Muscles Tissue

IE 665Applied Industrial Ergonomics

Suggested external links:

http://people.eku.edu/ritchisong/301notes3.htm

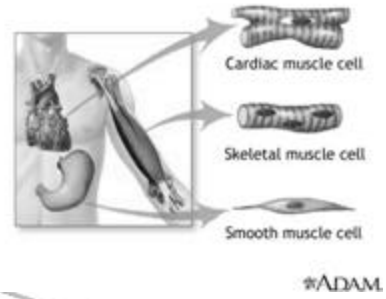
http://www.youtube.com/watch?v=0_ihc26yxN4&NR=1

Topics to be covered

Cardiac.

- Some basic functions and fundamental characteristics of skeletal muscles.
- Function and Structure of skeletal muscle tissue
- The nerve tissue and motor unit
- Microscopic anatomy of a skeletal muscle tissue
  - How a muscle tissue contracts
  - Action potential
  - Length tension characteristics of a muscle tissue
- Force regulation in skeletal muscles
- How energy is metabolized for muscle contraction and cellular respiration
- Fatigue in static and dynamic muscular work

Types of muscle tissues



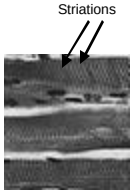
Three types of muscle tissue

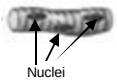
- Skeletal muscle attaches to bones, holds the skeleton against gravitational forces & moves skeleton to produce motion
- Smooth muscles are present in the walls of blood vessels, intestine & other 'hollow' organs. Its rhythmic contraction moves body fluids.
- Cardiac muscle are present in the wall of the heart. Its rhythmic contraction moves blood.

FOCUS OF THIS COURSE IS THE SKELETAL MUSCLES

Skeletal muscle tissue

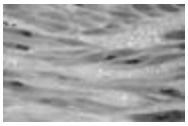
- It is under voluntary control. The muscle can be contracted and relaxed at will.
- It has a striated appearance under microscope, which is due to the orderly arrangement of the contractile proteins within the tissue.
- The cells are cylindrical and multinucleated.





Smooth muscle tissue

- Involuntary muscle, ie., not under voluntary control
- Not striated under microscope
- Not multinucleated



Cardiac muscle tissue

- Involuntary, ie., not under voluntary control
- Striated appearance under microscope
- Auto-rhythmic, ie. contracts rhythmically without any nervou impulse (nerve impulse modifies the rhythm)
- Not multinucleated
- Rectangular in shape

Functions of muscle tissue

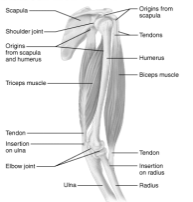
- Produces motion – fundamental characteristics of all living things
- Produces force (tension)
- Maintains posture – works against gravitational forces
- Provides joint stability
- Produces heat as a bi-product of contraction

Characteristics of muscle tissue

- Excitability - responds to stimuli (e.g., nervous and other impulses)
- Contractility - able to shorten in length
- Extensibility - stretches when pulled
- Elasticity - tends to return to original shape & length after contraction or extension

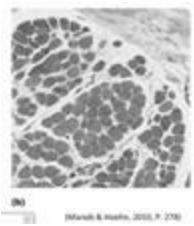
Physical Structure of Skeletal Muscle

- Each skeletal muscle spans over one or more skeletal joints and the muscle contraction produces a force that tends to turn a bone about its joint axis.
- Skeletal muscles vary in **size, shape, and arrangement of fibers**. They range from extremely tiny strands such as the stapedium muscle of the middle ear to large masses such as the muscles of the thigh.
- A gross muscle contains skeletal muscle tissues, connective tissues, nerve tissues, and vascular (blood circulation) tissues. ***Out of these, only the muscle tissue has the contractile property.***



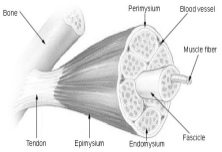
Connective Tissues in Skeletal Muscle

Each muscle is surrounded by a connective tissue sheath called the epimysium. Fascia, connective tissue outside the epimysium, surrounds and separates the muscles. Portions of the epimysium project inward to divide the muscle into compartments. Each compartment contains a bundle of muscle fibers. Each bundle is called a fasciculus and is surrounded by a layer of connective tissue called the perimysium. Within the fasciculus, each individual muscle cell, called a muscle fiber, is surrounded by connective tissue called the endomysium. All these connective tissue fuse together at the two end and forms tendon, which connects muscles to bones



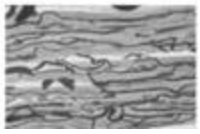
Role of Connective Tissues in Skeletal Muscle

- Skeletal muscle cells (fibers), like other body cells, are soft and fragile. The connective tissue covering furnish support and protection for the delicate cells and allow them to withstand the forces of contraction.
- Through these tough tissues contractile force of the muscle cells are transmitted to the bone.
- The coverings also provide pathways for the passage of blood vessels and nerves .



Vascularization of Skeletal Muscle

- Skeletal muscles have an abundant supply of blood vessels, approximately 2 capillaries per muscle cell. Capillaries supply the essential oxygen and nutrients to each muscle fiber.
- Since the capillaries spreads evenly in the muscle body the smaller muscles cells have more capillaries.



http://www.udel.edu/biology/Wags/histopage/colorpage/cmu/cmusmu.gif

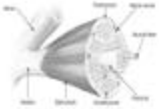
Tendons and Ligaments

The connective tissues, the epimysium, perimysium, and endomysium extend beyond the fleshy part of the muscle to form a thick ropelike **tendon** or a broad, flat sheet-like **aponeurosis**.

The tendon form attachments from muscles to the bones and aponeurosis forms connection to the connective tissue of other muscles.

Typically a muscle spans a joint and is attached to bones by tendons at both ends. One of the bones remains relatively fixed or stable while the other end moves as a result of muscle contraction.

Ligaments forms joint capsules are fibrous tissues that connect bone to bone.

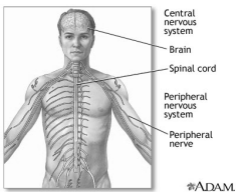


Nervous System functions

- It is the major controlling, regulatory, and communicating system in the body. If muscles are power house, then the nerves are the control mechanism.
- It is the center of all mental activity including thought, learning, and memory.
- Together with the **endocrine system** (producing hormones), the nervous system is responsible for regulating and maintaining **homeostasis (regulates internal environment so as to maintain a stable, constant condition)**.
- Through its receptors, the nervous system keeps us in touch with our environment, both external and internal.

Nervous System

- The nervous system is composed of central nervous system (brain and spinal chord) and peripheral nervous system (containing nerve cells external to the brain or spinal cord).
- These, in turn, consist of various tissues, including nerve, blood, and connective tissue.

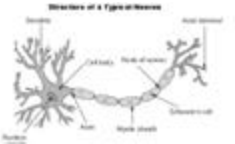


How Nervous System Works

- Millions of sensory receptors detect changes, called stimuli, which occur inside and outside the body. They monitor such things as temperature, light, and sound from the external environment. Inside the body, the internal environment, receptors detect variations in pressure, pH, carbon dioxide concentration, and the levels of various electrolytes. All of this gathered information is called sensory input (**afferent nervous system**).
- Sensory input is converted into electrical signals called **nerve impulses** that are transmitted to the brain. There the signals are brought together to create sensations, to produce thoughts, or to add to memory; Decisions are made each moment based on the sensory input. This is integration.
- Based on the sensory input and integration, the nervous system responds by sending signals to muscles, causing them to contract, or to glands, causing them to produce secretions.
- The nerve cells that send impulse to muscle cells are called **motor nerve (efferent nervous system).**

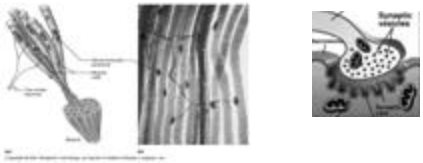
Typical motor (neurons) nerves and motor unit

- Axon terminals of one motor neuron innervate a number of muscle cells that are dispersed randomly in the overall muscle mass. **The muscle cells and the single motor neuron that innervates them make one motor unit.**



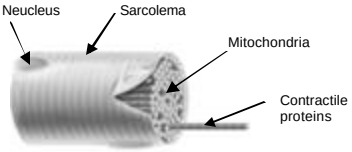
- When the neuron of a motor unit sends a nerve impulse which exceeds a threshold value, all the muscle cells (fibers) of the motor unit contract together. ***All or none principle***
- Number of muscle cells controlled by a motor neuron varies. Muscles which require fine controls may have innervations of a few muscle cells per motor neuron, where as, when gross force production is the primary objective, motor units innvervates large (over hundred) number of muscles cells.

Innervation of muscle cells



- When the nerve impulse (electrical) reaches axon end, the permeability of the synaptic vesicle membranes at its axon ends releases chemical neurotransmitter (acetylcholine).
- This chemical binds with the muscle cell membrane molecules at the synaptic cleft (known as **motor end plate**), and stimulates the muscle cell.

Microscopic Structure of a Muscle Cell

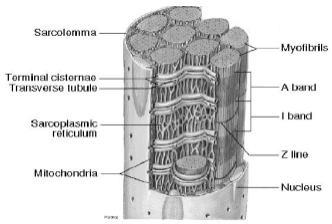


Sarcolemma: Bi-layer lipid membrane, semi-permeable, has specialized molecules that selectively control inflow and outflow of ions from the extra-cellular space.

Motochondria: Organelle, where ATP (Adenosine Tri-phosphate) is synthesized by oxidative process. ATP is only form of energy that muscle cells can utilize to produce mechanical energy.

Contractile proteins: Responsible for muscle contraction.

T-tubules and Sarcoplasmic reticulum



Arrangement of Protein filaments

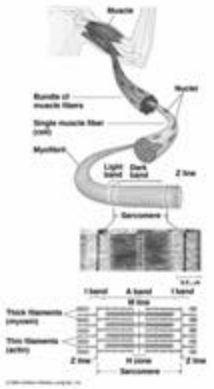
Muscles cells are packed with myofibrils.

Myofibrils are composed of two main types of myo-filaments: thick and thin. They are arranged in a very regular, precise pattern.

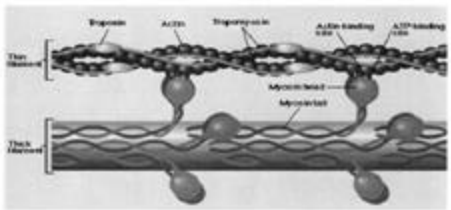
- Myosin – thick filaments
- Actin – thin filaments

Sliding of the thin filaments over the thick filaments causes sarcomere to contract.

Sarcommere: The smallest contractile unit.



Models of Protein filaments



Review – U-tube video

- http://www.youtube.com/watch?v=EdHzKYDxrKc&feature=player_embedded

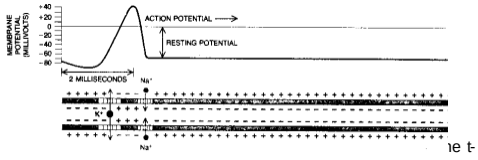
Resting potential of sarcolemma

- In a resting muscle, there is a higher concentration of Na+ ions in the extra-cellular space and a higher concentration of K+ ions in the intracellular space (inside the muscle cell membrane).
- **In resting state the muscle cell membrane remains electrically polarized (i.e. outside has higher positive ion concentration than inside).** This is due to the fact that K+ ions are small and can freely defuse across the cell membrane but larger Na+ ions cannot, which makes the cell membrane polarized.

Single Action Potential: Initiation of muscle contraction

- Nerve impulse (electrical) reaches the axon end of the nerve cell. The Impulse releases a neurotransmitter chemical (acetylcholine) that binds with specific molecules at the motor end plate
- Due to this chemical reaction, some molecules at the motor end-plate change their shapes opening gates (pores) for Na+ ions.
- Na+ ions start to diffuse in the muscle cell. The influx of Na+ ions locally depolarizes the cell membrane.
- After the depolarization reaches a threshold level, a local electric current sets up between the depolarized region at motor end plate and the neighboring polarized (resting) regions of the cell membrane.
- This electric current opens more voltage sensitive Na-gates on the cell membrane and causes Na+ ions influx in the neighboring region of the cell membrane.
- This newly depolarized region, in turn, depolarizes their neighboring region and the depolarization wave propagates in the outward direction from the motor end plate, and travels the entire length of the muscle cell. This phenomena is called **Action Potential**.

Action potential: Continued



- This whole phenomena starts with a single nerve stimulus that exceeds a threshold level. Once a single nerve stimulus level exceeds a threshold value, the action potential starts with the same intensity (all or none principal). **Larger discharge of neurotransmitter would not produce stronger Action potential.**
- Right after the depolarization, acetylcholine is broken down by enzymes and Na+ ions are actively (using energy molecules) transported back to the outside of cell membrane and the cell membrane returns to its normal polarized (resting) state.

Conversion of chemical to mechanical energy

- Action potential reaches deep in the muscle through the T-tubules, which causes release of Ca^{+2} ions.
- Ca^{+2} ions binds with tropomyosin protien, and shifts the troponin molecules to open the binding site of actin and myosin.
- Myosin molecule attaches to actin molecule and change its shape, and sliding the actin molecule.
- With the presence of energy molecule (ATP), myosin combines with ATP, and the mysin-actin bond is broken.
- As long as ATP and Ca^{+2} ions are present, this process continues.
- If no new nerve impulse is there, then Ca^{+2} ions are actively pushed back in to SR, and binding sites of actin-myosin are closed and the sliding stops.

Conversion of chemical to mechanical energy (continued)

WATCH HOW MUSCLE CELLS CONTRACT

- http://www.youtube.com/watch?v=gJ309LfHQ3M&feature=player_embedded#!
- http://www.mmi.mcgill.ca/mmimediasampler/