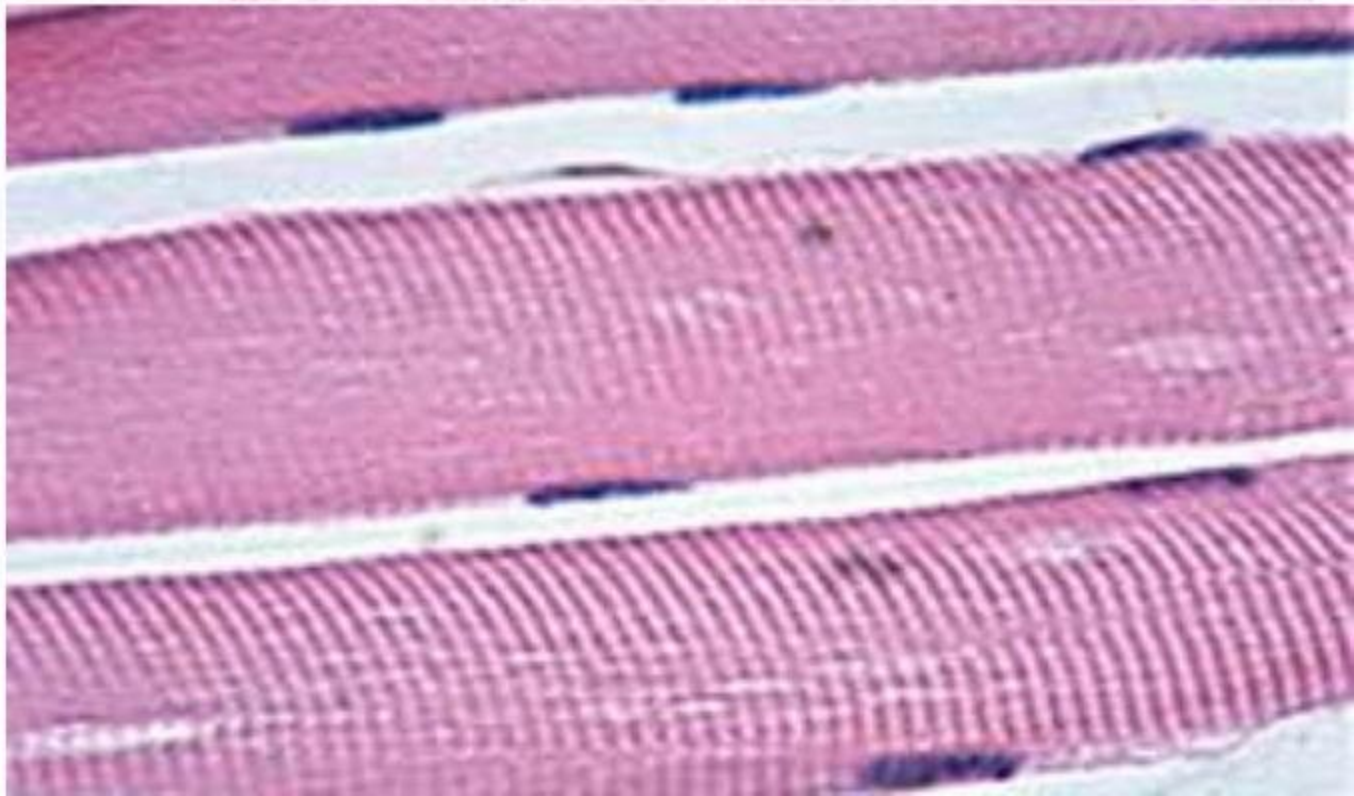


1. What "view" is this?
2. Arrow #1 is what?
3. Arrow #2 is what?
4. Are striations visible?

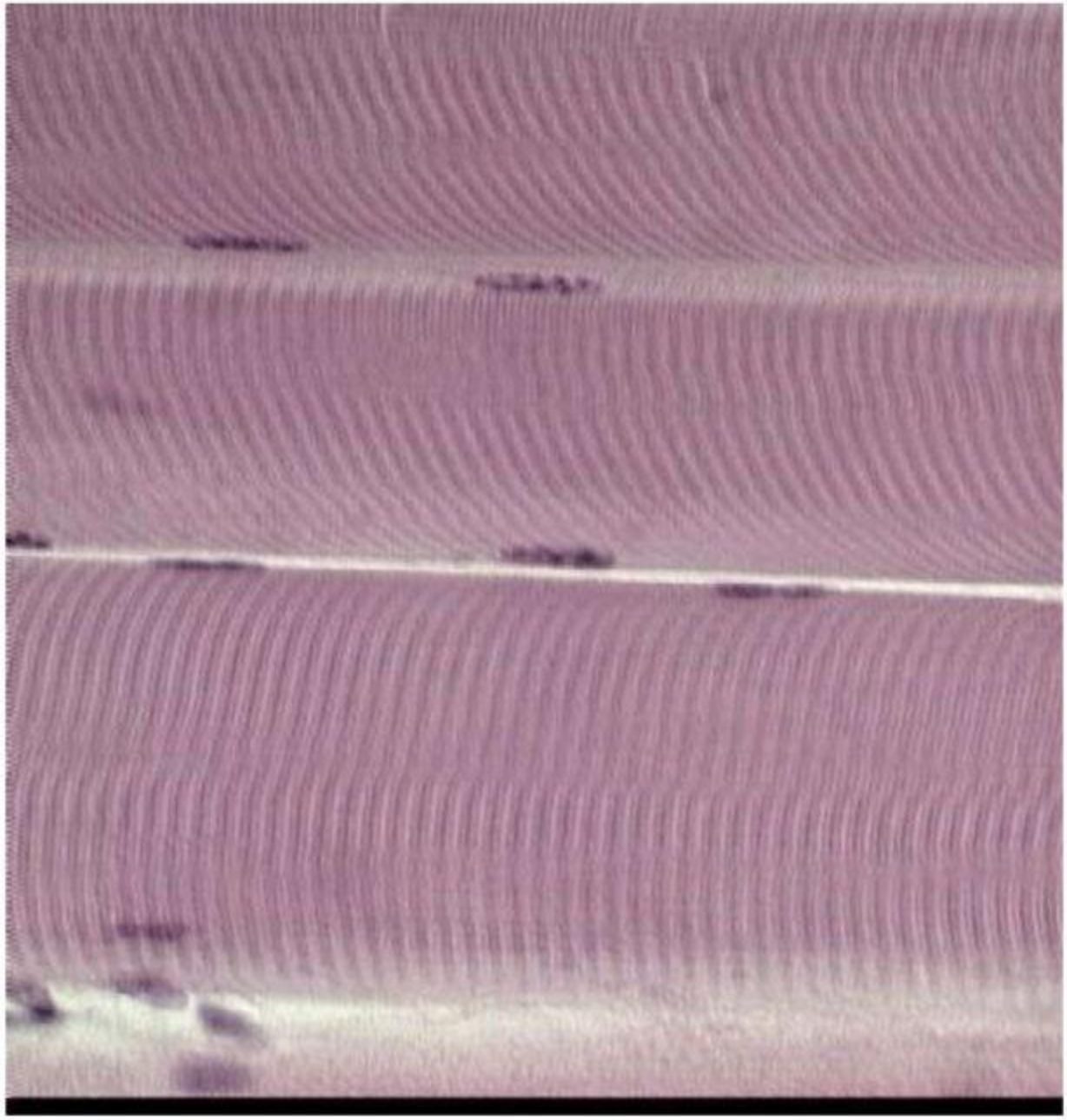


A comparison between cardiac (top) and skeletal (bottom).





What tissue is this?

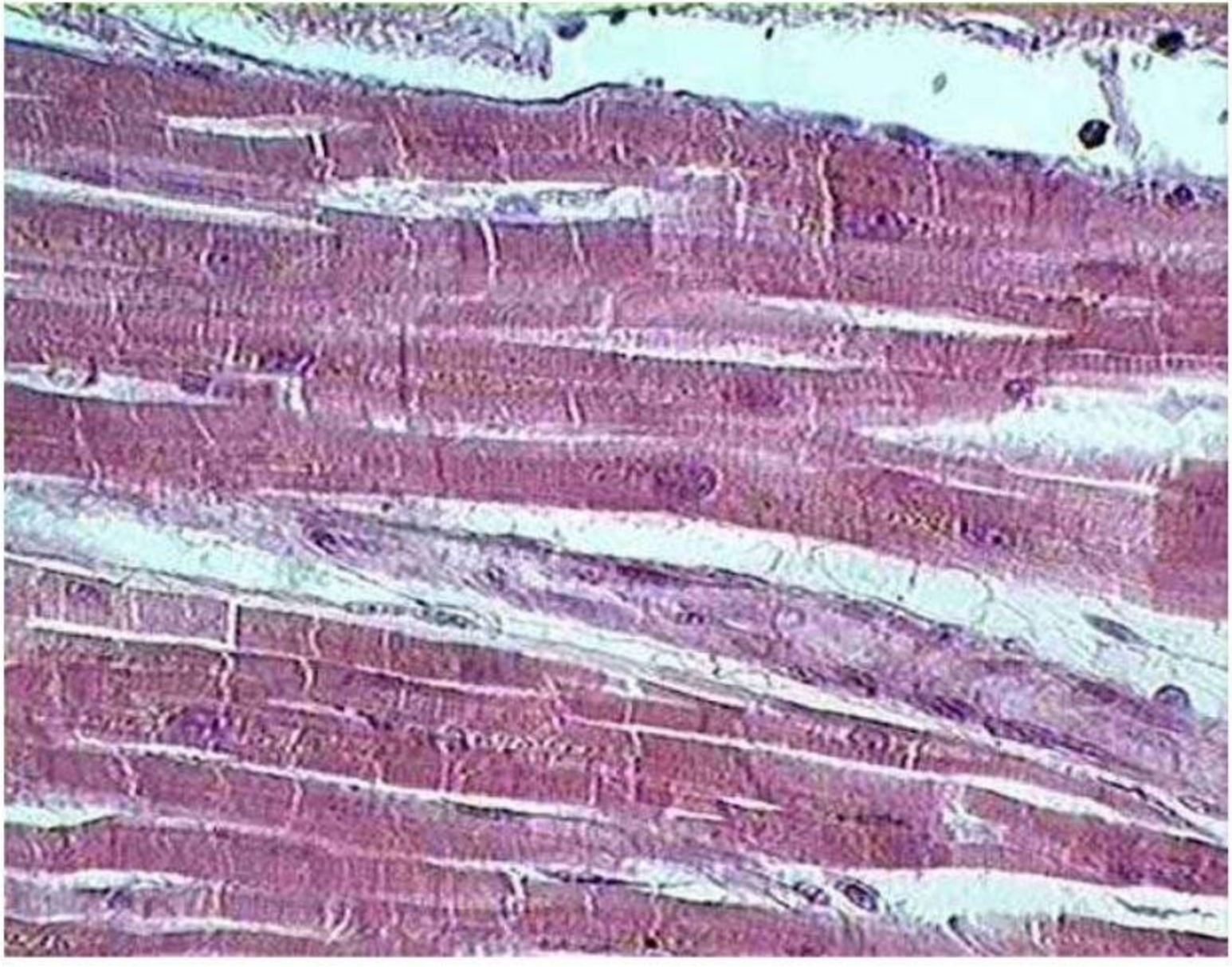


How did you know?

How did you know what it was?

- 1. Multiple peripheral nuclei
- 2. Parallel fibers
- 3. Strongly visible striations

What tissue is this?



How did you know?

How did you know what it was?

- 1. Intercalated discs
- 2. Branching, weaving network of cells
- 3. Single nucleus in the center of fiber
- 4. Lightly visible striations