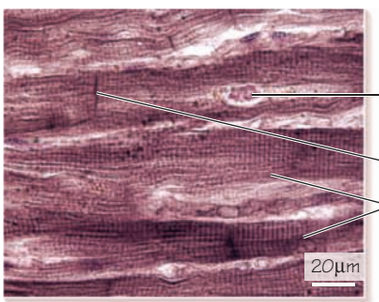
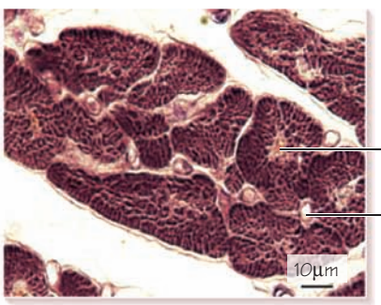
9 Cardiac and smooth muscle

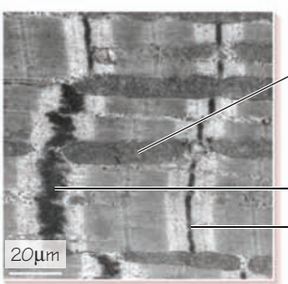
(a) Cardiac muscle (LS, iron hematoxylin stain)



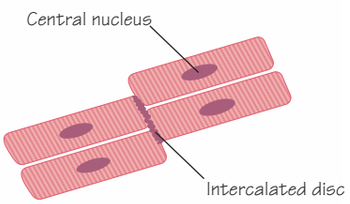
(b) Cardiac muscle (TS, iron hematoxylin stain)



(c) EM of cardiac muscle showing intercalated disc

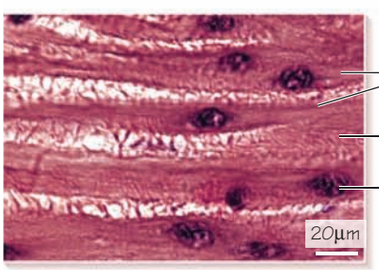


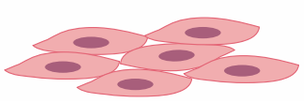
EM reproduced from *Skeletal Muscle, Henning Schmalbruch, (1986) Springer Verlag, with kind permission of Springer Science+Business Media*



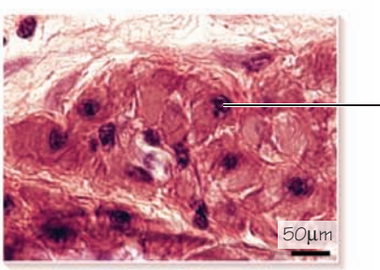
Cardiac muscle cells (about 100 μm long) have a single centrally located nucleus. They are tightly connected to each other by intercalated discs and can make branching connections with more than one cell

(d) Smooth muscle (LS, modified hematoxylin stain)



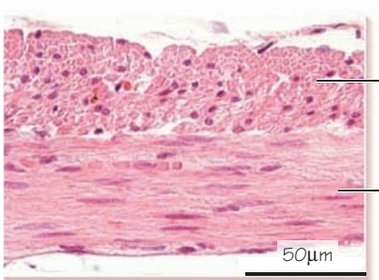


(e) Smooth muscle (TS)

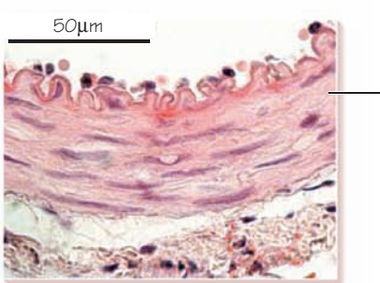


Smooth muscle cells are spindle shaped, and have a single centrally localized nucleus.They are attached to each other by desmosomes, and communicate by gap junctions. Here the cells have shrunk slightly due to processing, and the connections between the cells can be seen

(f) Lower power image of layers of smooth muscle from the small intestine (H&E)



(g) Layers of circumferentially arranged smooth muscle cells around the lumen of a blood vessel



Cardiac muscle

This type of muscle is found in the myocardium of the heart, and is 'involuntary'. It is innervated by the regular pacemaker activity of the sino-atrial node.

Cardiac muscle is made up of a functional syncytium of cells that only have **one nucleus** (occasionally two), which is **centrally localized** (Fig. 9a,b).

These cells are called **cardiomyocytes**.

Structure and excitation of cardiomyocytes

Similar to skeletal muscle fibers, cardiomyocytes have a striated (stripy) appearance, which arises from the regular arrangement of actin-containing thin filaments and myosin-containing thick filaments in muscle sarcomeres (Fig. 9a). Resting sarcomere length in cardiac muscle (about 2.2 µm) is slightly shorter than that in skeletal muscle.

Cardiomyocytes are much smaller (about 80–100 µm long and about 15 µm in diameter) than skeletal muscle fibers.

Intercalated discs connect the cardiomyocytes to each other (Fig. 9a,c). These structures contain adherens junctions and desmosomes, which tightly connect adjacent cells, and gap junctions.

The gap junctions electrically couple the cardiomyocytes, enabling the rapid spread of contraction around the heart.

This tight structural and electrical connectivity results in the functional syncytium.

Although not directly stimulated by a nerve, cardiac cells are stimulated to contract by the influx of Ca^{2+} ions as a result of T-tubule depolarization, release of Ca^{2+} from the sarcoplasmic reticulum (SR) and the uptake of Ca^{2+} from the extracellular space.

Growth and repair

Cardiac muscle cells can hypertrophy (grow larger) or hypotrophy (grow smaller) as a result of changing demands on the heart, but the cells are terminally differentiated and cannot divide.

The heart does not appear to contain large numbers of 'stem' cells similar to the satellite cells of skeletal muscle, and therefore only has a limited ability to regenerate when damaged.

Smooth muscle

Structure and excitation of smooth muscle cells

Smooth muscle contains spindle-shaped cells, with a central nucleus, that are connected together in a functional syncytium (Fig. 9d–g). Desmosomes connect the cells together structurally, and gap junctions connect the cells electrically and chemically.

These cells **do not** have a striated appearance because they **do not** contain muscle sarcomeres. Instead, arrays of actin filaments, connected to dense bodies, surround myosin filaments in a less well-organized fashion.

The dense bodies are connected to the plasma membrane by intermediate filaments, which transmit the force generated by the interaction of actin and myosin and enable the whole cell to contract.

The SR is much reduced in this muscle.

Contraction is activated by Ca^{2+}, which mainly enters through ion channels from the extracellular space.

The Ca^{2+} influx activates myosin light chain kinase, which phosphorylates the myosin molecules in the thick filaments and activates them so that they can then interact with actin. (Thin filaments in smooth muscle do not contain troponin.) The muscle relaxes when myosin is dephosphorylated. This type of muscle generates long, slow, contractions.

Myoepithelial cells are single smooth muscle cells that surround ducts or blood vessels, and lie within the basement membrane. When these cells contract, they squeeze the ducts, helping to extrude the contents.

Growth and repair

Of all the muscle types, smooth muscle cells have the greatest capacity for regeneration. They can divide and increase in number. Numerous cells called pericytes, which lie along the small blood vessels, can divide and generate new smooth muscle cells. Smooth muscle cells can also hypertrophy.