Unit 3 Lecture 8

MUSCLE TISSUE

TYPES OF MUSCLE TISSUE

There are three types of muscular tissue. Below is listed the characteristics of each of the types.

	Skeletal	**Smooth**	**Cardiac**
Location	Skeletal muscles	Walls of hollow organs	Wall of heart
Function	Movement of bones at joints	Peristalsis	Pumping action of heart
Striations	Present	Absent	Present
Nucleus	Multiple	Single	Single
Mode of control	Voluntary	Involuntary	Involuntary
Contraction/ relaxation	Relatively rapid	Slowly, rhythmic	Rhythmic

FUNCTIONS OF MUSCLE TISSUE

Motion, movement of substances within the body, stabilizing body positions, regulating organ volumes, and generation of heat are the functions of the muscular system.

CHARACTERISTICS OF MUSCLE TISSUE

Muscle tissue exhibits **Excitability** or the ability to respond to certain stimuli by producing electrical signals called action potentials. The ability of a muscle to propagate or conduct action potentials along the plasma membrane is called **Conductivity**. **Contractility** is the ability to shorten and thicken (contract), generate force to do work. **Extensibility** is the ability to be extended (stretched) without damage to tissue. Finally, **Elasticity** is the ability to return to original shape after contraction or extension.

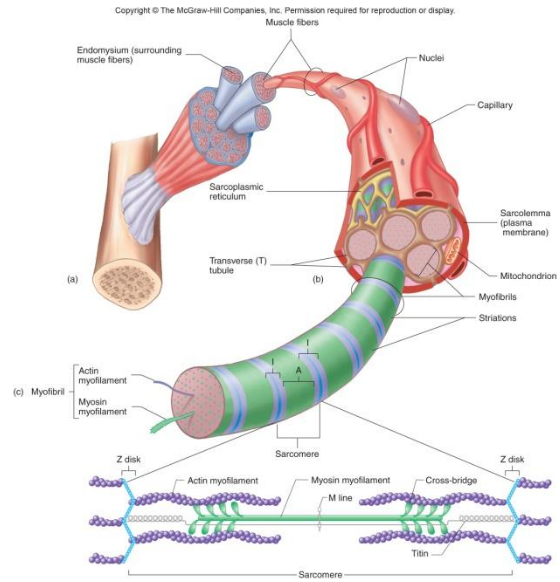
Connective Tissue Components

Single muscle fibers are encased in a thin layer of connective tissue called endomysium. Muscle fibers are grouped in bundles called fascicles which are separated from other fascicles by another layer of connective tissue called perimysium. The muscle as a whole is surrounded still by another layer of connective tissue called epimysium which becomes fasciae - deep fasciae between adjacent muscles and superficial fascia between the skin and muscles. All three layers of connective tissue may extend beyond the muscle fiber as tendons (a cord of dense connective tissue that attaches the muscle to the periosteum of a bone.

ANATOMY AND INNERVENTION OF SKELETAL MUSCLE TISSUE

Microscopic Anatomy of Skeletal Muscle

Muscle is composed of many muscle fibers or myofibers. The plasma membrane that separates fibers is called the sarcolemma. The fiber's cytoplasm is called the sarcoplasm.



At high magnification the sarcoplasm appears to be stuffed with little threads; these are called myofibrils. Myofibrils are the contractile elements of skeletal muscle and contain three types of structures called filaments or myofilaments (thin, thick, and elastic filaments).

Actin is the protein that makes up the thin filaments. Myosin is the protein that makes up the thick filaments. Titan is an elastic protein that along with nebulin helps align the filaments and return them to their original state. These filaments are arranged in compartments called sarcomeres.

One sarcomere consists of two Z disks and the filaments between them. Z disc (lines) separate one sarcomere from another. A bands are the darker area composed of mostly of thick filaments. I bands consist only of thin filaments. H zones contain only thick filaments and is at the center of the A band. M line divides the H zone. The contractile proteins are myosin which makes the thick filaments. The thin filaments are composed of Actin, troponin and tropomyosin. Elastic filaments contain titin which anchors the thick filaments to the Z disc. The M line and the Z disks represent attachment sites for myosin and actin.

CONTRACTION OF MUSCLE

Muscle contraction can be explained by the **Sliding Filament Theory**. In this theory Myosin heads pull on the thin filaments causing them to slide toward the H zone. Sliding of the filaments causes a shortening of the muscle fibers and the muscle. Calcium plays important role in muscular contraction; an increase in the level of calcium in the sarcoplasm starts the movement of thin filaments. Myosin converts energy from ATP into motion. Myosin ATPases hydrolyses ATP to ADP and P_i. When myosin releases P_i the myosin molecule moves in the power stroke. At the end of the power stroke, myosin releases ADP. The cycle ends in a rigor state, with myosin tightly bound to actin. Tropomyosin clocks the myosin-binding site on actin. Contraction is regulated by troponin and tropomyosin. As contraction begins, troponin binds to calcium. This unlocks the myosin-binding sites and allows myosin to complete its power stroke.

Nerves containing motor neurons convey impulses for muscular contraction. A motor neuron and the muscle fibers it stimulates form a **motor unit**. A single motor unit may innervate as few as ten or as many as 2,000 muscle fibers, with an average of 150 fibers being innervated by each motor neuron.

The **Neuromuscular Junction** is the junction between a motor neuron and a muscle fiber. Excitable cells communicate with one another and other target cells at specialized regions called synapses. In most synapses there is a gap called a synaptic cleft. The first cell releases a neurotransmitter, a chemical that bridges the gap. In most cases the neurotransmitter that initiates excitation-contraction coupling is acetylcholine.

- Acetylcholine (ACh) is released from the somatic motor neuron.
- ACh initiates an action potential in the muscle fiber.
- The muscle action potential triggers calcium release from the sacroplasmic reticulum.
- Calcium combines with troponin and initiates contraction.
- Relaxation occurs when the sacroplasmic reticulum pumps calcium back into its lumen.

Energy Source

Muscles constantly require energy. The amount of ATP stored within the muscle fiber at any one time is sufficient for only about eight twitches. As a backup energy source, muscles contain creatine phosphate. The enzyme creatine kinase (CK), or creatine phosphokinase (CPK) transfers a phosphate group from creatine phosphate to ADP to create ATP. Muscle cells contain huge amounts of this enzyme. Elevated levels of CK usually indicate skeletal or cardiac muscle damage (myocardial infarct). Since the ATP in muscle tissue is rapidly used up, it must be replaced. Carbohydrates, particularly glucose, are the most rapid and efficient source of energy for ATP production. Glucose is metabolized to pyruvate through glycolysis. In the presence of oxygen (aerobic respiration), pyruvate produces about 30 ATP for each molecule of glucose. Anaerobic respiration is a quicker source of ATP, but only produces two ATP. Muscles also obtain energy from fatty acids. This process always requires oxygen but is a slow process. Proteins are rarely a source of energy for muscles. Most amino acids in muscle fibers are used to synthesize proteins. Blood provides nutrients and oxygen for contraction.

Muscle fatigue

Muscle fatigue occurs when a muscle is no longer able to generate or sustain the expected power output. Two types of fatigue have been identified: central fatigue (arises in the CNS) and peripheral fatigue (arise anywhere between the neuromuscular junction and the contractile elements of the muscle). Central fatigue includes subjective feelings of tiredness and a desire to cease activity. Depletion of cellular glycogen to accumulation of lactic acid has been proposed as reasons for muscular fatigue.

MUSCLE RESPONSES

A **Twitch Contraction** is a brief contraction of all the muscle fibers in a motor unit of a muscle in response to a single action potential. During the Latent period calcium is being released. The latent period is followed by a Contraction period, then a Relaxation period, and finally a Refractory period. The Refractory period can be describes as follows. If two stimuli are applied one immediately after the first, the muscle will respond only to the first, but not the second and will not respond until the responsiveness of the muscle is retained. Usually this time is about 5 milliseconds for skeletal muscle and 300 milliseconds for cardiac muscle.

In the **All-or-None Effect**, a single action potential elicits a single contraction in all the muscle fibers. Individual muscle fibers contract to their fullest. Amount of tension (force) develops depends on the frequency of stimulation of the muscle fibers by the neurons, the length of the muscle fiber just before they contract, the number of muscle fibers contracting, and the structural components of the muscle itself.

Wave summation is defined as if two stimuli are applied and the second one is delayed until the refractory period is over, the skeletal muscle will respond to both and the second will be stronger than the first. Tetanus can be partial or complete depending on the number of stimulations per second; most voluntary contractions involve short term tetanic contractions. The Staircase Effect (Treppe) is similar to wave summation, except there is complete relaxation between stimuli.

Number of Muscle Fibers Contracting: Recruitment is the process of increasing the number of active motor units. It prevents fatigue and helps provide smooth muscular movements.

Muscle tone is the involuntary activation of a small number of motor units that causes sustained, small contractions that give firmness to a relaxed skeletal muscle. It is Essential for maintaining posture and keeping the head upright.

Mechanics of body movement

Mechanics refers to how muscles move loads. The different Types of Contractions are: Isotonic where the muscle shortens during contraction, Isometric contraction where the muscle contracts but does not shorten, and Isokinetic contraction where the muscle lengthens. Contractions move loads, but isometric contractions create force without movement. Concentric actions are shortening contractions whereas eccentric contractions are lengthening contractions.

Classification of Skeletal Muscle Fibers

	SLOW OXIDATIVE; (SO) FIBERS	FAST OXIDATIVE GLYCOLYTIC (FOG) FIBERS	FAST GLYCOLIC; (FG) FIBERS
Time to max tension	Slowest	Intermediate	Fastest
Myosin ATP activity	Slow	Fast	Fast
Diameter	Small	Medium	Large
Contraction duration	Longest	Short	Short
Endurance	Fatigue resistant	Fatigue resistant	Easily fatigued
Use	Most used: posture	Standing, walking	Least used, jumping
Metabolism	Aerobic; numerous large mitochondria	Glycolytic but becomes oxidative with endurance training	Glycolytic; more anaerobic
Color	Dark red (myoglobin)	Red	Pale

The slow oxidative ones are usually used for endurance, as in the back muscles used for posture. They contract slower, process oxygen efficiently and can be used for long periods of time. The fast oxidative muscle fibers react very quickly but run out of energy after a short time.

SMOOTH MUSCLE and CARDIAC MUSCLE

Smooth muscle is slower than skeletal muscle but can sustain contractions for a longer period of time. Single-unit smooth muscle contracts as a single unit when depolarization passes from cell to cell through gap junctions. In multi-unit smooth muscle, individual muscle fibers are stimulated independently. Actin and myosin are arranged in smooth muscle cell's periphery. Smooth muscle actin lacks troponin. Smooth muscle has relatively little sacroplasmic reticulum. Smooth muscle is controlled by sympathetic and parasympathetic neurons and a variety of chemical signals. Smooth muscles regulate blood vessel diameter allowing or preventing blood to flow to the skin. Skeletal Muscles produce heat during contraction. A portion of the heat released during muscular contractions helps maintain normal body temperature. Excess heat is removed through the skin and lungs.

Cardiac muscle fibers are striated have a single nucleus, and are linked through gap junctions. Cardiac muscle shares features of both skeletal and smooth muscle. Refer to Table 10.4 for a summary of the major features of the three different types of muscular tissue.

Why is this chapter important?

In this chapter we looked at the functions of the muscular system, the properties of muscular tissue, and the structure of a muscle from the subcellular level to muscle as a whole. We also looked at muscle tissue physiology; what happens at a contraction or number of contractions. Lastly, we looked at the different types of skeletal muscles as well as the different types of muscle tissue.