Muscle Tissue

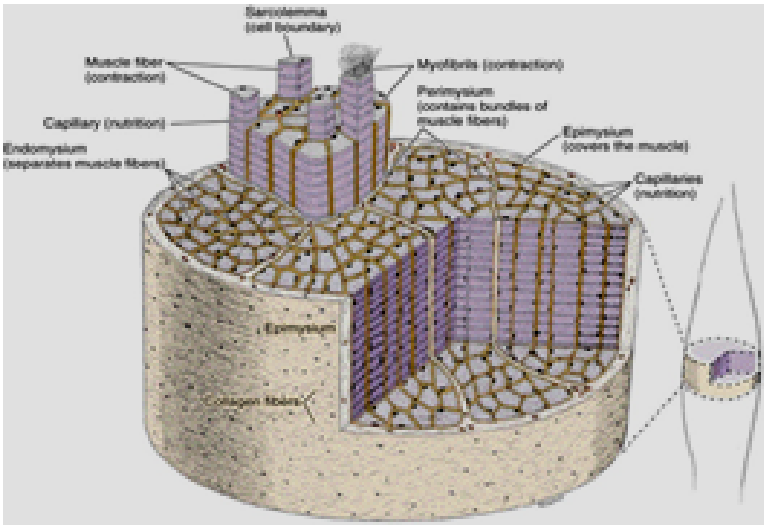
- Muscle tissue is composed of differentiated cells containing contractile proteins. The structural biology of these proteins generates the forces necessary for cellular contraction, which drives movement within certain organs and the body as a whole.
- Most muscle cells are of mesodermal origin.
- Three types of muscle tissue in mammals can be distinguished on the basis of morphological and functional characteristics Skeletal,Cardiac,Smooth muscles
- The cytoplasm of muscle cells is called sarcoplasm formed), and the smooth endoplasmic reticulum is called sarcoplasmic reticulum. The sarcolemma is the cell membrane, or plasmalemma

Skeletal Muscle

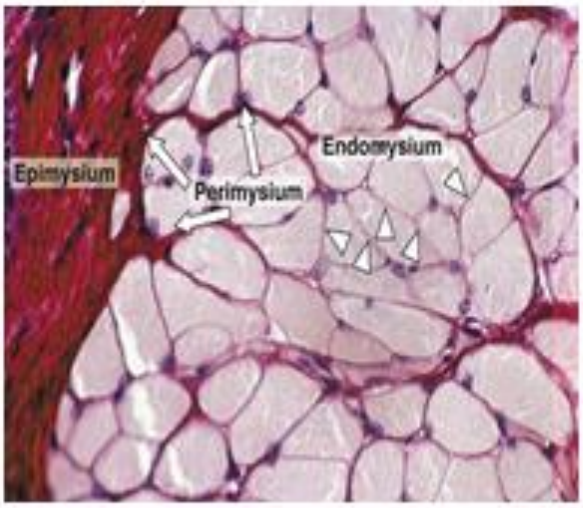
- Skeletal muscle consists of muscle fibers ·bundles of very long (up to 30 cm) cylindrical multinucleated cells .
- Multinucleation results from the fusion of embryonic mononucleotides myoblasts (muscle cell precursors). The oval nuclei are usually found at the periphery of the cell under the cell membrane.

Organization of Skeletal Muscle

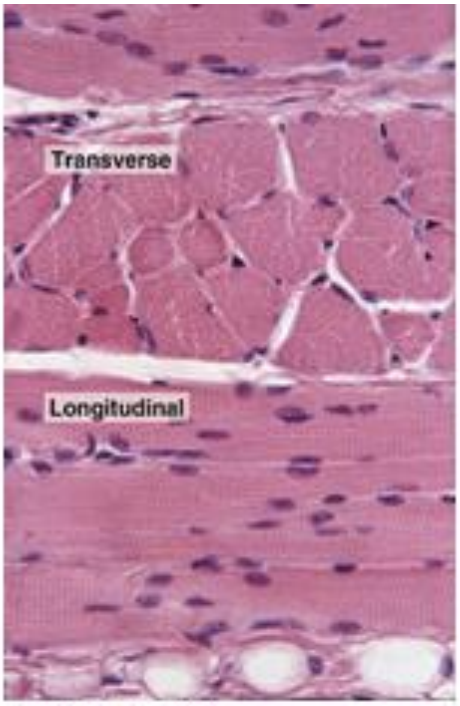
- The masses of fibers that make up the various types of muscle are arranged in regular bundles surrounded by the (epimysium) , an external sheath of dense connective tissue surrounding the entire muscle, from the epimysium, thin septa of connective tissue extend inward, surrounding the bundles of fibers within a muscle.
- The connective tissue around each bundle of muscle fibers is called the (perimysium) .
- Each muscle fiber is itself surrounded by a delicate layer of connective tissue, the endomysium composed mainly of a basal lamina and reticular fibers .
- Blood vessels penetrate the muscle within the connective tissue septa and form a rich capillary network that runs between and parallel to the muscle fibers..



- **Figure 10—2.**
- Structure and function of skeletal muscle. The drawing at right shows the area of muscle detailed in the enlarged segment. Color highlights endomysium, perimysium, and epimysium.

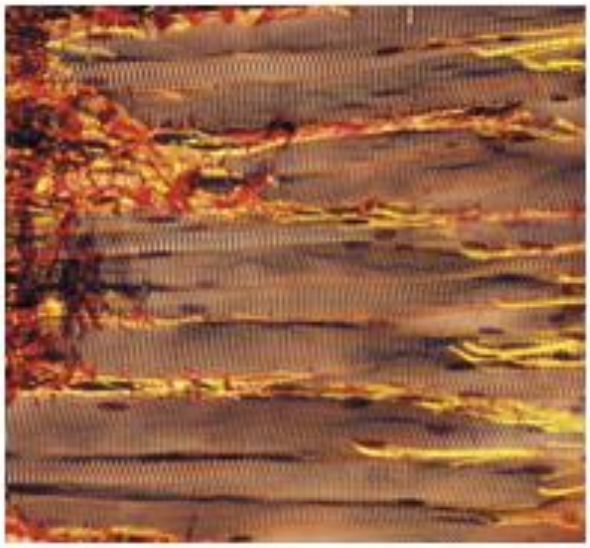


- **Figure 10—3.** Cross section of striated muscle stained to show collagens type I and III and cell nuclei. The endomysium is indicated by arrowheads and the perimysium by arrows. At left is a piece of epimysium. Picrosirius-hematoxylin stain. High magnification.

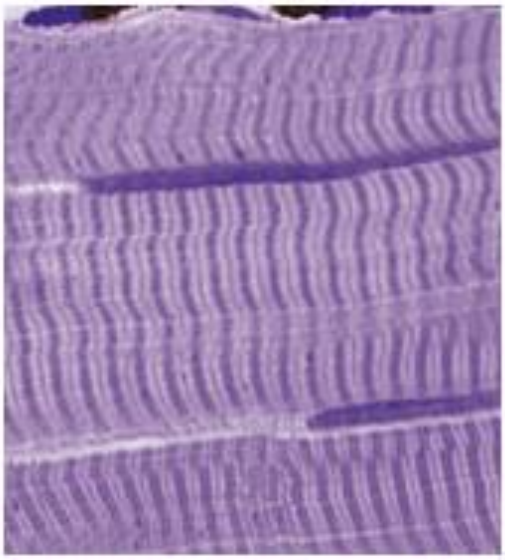


- **Figure 10—6.**
- Striated skeletal muscle in longitudinal section (lower) and in cross section (upper). The nuclei can be seen in the periphery of the cell, just under the cell membrane, particularly in the cross sections of these striated fibers.

Some muscles taper off at their extremities, where a myotendinous junction is formed. The electron microscope shows that in this transitional region, collagen fibers of the tendon insert themselves into complex infoldings of the plasma lemma of the muscle fibers



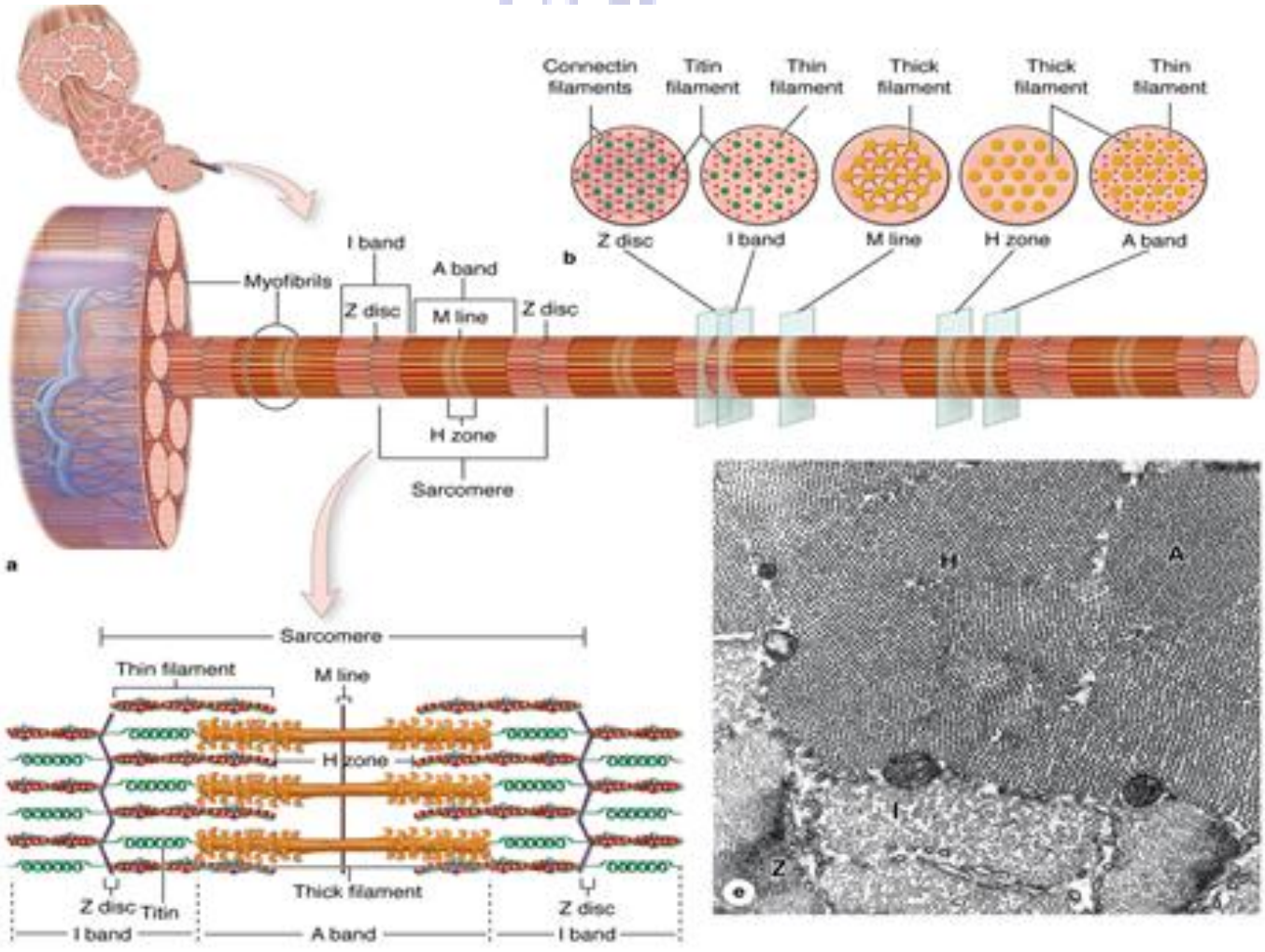
- Figure 10—7. Striated skeletal muscle in longitudinal section. In the left side of the photomicrograph the insertion of collagen fibers with the muscle is clearly seen..



- Figure 10—8. Longitudinal section of skeletal muscle fibers. Note the dark-stained A bands and the light-stained I bands, which are crossed by Z lines.

Organization of Skeletal Muscle Fibers

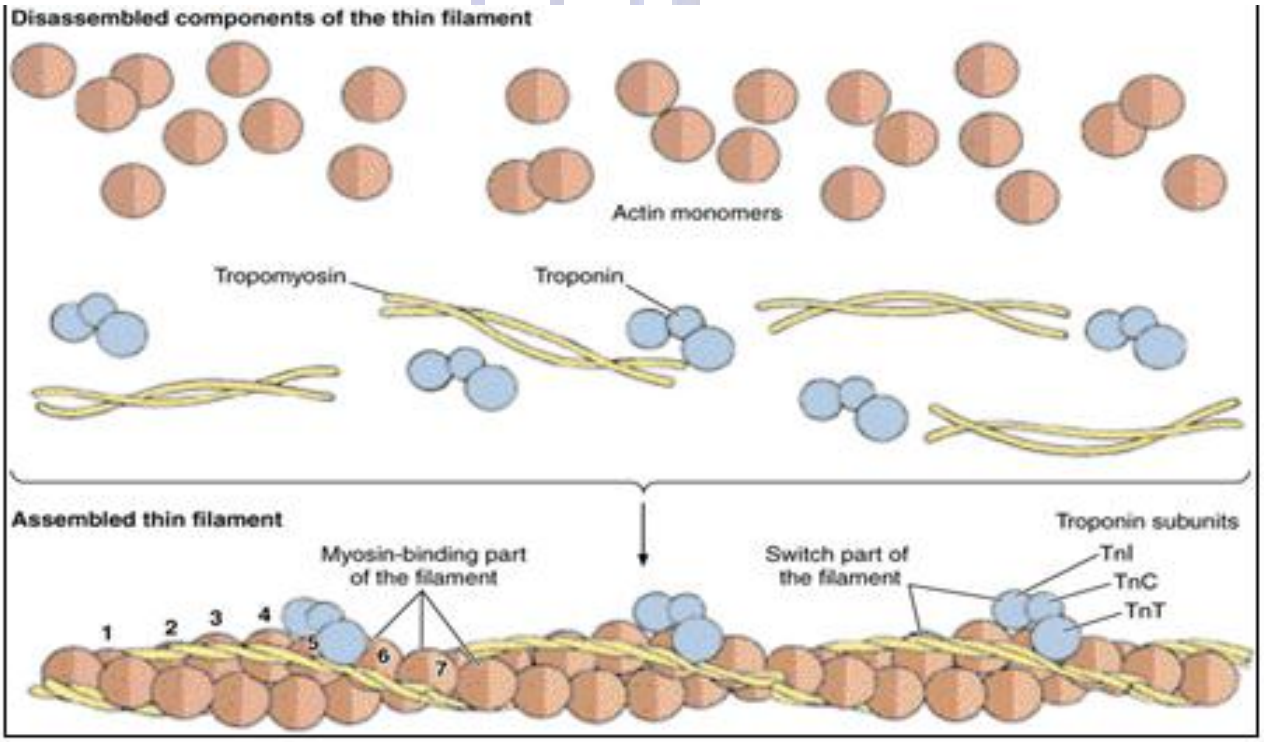
- Longitudinally sectioned muscle fibers show cross-striations of alternating light I bands (isotropic) and dark bands A bands (anisotropic)
- In the electron microscope, each I band is bisected by a dark transverse line, the Z line .The smallest repetitive subunit of the contractile apparatus, the sarcomere, extends from Z line to Z line and is about 2.5 m long in resting muscle .
- The sarcoplasm is filled with long cylindrical filamentous bundles called myofibrils.
- Two types of filaments thick and thin that lie parallel to the long axis of the myofibrils in a symmetric pattern..
- The thick filaments occupy the A band, the central portion of the sarcomere. The thin filaments run between and parallel to the thick filaments and have one end attached to the Z line)..
- The A bands are composed mainly of thick filaments in addition to portions of overlapping thin filaments . Close observation of the A band shows the presence of a lighter zone in its center, the H band.
- Bisecting the H band is the M line ، a region at which lateral connections are made between adjacent thick filaments The major protein of the M line is creatine kinase that catalyzes the transfer of a phosphate group from phosphocreatine (a storage form of high-energy phosphate groups) to adenosine diphosphate (ADP), thus supplying adenosine triphosphate (ATP) for muscle contraction.



- Striated muscle filaments contain several proteins; the four main proteins are actin, tropomyosin, troponin, and myosin.
- Thin filaments are composed of the first three proteins, whereas thick filaments consist primarily of myosin.
- Myosin and actin together represent 55% of the total protein of striated muscle.
- Actin is present as long filamentous polymers consisting of two strands of globular twisted around each other in a double helical formation ..Each actin monomer contains a binding site for myosin.
- Tropomyosin - a long, thin molecule about 40 nm in length, contains two polypeptide chains. These molecules are bound head to tail, forming filaments that run over the actin subunits alongside the outer edges of the groove between the two twisted actin strands
- Troponin is a complex of three subunits: TnT, which strongly attaches to tropomyosin; TnC, which binds calcium ions; and TnI, which inhibits the actin &" myosin interaction.
- A troponin complex is attached at one specific site on each tropomyosin molecule
- Myosin. A much larger complex, can be dissociated into two identical heavy chains twisted together and two pairs of light chains.

  Small globular projections at one end of each heavy chain form the heads, which have ATP-binding sites as well as the enzymatic capacity to hydrolyze ATP (ATPase activity) and the ability to bind to actin, the four light chains are associated with the head

  Several hundred myosin molecules are arranged within each thick filament with their rod like portions overlapping and their globular heads directed toward either end



- Figure 10—13.
- 3 major protein components–actin, tropomyosin, and troponin. The individual components in the upper part of the drawing are shown in polymerized form in the lower part. The globular actin molecules are polarized and polymerize in one direction. Note that each tropomyosin molecule extends over 7 actin molecules. TnI, TnC, and TnT are troponin subunits.

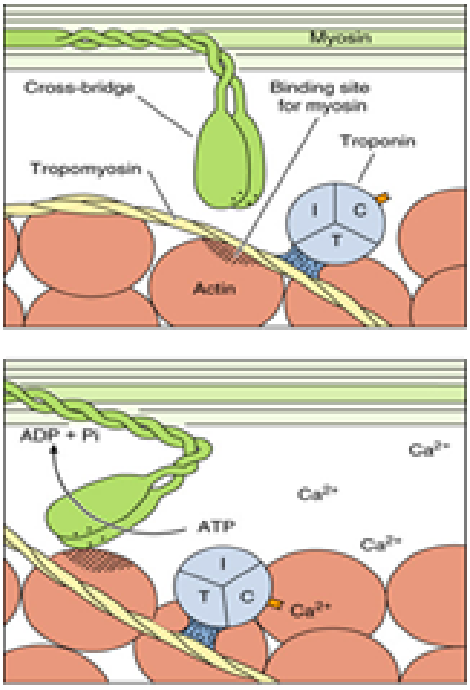
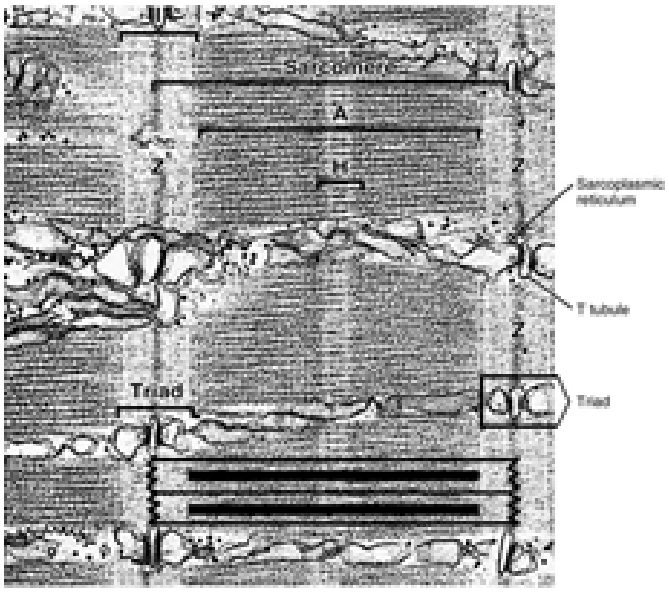
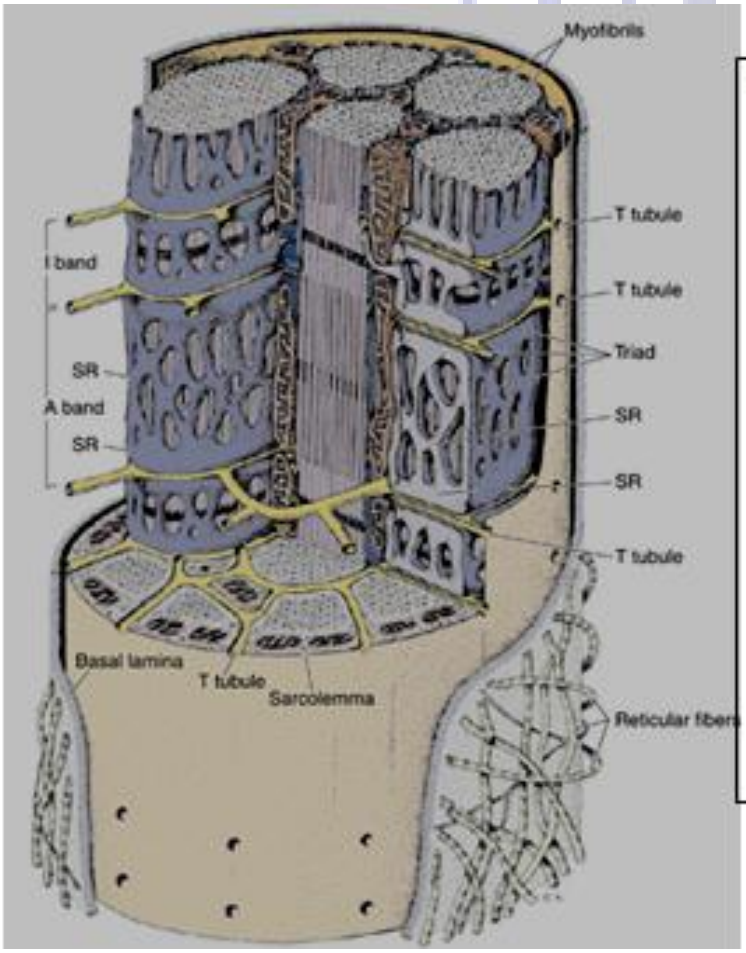


Figure 10—14. Muscle contraction, initiated by the binding of Ca2+ to the TnC unit of troponin, which exposes the myosin binding site on actin (cross-hatched area). In a second step, the myosin head binds to actin and the ATP breaks down into ADP, yielding energy, which produces a movement of the myosin head. As a consequence of this change in myosin, the bound thin filaments slide over the thick filaments. This process, which repeats itself many times during a single contraction, leads to a complete overlapping of the actin and myosin and a resultant shortening of the whole muscle fiber. I, T, C are troponin subunits..)



- Figure 10—10. Electron micrograph of skeletal muscle of a tadpole. Note the sarcomere with its A, I, and H bands and Z line. The position of the thick and thin filaments in the sarcomere is shown schematically in the lower part of the figure. As illustrated here, triads in amphibian muscle are aligned with the Z line in each sarcomere. In mammalian muscle, however, each sarcomere exhibits 2 triads, one at each A—I band interface



- Figure 10—17. Segment of mammalian skeletal muscle. The sarcolemma and muscle fibrils are partially cut, showing the following components: The invaginations of the T system occur at the level of transition between the A and I bands twice in every sarcomere. They associate with terminal cisternae of the sarcoplasmic reticulum (SR), forming triads. Abundant mitochondria lie between the myofibrils. The cut surface of the myofibrils shows the thin and thick filaments. Surrounding the sarcolemma are a basal lamina and reticular fibers..)

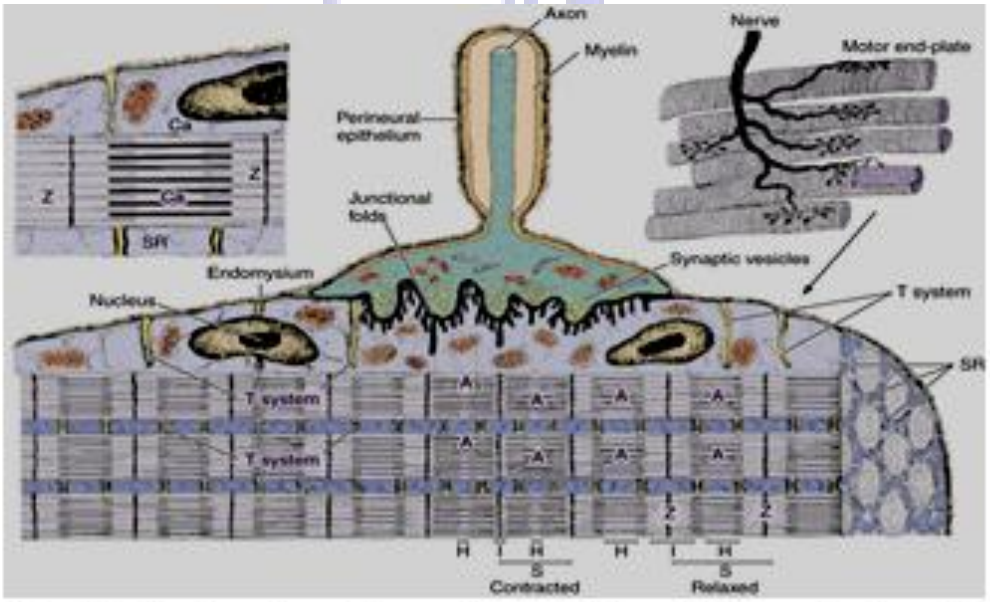
Innervations

Myelinated motor nerves branch out within the perimysial connective tissue, where each nerve gives rise to several terminal twigs. At the site of innervation, the nerve loses its myelin sheath and forms a dilated termination. This structure is called the motor end plate or myoneural junction

At this site, the axon is covered by a thin cytoplasmic layer of Schwann cells.

Within the axon terminal are numerous mitochondria and synaptic vesicles, the latter containing the neurotransmitter acetylcholine

. Between the axon and the muscle is a space, the synaptic cleft in which an amorphous basal lamina matrix lies. At the junction, the sarcolemma is thrown into numerous deep junctional folds. In the sarcoplasm below the folds lie several nuclei and numerous mitochondria, ribosomes, and glycogen granules.



- Figure 10—18. Ultrastructure of the motor end-plate and the mechanism of muscle contraction... Note that the axon terminal bud contains synaptic vesicles. The region of the muscle cell membrane covered by the terminal bud has clefts and ridges called. Muscle contraction begins with the release of acetylcholine from the synaptic vesicles of the end-plate.
- This neurotransmitter causes a local increase in the permeability of the sarcolemma.
- The process is propagated to the rest of the sarcolemma, including its invaginations (all of which constitute the T system), and is transferred to the sarcoplasmic reticulum (SR).
- The increase of permeability in this organelle liberates calcium ions (drawing at upper left) that trigger the sliding filament mechanism of muscle contraction. Thin filaments slide between the thick filaments and reduce the distance between the Z lines, thereby reducing the size of all bands except the A band. H, H band; S, sarcomere.

Other Components of the Sarcoplasm

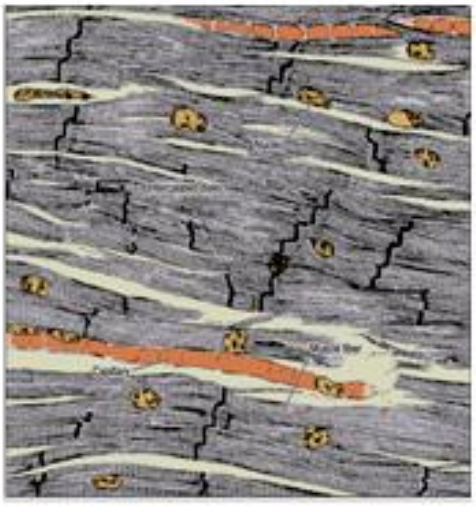
- Glycogen is found in abundance in the sarcoplasm in the form of coarse granules It serves as a depot of energy that is mobilized during muscle contraction.
- Another component of the sarcoplasm is myoglobin; this oxygen-binding protein, which is similar to hemoglobin, is principally responsible for the dark red color of some muscles
- . Myoglobin acts as an oxygen-storing pigment, which is necessary for the high oxidative phosphorylation level in this type of fiber.
- For obvious reasons, it is present in great amounts in the muscle of deep-diving ocean mammals (e.g., seals, whales). Muscles that must maintain activity for prolonged periods usually are red and have a high myoglobin content

Medical application

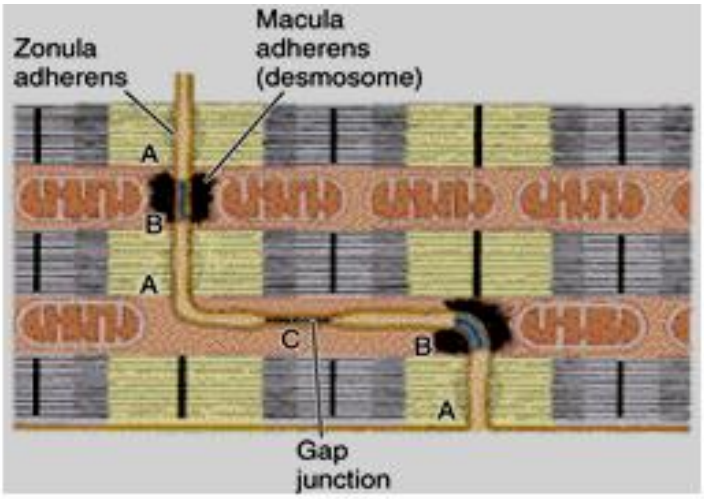
- The increase in muscle thus obtained is caused by formation of new myofibrils and a pronounced growth in the diameter of individual muscle fibers. This process,, is called hypertrophy
- Tissue growth by an increase in the number of cells is termed hyperplasia .
- Hyperplasia does not occur in either skeletal or cardiac muscle but does take place in smooth muscle, whose cells have not lost the capacity to divide by mitosis.
- Hyperplasia is rather frequent in organs such as the uterus, where both hyperplasia and hypertrophy occur during pregnancy.

Cardiac Muscle

- Mature cardiac muscle cells are approximately 15µm in diameter and from 85 to 100 µ m in length. They exhibit a cross-striated banding pattern.
- Unlike multinucleated skeletal muscle, however, each cardiac muscle cell possesses only one or two centrally located pale-staining nuclei.µ
- Surrounding the muscle cells is a delicate sheath of endomysial connective tissue containing a rich capillary network
- Intercalated disks represent junctional complexes found at the interface between adjacent cardiac muscle cells The junctions may appear as straight lines or may exhibit a steplike pattern.
- Two regions can be distinguished in the sleeplike junctions"a transverse portion، which runs across the fibers at right angles, and a lateral portion، which runs parallel to the my µfilaments.
- Fasciae adherentes، the most prominent membrane specialization in transverse portions of the disk, serve as anchoring sites for actin filaments of the terminal sarcomeres. Essentially, they represent hemi-Z bands
- .Maculae adherentes desmosomes are also present in the transverse portion and bind the cardiac cells together, preventing them from pulling apart under constant contractile activity.
- On the lateral portions of the disk، gap junctions provide ionic continuity between adjacent cells
- The significance of ionic coupling is that chains of individual cells act as a syncytium, allowing the signal to contract to pass in a wave from cell to cell .The T tubules are more numerous and larger in ventricular muscle than in skeletal muscle. Cardiac T tubules are found at the level of the Z band rather than at the A-"I junction



- Figure 10—22. Drawing of a section of heart muscle, showing central nuclei, cross-striation, and intercalated disks.



- Figure 10—26. Junctional specializations making up the intercalated disk. Fasciae (or zonulae) adherentes (A) in the transverse portions of the disk anchor actin filaments of the terminal sarcomeres to the plasmalemma. Maculae adherentes, or desmosomes (B), found primarily in the transverse portions of the disk, bind cells together, preventing their separation during contraction cycles. Gap junctions (C), restricted to longitudinal portions of the disk–the area subjected to the least stress–ionically couple cells and provide for the spread of contractile depolarization.

- Cardiac muscle cells contain numerous mitochondria, which occupy 40% or more of the cytoplasmic volume, reflecting the need for continuous aerobic metabolism in heart muscle.
- By comparison, only about 2% of skeletal muscle fiber is occupied by mitochondria.
- Fatty acids, transported to cardiac muscle cells by lipoproteins, are the major fuel of the heart.
- Fatty acids are stored as triglycerides in the numerous lipid droplets seen in cardiac muscle cell
- A small amount of glycogen is present and can be broken down to glucose and used for energy production during periods of stress.
- Lipofuscin pigment granules (aging pigment), often seen in long-lived cells, are found near the nuclear poles of cardiac muscle cells
- A few differences in structure exist between atrial and ventricular muscle. The arrangement of myofilaments is the same in the two types of cardiac muscle, but atrial muscle has markedly fewerT tubules, and the cells are somewhat smaller

Smooth Muscle

- Is composed of elongated, nonstriated cells each of which is enclosed by a basal lamina and a network of reticular fibers.
- Smooth muscle cells are fusiform, ie, they are largest at their midpoints and taper toward their ends. They may range in size from 20μ m to 500μ m.
- During pregnancy, uterine smooth muscle cells undergo a marked increase in size and number
- Each cell has a single nucleus located in the center of the broadest part of the cell. To achieve the tightest packing, the narrow part of one cell lies adjacent to the broad parts of neighboring cells. Such an arrangement viewed in cross section shows a range of diameters, with only the largest profiles containing a nucleus

- The characteristic contractile activity of smooth muscle is related to the structure and organization of its actin and myosin filaments
- ‹In smooth muscle cells, bundles of myofilaments crisscross obliquely through the cell, forming a latticelike network. These bundles consist of thin filaments containing actin and tropomyosin and thick filaments consisting of myosin.
- Both structural and biochemical studies reveal that smooth muscle actin and myosin contract by a sliding filament mechanism similar to what occurs in striated muscles.
- An influx of Ca + ٢ is involved in the initiation of contraction in smooth muscle cells. The myosin of smooth muscle, however, interacts with actin only when its light chain is phosphorylated. For this reason, and because the troponin complex of skeletal muscle is absent, the contraction mechanism in smooth muscle differs somewhat from skeletal and cardiac muscle.
- Ca + ٢ in a smooth muscle complexes with calmodulin ‹a calcium-binding protein that is also involved in the contraction of nonmuscle cells.
- The Ca+٢ calmodulin complex activates myosin light-chain kinase, the enzyme responsible for the phosphorylation of myosin
- 2-Contraction or relaxation may be regulated by hormones that act via cyclic adenosine monophosphate (cAMP). The action of sex hormones on uterine smooth muscle is another example of nonneural control. Estrogens increase cAMP and promote the phosphorylation of myosin and the contractile activity of uterine smooth muscle. Progesterone has the opposite effect: It decreases cAMP, promotes dephosphorylation of myosin, and relaxes uterine musculature. smooth muscle occurs in large sheets such as those found in the walls of hollow viscera, e.g., the intestines, uterus, and ureters. Their cells possess abundant gap junctions and a relatively poor nerve supply,are called visceral smooth muscles. In contrast, the multiunit smooth muscles have a rich innervations and can produce precise and grade contractions such as those occurring in the iris of the eye. smooth muscle cells also synthesize collagen, elastin, and proteoglycans, which are extracellular products normally associated with the function of fibroblasts.

Regeneration of Muscle Tissue

- The three types of adult muscle have different potentials for regeneration after injury.
- Cardiac muscle has almost no regenerative capacity beyond early childhood. Defects or damage (eg, infarcts) in heart muscle are generally replaced by the proliferation of connective tissue, forming myocardial scars.
- In skeletal muscle,, the tissue can undergo limited regeneration. The source of regenerating cells is believed to be the satellite cells. The latter are a sparse population of mononucleated spindle-shaped cells that lies within the basal lamina surrounding each mature muscle fiber.
- After injury or certain other stimuli, the normally quiescent satellite cells become activated, proliferating and fusing to form new skeletal muscle fibers.
- Smooth muscle is capable of an active regenerative response. After injury, viable mononucleated smooth muscle cells and pericytes from blood vessels undergo mitosis and provide for the replacement of the damaged tissue