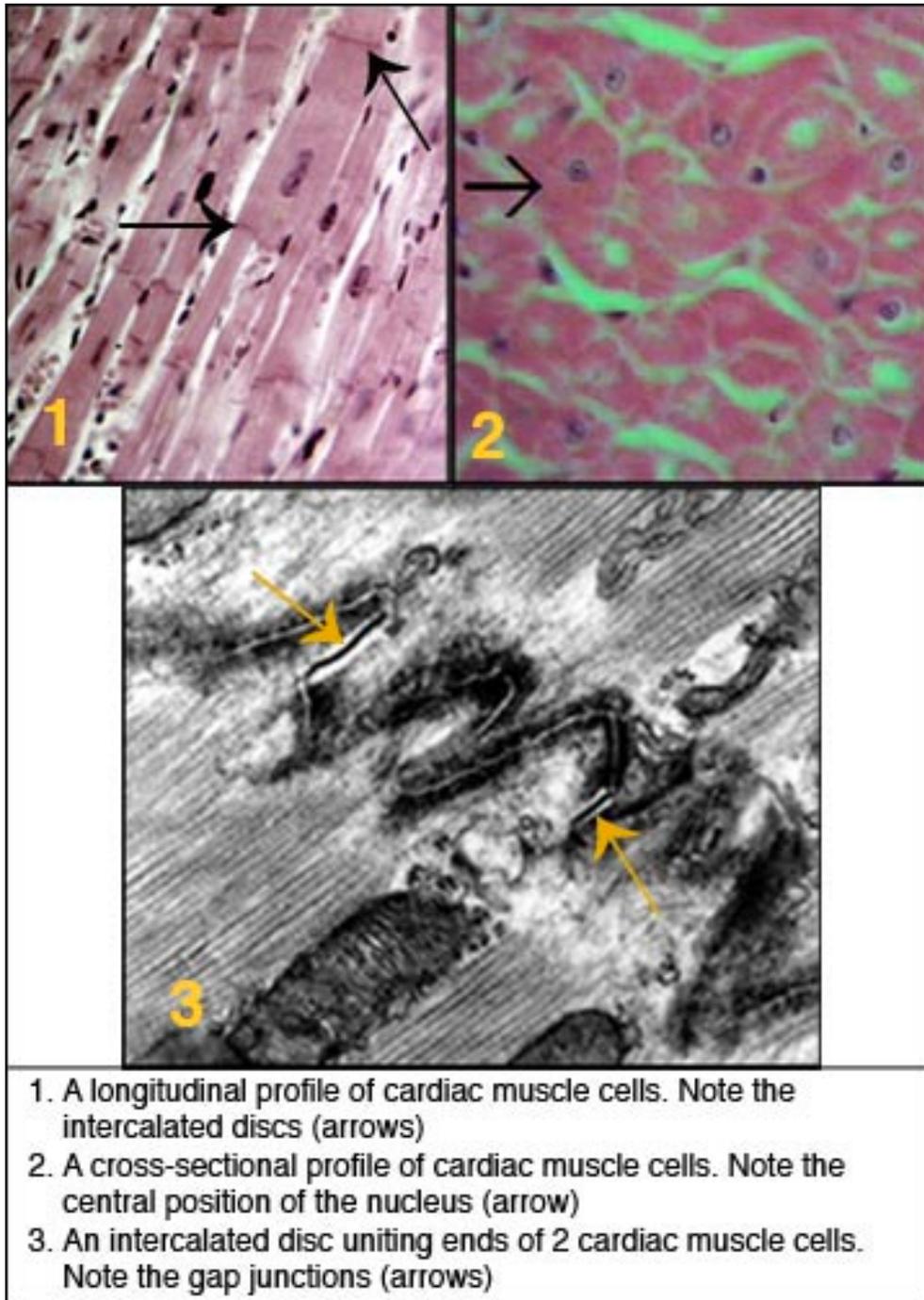


Cardiac Muscle



Cardiac muscle occurs only in the heart, where it forms the muscle wall (myocardium). It resembles both smooth and skeletal muscle; both skeletal and cardiac muscle are striated, but like smooth muscle, cardiac muscle is involuntary. However, cardiac muscle is unlike either in many of its structural details and is unique in that its contractions are automatic and spontaneous, requiring no external stimulus.

Organization

As in skeletal muscle, the histologic unit of structure of cardiac muscle is the cell (fiber), but in cardiac muscle the cells are associated end to end to form long tracts. The cells may divide at their ends before joining to adjacent fibers and thus form a network of branching fibers. Individual cardiac muscle cells are small in comparison to skeletal muscle cells measuring about $120\ \mu\text{m}$ in length and $20\ \mu\text{m}$ in width. A web of collagenous and reticular fibers is present between the muscle fibers and corresponds to an endomysium, but because of the branching fibers, it is more irregular than in skeletal muscle. Large bundles of cardiac muscle fibers are wrapped in a coarser connective tissue of collagen and reticular fibers, forming a perimysium, as in skeletal muscle.

The Cardiac Muscle Fiber (Cell)

Each cell (fiber) is enclosed in a sarcolemma external to which is an external lamina associated with fine reticular fibers. Each fiber contains one or on occasion two central nuclei. The same banding pattern seen in skeletal muscle is present on cardiac fibers, and A, I, M, H, and Z bands can be distinguished but are not as conspicuous as in skeletal muscle. The banding pattern is due to the arrangement of actin and myosin filaments, but the aggregation of filaments into myofibrils is not as well defined, and bundles of myofibrils often become confluent with those of adjacent bundles or are separated by rows of mitochondria. Mitochondria make up as much as 30% of the cytoplasmic volume of cardiac myocytes making them fatigue resistant. The bundles of myofibrils diverge around the nuclei to leave a fusiform area of sarcoplasm at each nuclear pole. These areas are occupied by small Golgi complexes and numerous large mitochondria that have closely packed cristae. Glycogen is a prominent inclusion of cardiac muscle. The sarcoplasmic reticulum is neither as extensive nor as well developed as that of skeletal muscle. The sarcotubules are continuous over the length of the sarcomere and anastomose freely to give a plexiform pattern with no special anastomosis at the H band. There are no terminal cisternae, and the sarcoplasmic reticulum makes contact with the T-tubules via irregular expansions of the sarcotubules. Since most T-tubules are apposed to only one cisterna at any point, the couplings of T-tubule to sarcoplasmic reticulum have been called diads.

The T-tubules of cardiac muscle are located at Z lines rather than at A-I junctions, and their lumina are much wider than the T-tubules of skeletal muscle. The luminal surfaces of the cardiac T-tubules are coated by a continuation of the external lamina of the sarcolemma. Sarcotubules at the periphery of the cell may be closely applied to the sarcolemma, and these couplings have been called peripheral couplings or subsarcolemmal cisternae. As in skeletal muscle, the functional unit of cardiac muscle is the sarcomere, demarcated by two successive Z lines.

Intercalated Discs

At their end-to-end associations, cardiac muscle cells are united by special junctions that are visible under the light microscope as dark lines. These are the intercalated discs that cross the fibers in stepwise fashion at the level of Z lines and thus have transverse and horizontal parts. Along the transverse parts, the opposing cells are extensively interdigitated and at points are united by desmosomes. The desmosomal junctions function to anchor intermediate (desmin) filaments of the cytoskeleton to the plasmalemma. For the most part, the junction between

cells is more extensive than that of a desmosome and thus is called a fascia adherens. The sarcoplasm immediately adjacent to the cytoplasmic surface of the cell membrane at these locations contains a dense mat of filaments into which the actin filaments insert. The fascia adherens contains the actin-binding proteins, α -actinin and vinculin, which function to anchor actin to the plasmalemma. Transmembrane glycoproteins A-CA and plakoglobin function as cell-adhesion molecules and tightly unite cardiac muscle cells end to end at the intercalated disc. The large titin molecules also are present in cardiac myocytes and, as in skeletal muscle, have an important role in passive force acting together with connective tissue surrounding myocytes to resist forces that pull actin myofilaments from between the myosin filaments of the A band. At irregular sites along the junctions, the membranes of opposing cells are united by nexus (gap) junctions. The longitudinal part of the intercalated disc is continuous with the transverse portion and also shows gap junctions that, however, are much more extensive. The gap junctions represent areas of low electrical resistance and allow rapid spread of excitation impulses from cell to cell resulting in the synchronization of muscle contraction.

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