# الفسلجة
# مرحلة ثانية

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# CARDIOVASCULAR SYSTEM

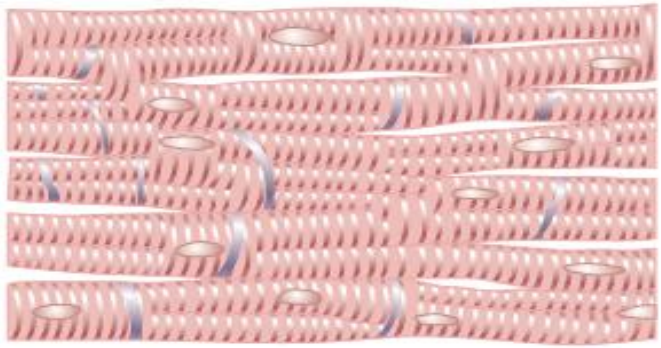
# Physiology of cardiac muscle:

- The myocardium is composed of cardiac muscle cells.
- There are three major types of cardiac muscles:

**1- The atrial muscle.**

**2- The ventricular muscle.**

**3-Specialized excitatory and conductive m**
**contractile fibers.**



Figure

"Syncytial," interconnecting nature of cardiac muscle fibers.

# Physiological anatomy of cardiac muscle:

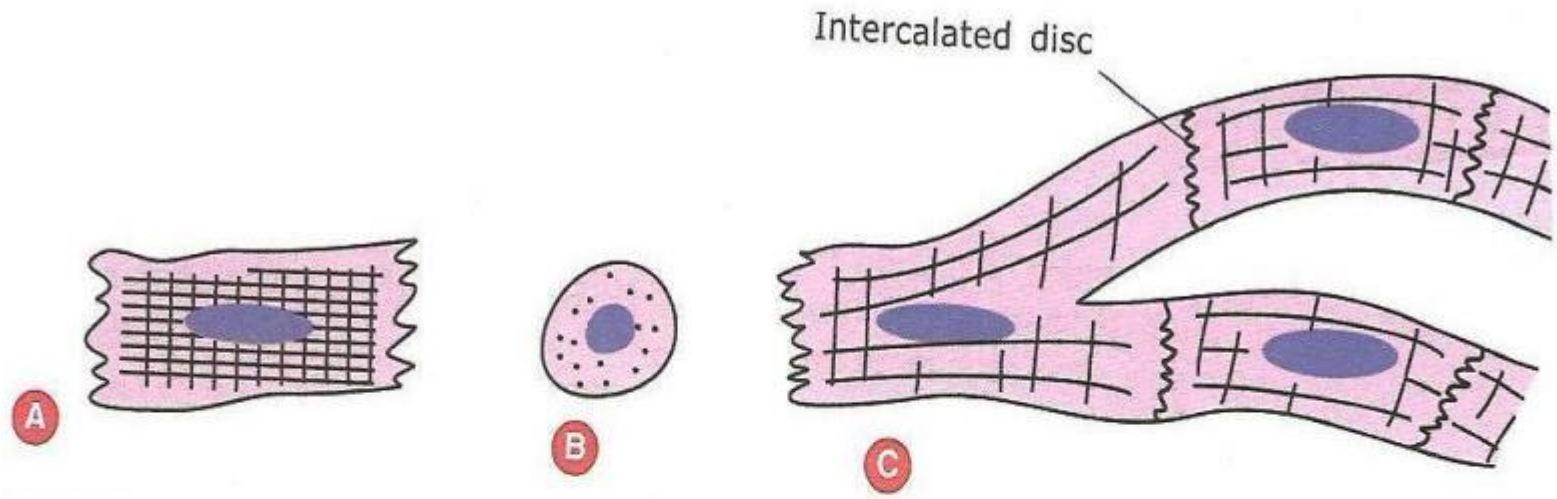
- **Actually there are two syncytiums: atrial and ventricular, separated by the fibrous skeleton.**
- **Normally, potentials are conducted between the two syncytiums only by a specialized conductive system.**
- **This division of the heart muscle into two functional syncytiums is important for effectiveness of heart pumping.**

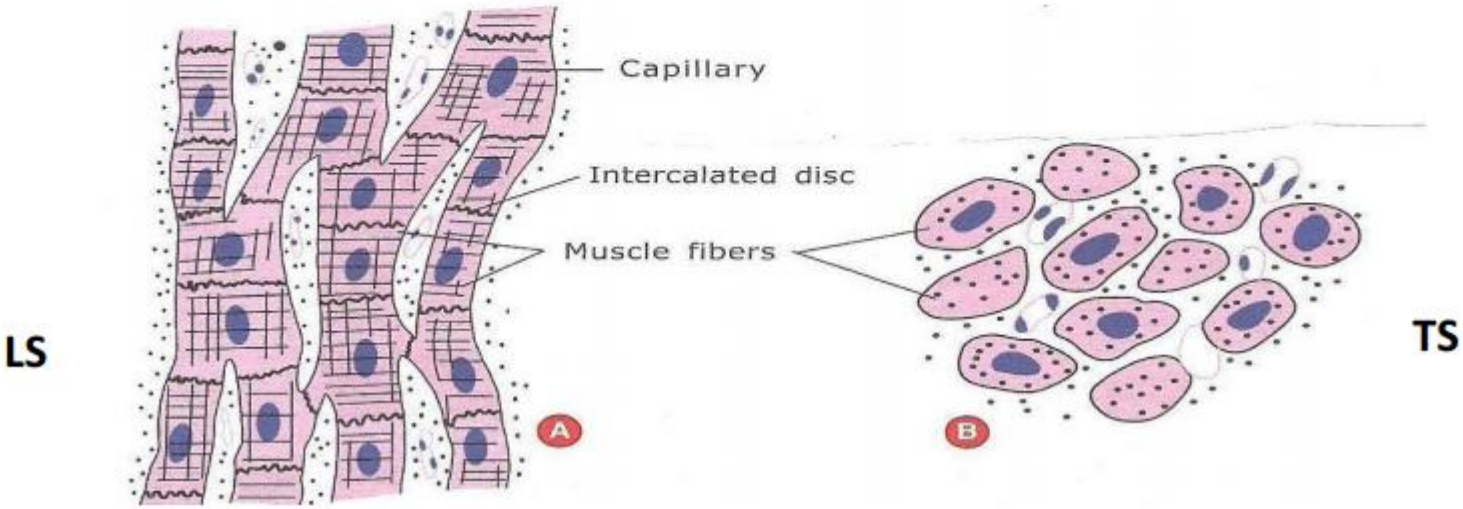
# Cardiac Muscle

- Striated and involuntary
- Present exclusively in heart
- Originates in splanchnopleuric mesoderm
- Supplied by ANS (sympathetic & parasympathetic)

# Microscopic structure of Cardiac Muscle

- Consists of long and thick branching muscle fibers (may appear as Y shaped)
- Intercalated discs
- Centrally placed single oval nucleus
- Faint transverse striations
- A & I bands along with Z discs present


Intercalated disc
A
B
C


Capillary
Intercalated disc
Muscle fibers
A
B

LS

TS

# Metabolism

Cardiac muscle is adapted to be highly resistant to fatigue: it has a large number of mitochondria, enabling continuous aerobic respiration via oxidative phosphorylation, numerous myoglobins (oxygen-storing pigment) and a good blood supply, which provides nutrients and oxygen. The heart is so tuned to aerobic metabolism that it is unable to pump sufficiently in ischaemic conditions. At basal metabolic rates, about 1% of energy is derived from anaerobic metabolism. This can increase to 10% under moderately hypoxic conditions, but, under more severe hypoxic conditions, not enough energy can be liberated by lactate production to sustain ventricular contractions.

Under basal aerobic conditions, 60% of energy comes from fat (free fatty acids and triglycerides), 35% from carbohydrates, and 5% from amino acids and ketone bodies. However, these proportions vary widely according to nutritional state. For example, during starvation, lactate can be recycled by the heart. This is very energy efficient, because one NAD+ is reduced to NADH and H+ (equal to 2.5 or 3 ATP) when lactate is oxidized to pyruvate, which can then be burned aerobically in the TCA cycle, liberating much more energy (ca 14 ATP per cycle).

In the condition of diabetes, more fat and less carbohydrate is used due to the reduced induction of GLUT4 glucose transporters to the cell surfaces. However, contraction itself plays a part in bringing GLUT4 transporters to the surface. This is true of skeletal muscle as well, but relevant in particular to cardiac muscle due to its continuous contractions

# Striation

Cardiac muscle exhibits cross striations formed by alternating segments of thick and thin protein filaments. Like skeletal muscle, the primary structural proteins of cardiac muscle are actin and myosin. The actin filaments are thin causing the lighter appearance of the I bands in striated muscle, while the myosin filament is thicker lending a darker appearance to the alternating A bands as observed with electron microscopy. However, in contrast to skeletal muscle, cardiac muscle cells may be branched instead of linear and longitudinal.

# T-Tubules

Another histological difference between cardiac muscle and skeletal muscle is that the T-tubules in cardiac muscle are larger, broader and run along the Z-Discs. There are fewer T-tubules in comparison with skeletal muscle. Additionally, cardiac muscle forms diads instead of the triads formed between the T-tubules and the sarcoplasmic reticulum in skeletal muscle. T-tubules play critical role in excitation-contraction coupling (ECC).

# Gap Junctions (Cell-to-Cell Conduction)

In the heart, cardiac muscle cells (myocytes) are connected end to end by structures known as ***intercalated discs***.

These are irregular transverse thickenings of the sarcolemma, within which there are ***desmosomes*** that hold the cells together and to which the myofibrils are attached.
Adjacent to the intercalated discs are the gap junctions that allow action potentials to directly spread from one myocyte to the next.

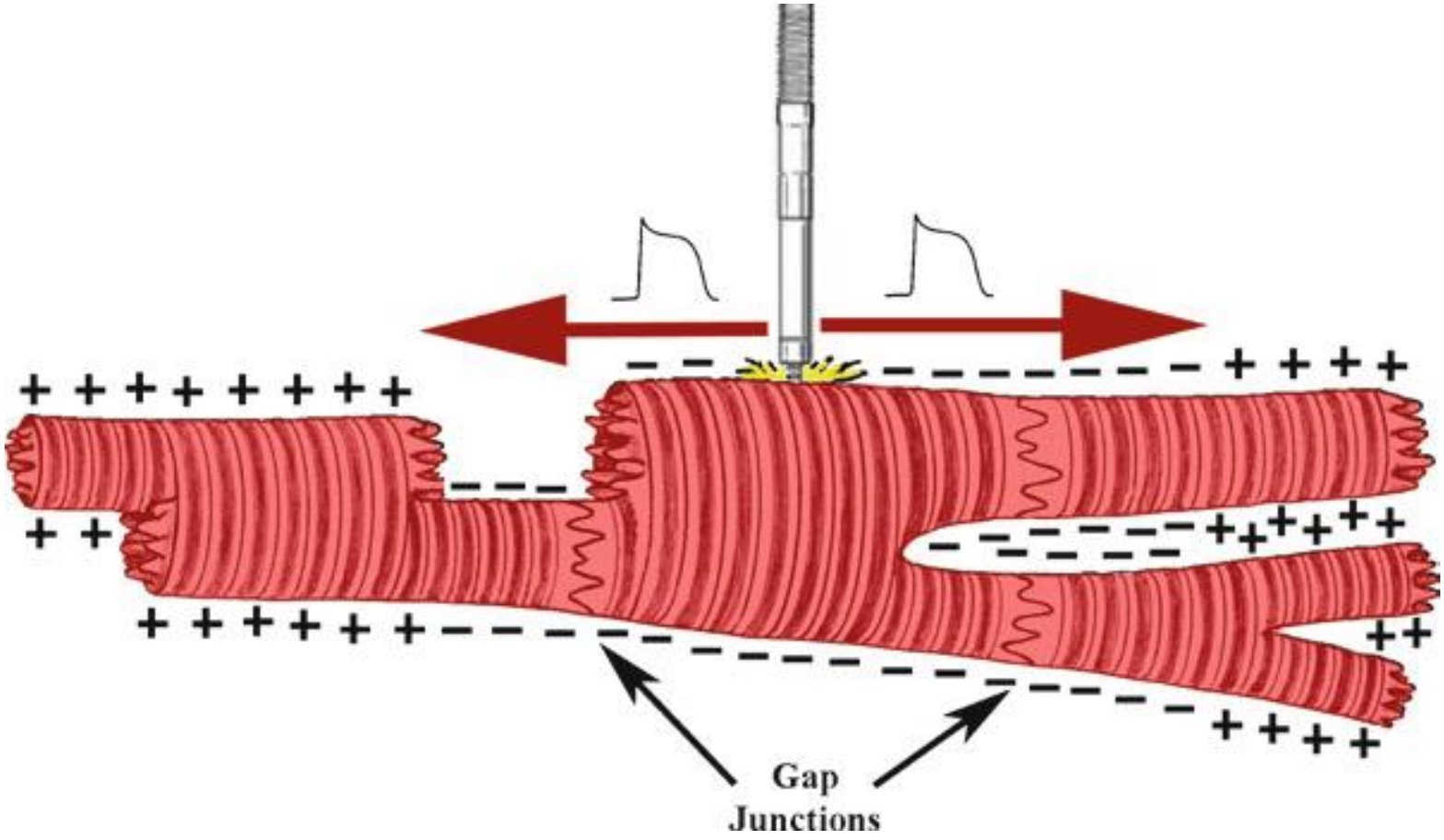
More specifically, the disks join the cells together by both mechanical attachment and protein channels. The firm mechanical connections are created between the adjacent cell membranes by proteins. The electrical connections (low resistance pathways, gap junctions) between the myocytes are via the channels formed by the protein connexin. These channels allow ion movements between cells There are several different isoforms of connexins that can be identified within the various populations of myocytes

# Intercalated discs

Intercalated discs (IDs) are complex adhering structures which connect single cardiac myocytes to an electrochemical syncytium (in contrast to the skeletal muscle, which becomes a multicellular syncytium during mammalian embryonic development) and are mainly responsible for force transmission during muscle contraction.

Intercalated discs also support the rapid spread of action potentials and the synchronized contraction of the myocardium. IDs are described to consist of three different types of cell-cell junctions: the actin filament anchoring adherent junctions (fascia adherens), the intermediate filament anchoring desmosomes (macula adherent) and gap junctions. Gap junctions are responsible for electrochemical and metabolic coupling. They allow action potentials to spread between cardiac cells by permitting the passage of ions between cells, producing depolarization of the heart muscle.

Under light microscopy, intercalated discs appear as thin, typically dark-staining lines dividing adjacent cardiac muscle cells. The intercalated discs run perpendicular to the direction of muscle fibers. Under electron microscopy, an intercalated disc's path appears more complex. At low magnification, this may appear as a convoluted electron dense structure overlying the location of the obscured Z-line. At high magnification, the intercalated disc's path appears even more convoluted, with both longitudinal and transverse areas appearing in longitudinal section.


Gap
Junctions