Muscle

I. Overview of Muscle Tissues (pp. 280-281; Marieb Table 9.3)

A. Types of Muscle Tissue (p. 280; Marieb Table 9.3)
   1. Skeletal muscle is associated with the bony skeleton, and consists of large cells that bear striations and are controlled voluntarily.
   2. Cardiac muscle occurs only in the heart, and consists of small cells that are striated and under involuntary control.
   3. Smooth muscle is found in the walls of hollow organs, and consists of small elongated cells that are not striated and are under involuntary control.

B. Functional Characteristics of Muscle Tissue (p. 280)
   1. Excitability, or irritability, is the ability to receive and respond to a stimulus.
   2. Contractility is the ability to contract forcibly when stimulated.
   3. Extensibility is the ability to be stretched.
   4. Elasticity is the ability to resume the cells' original length once stretched.

C. Muscle Functions (pp. 280-281; Marieb Table 9.3)
   1. Muscles produce movement by acting on the bones of the skeleton, pumping blood, or propelling substances throughout hollow organ systems.
   2. Muscles aid in maintaining posture by adjusting the position of the body with respect to gravity.
   3. Muscles stabilize joints by exerting tension around the joint.
   4. Muscles generate heat as a function of their cellular metabolic processes.

II. Skeletal Muscle (pp. 281-309; Marieb Figs. 9.1-9.23; Marieb Tables 9.1-9.3)

A. Gross Anatomy of Skeletal Muscle (pp. 281-284; Marieb Figs. 9.1-9.2; Marieb Tables 9.1, 9.3)
   1. Each muscle has a nerve and blood supply that allows neural control and ensures adequate nutrient delivery and waste removal.
   2. Connective tissue sheaths are found at various structural levels of each muscle: endomysium surrounds each muscle fiber, perimysium surrounds groups of muscle fibers, and epimysium surrounds whole muscles.
   3. Attachments span joints and cause movement to occur from the movable bone (the muscle's insertion) toward the less movable bone (the muscle's origin).
   4. Muscle attachments may be direct or indirect (tendons and aponeuroses).

B. Microscopic Anatomy of a Skeletal Muscle Fiber (pp. 284-288; Marieb Figs. 9.3-9.6; Marieb Tables 9.1, 9.3)
   1. Skeletal muscle fibers are long cylindrical cells with multiple nuclei beneath the sarcolemma.
   2. Myofibrils account for roughly 80% of cellular volume, and contain the contractile elements of the muscle cell.
   3. Striations are due to a repeating series of dark A bands and light I bands.
   4. Myofilaments make up the myofibrils, and consist of thick and thin filaments.
   5. Ultrastructure and Molecular Composition of the Myofilaments
      a. There are two types of myofilaments in muscle cells: thick filaments composed of bundles of myosin, and thin filaments composed of strands of actin.

    b. Tropomyosin and troponin are regulatory proteins present in thin filaments (more on these later).

  6. The sarcoplasmic reticulum is a smooth endoplasmic reticulum surrounding each myofibril.
  7. T tubules are infoldings of the sarcolemma that conduct electrical impulses from the surface of the cell to the terminal cisternae.

C. The sliding filament model of muscle contraction states that during contraction, the thin filaments slide past the thick filaments. Overlap between the myofilaments increases and the sarcomere shortens (pp. 288-289).

D. Generating and Maintaining a Resting Membrane Potential (pp. 81–83; Marieb Fig. 3.15)
  1. A membrane potential is a voltage across the cell membrane that occurs due to a separation of oppositely charged particles (ions).
  2. The resting membrane potential is a condition in which the inside of the cell membrane is negatively charged compared to the outside, and ranges in voltage from 25 to 2100 millivolts.
    a. The resting membrane potential is determined mainly by the concentration gradient of potassium (K^1).
    b. Active transport pumps ensure that passive ion movement does not lead to an electrochemical equilibrium across the membrane, thus maintaining the resting membrane potential.

E. Physiology of a Skeletal Muscle Fiber (pp. 288-294; Marieb Figs. 9.7-9.11; Marieb Table 9.3)
  1. The neuromuscular junction is a connection between an axon terminal and a muscle fiber that is the route of electrical stimulation of the muscle cell.
  2. A nerve impulse causes the release of acetylcholine to the synaptic cleft, which binds to receptors on the motor end plate, triggering a series of electrical events on the sarcolemma.
  3. Generation of an action potential across the sarcolemma occurs in response to acetylcholine binding with receptors on the motor end plate. It involves the influx of sodium ions, which makes the membrane potential slightly less negative.
  4. Excitation-contraction coupling is the sequence of events by which an action potential on the sarcolemma results in the sliding of the myofilaments.
  5. Ionic calcium in muscle contraction is kept at almost undetectable levels within the cell through the regulatory action of intracellular proteins.
  6. Muscle fiber contraction follows exposure of the myosin binding sites, and follows a series of events.

F. Contraction of a Skeletal Muscle (pp. 295-300; Marieb Figs. 9.12-9.18)
  1. A motor unit consists of a motor neuron and all the muscle fibers it innervates. It is smaller in muscles that exhibit fine control.
  2. The muscle twitch is the response of a muscle to a single action potential on its motor neuron.
  3. There are three kinds of graded muscle responses: wave summation, multiple motor unit summation (recruitment), and treppe.
  4. Muscle tone is the phenomenon of muscles exhibiting slight contraction, even when at rest, which keeps muscles firm, healthy, and ready to respond.
  5. Isotonic contractions result in movement occurring at the joint and shortening of muscles.
  6. Isometric contractions result in increases in muscle tension, but no lengthening or shortening of the muscle occurs.

G. Muscle Metabolism (pp. 300-304; Marieb Figs. 9.19-9.20)
  1. Muscles contain very little stored ATP, and consumed ATP is replenished rapidly through phosphorylation by creatine phosphate, glycolysis and anaerobic respiration, and aerobic respiration.

2. Muscles will function aerobically as long as there is adequate oxygen, but when exercise demands exceed the ability of muscle metabolism to keep up with ATP demand, metabolism converts to anaerobic glycolysis.
3. Muscle fatigue is the physiological inability to contract due to the shortage of available ATP.
4. Oxygen debt is the extra oxygen needed to replenish oxygen reserves, glycogen stores, ATP and creatine phosphate reserves, as well as conversion of lactic acid to pyruvic acid glucose after vigorous muscle activity.
5. Heat production during muscle activity is considerable. It requires release of excess heat through homeostatic mechanisms such as sweating and radiation from the skin.

H. Force of Muscle Contraction (pp. 304-305; Marieb Figs. 9.21-9.22)

1. As the number of muscle fibers stimulated increases, force of contraction increases.
2. Large muscle fibers generate more force than smaller muscle fibers.
3. As the rate of stimulation increases, contractions sum up, ultimately producing tetanus and generating more force.
4. There is an optimal length-tension relationship when the muscle is slightly stretched and there is slight overlap between the myofibrils.

III. Smooth Muscle (pp. 309-313; Marieb Figs. 9.24-9.26; Marieb Table 9.3)

A. Microscopic Structure of Smooth Muscle Fibers (pp. 309-311; Marieb Figs. 9.24-9.25; Marieb Table 9.3)

1. Smooth muscle cells are small, spindle-shaped cells with one central nucleus, and lack the coarse connective tissue coverings of skeletal muscle.
2. Smooth muscle cells are usually arranged into sheets of opposing fibers, forming a longitudinal layer and a circular layer.
3. Contraction of the opposing layers of muscle leads to a rhythmic form of contraction, called peristalsis, which propels substances through the organs.
4. Smooth muscle lacks neuromuscular junctions, but have varicosities instead, numerous bulbous swellings that release neurotransmitters to a wide synaptic cleft.
5. Smooth muscle cells have a less developed sarcoplasmic reticulum, sequestering large amounts of calcium in extracellular fluid within caveolae in the cell membrane.
6. Smooth muscle has no striations, no sarcomeres, a lower ratio of thick to thin filaments when compared to skeletal muscle, and has tropomyosin but no troponin.
7. Smooth muscle fibers contain longitudinal bundles of noncontractile intermediate filaments anchored to the sarcolemma and suurounding tissues via dense bodies.

B. Contraction of Smooth Muscle (pp. 311-316; Marieb Figs. 9.26-9.27; Marieb Table 9.3)

1. Smooth muscle fibers exhibit slow, synchronized contractions due to electrical coupling by gap junctions.
2. Like skeletal muscle, actin and myosin interact by the sliding filament mechanism. The final trigger for contraction is a rise in intracellular calcium level, and the process is energized by ATP.
3. During excitation-contraction coupling, calcium ions enter the cell from the extracellular space, bind to calmodulin, and activate myosin light chain kinase, powering the cross-bridging cycle.
4. Smooth muscle contracts more slowly and consumes less ATP than skeletal muscle.