

# Muscular System -Training Handout

Karen L. Lancour

National Rules Committee Chairman – Life Science

## Muscle Function

- Stabilizing joints
- Maintaining posture
- Producing movement
- Moving substances within the body
- Stabilizing body position and regulating organ volume
- Producing heat– muscle contraction generates 85% of the body’s heat

## Characteristics of Muscle Tissue

- Excitability- receive and respond to stimuli
- Contractility- ability to shorten and thicken
- Extensibility- ability to stretch
- Elasticity- ability to return to its original shape after contraction or extension

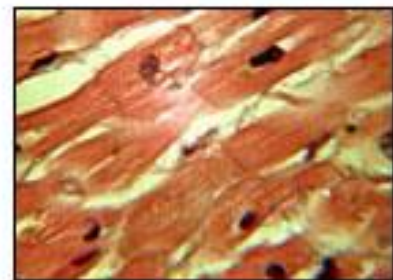
	Skeletal Muscle	Smooth Muscle	Cardiac Muscle
Location	Attached to bone	On hollow organs, glands and blood vessels	Heart
Function	Move the whole body	Compression of tubes & ducts	Heart contraction to propel blood
Nucleus	Multiple, peripheral	Single, central	Central & single
Control	voluntary	involuntary	involuntary
Striations	yes	no	yes
Cell Shape	Cylindrical	Spindle-shaped	Branched



Skeletal muscle



Smooth muscle



Cardiac muscle

## Muscle Function

- Skeletal muscles are responsible for all locomotion
- Smooth muscle helps maintain blood pressure, and squeezes or propels substances (i.e., food, feces) through organs
- Cardiac muscle is responsible for coursing the blood through the body

## Muscle Similarities

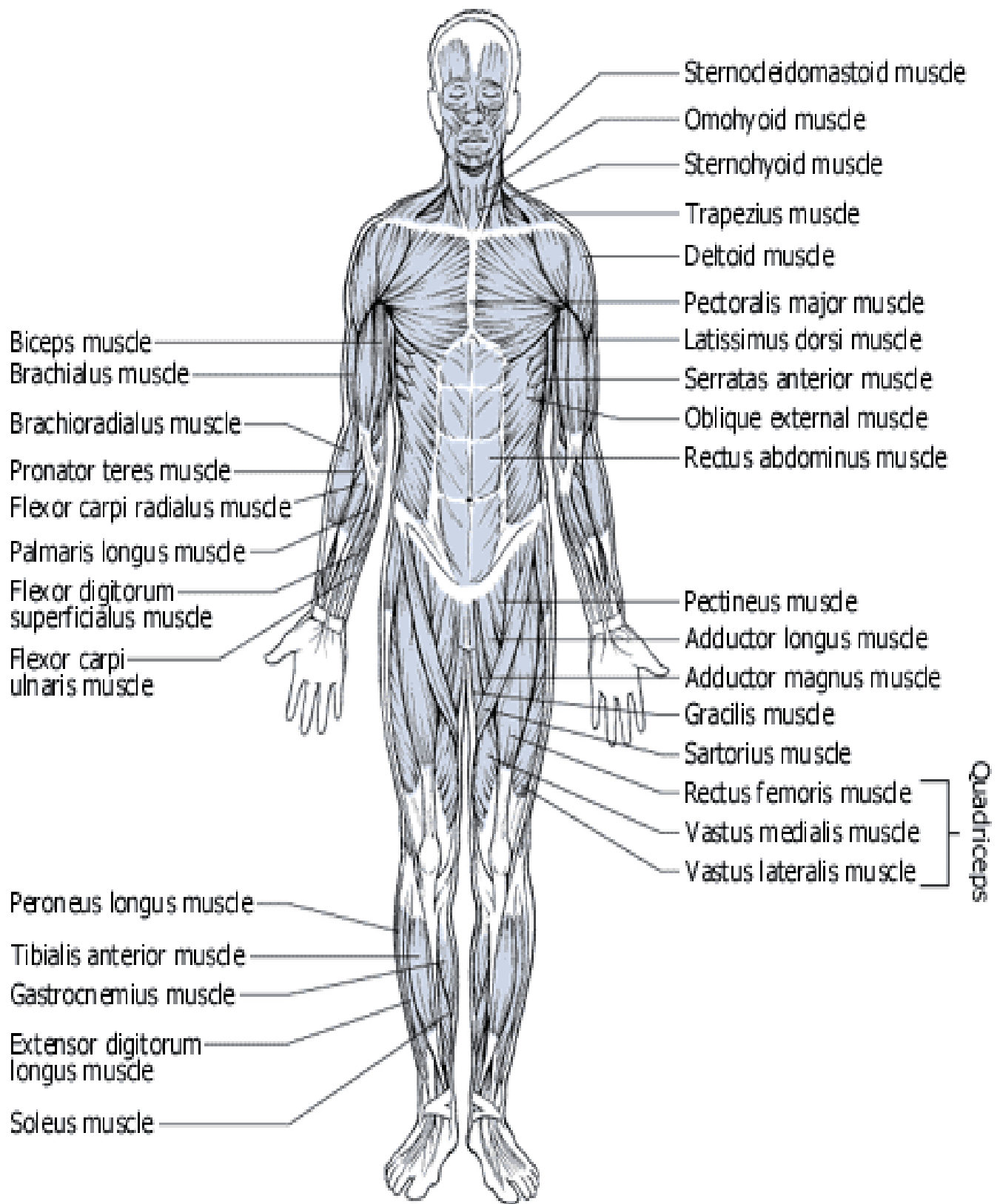
- Skeletal and smooth muscle cells are elongated and are called *muscle fibers*
- Muscle contraction depends on two kinds of myofilaments – actin and myosin
- Muscle terminology is similar
- Sarcolemma – muscle plasma membrane
- Sarcoplasm – cytoplasm of a muscle cell
- Prefixes – myo, mys, and sarco all refer to muscle

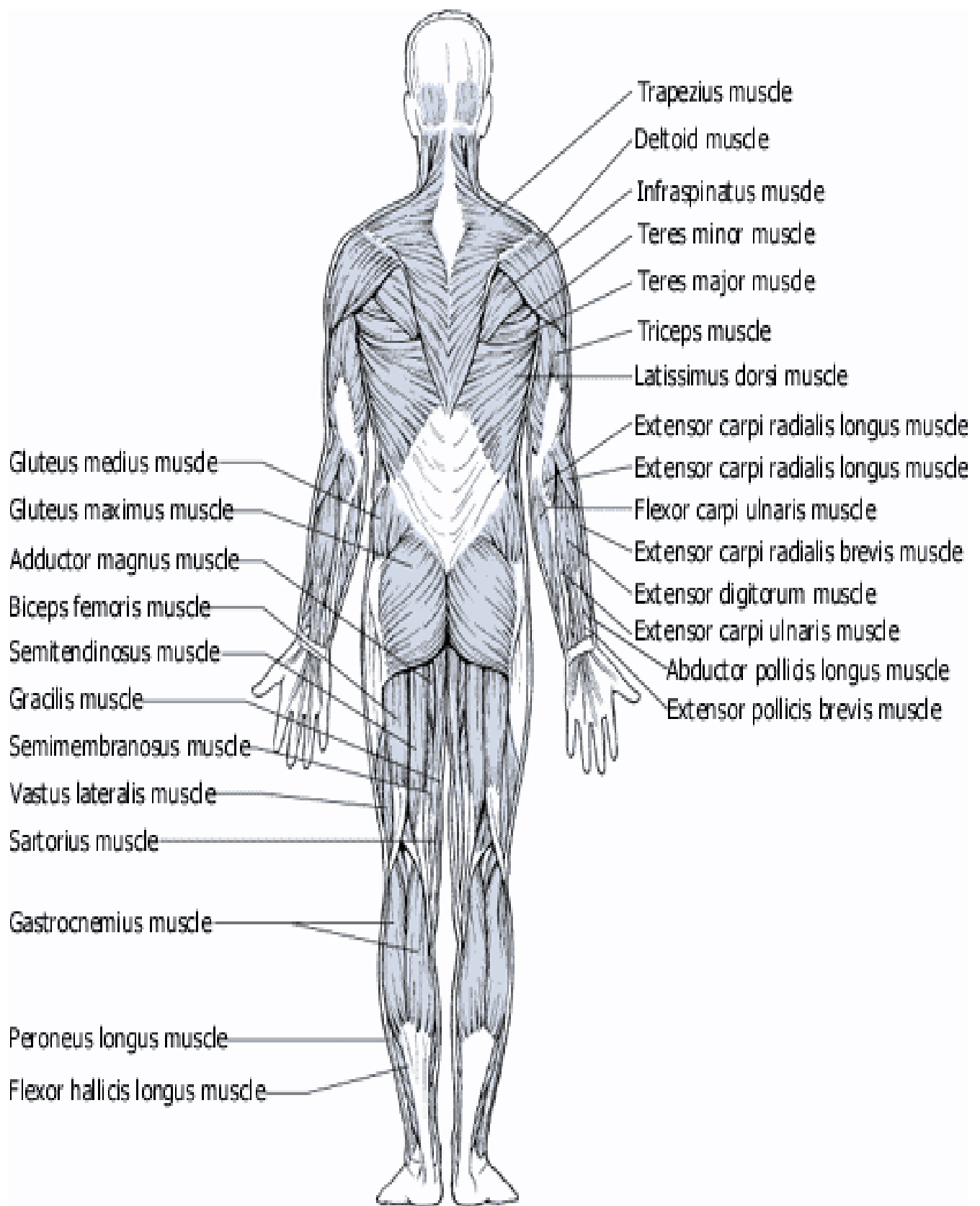
## Skeletal Muscles

- There are nearly **650** muscles attached to the skeleton. See muscle list for competitions.
- They work in pairs: one muscle moves the bone in one direction and the other moves it back again.
- Most muscles extend from one bone across a joint to another bone with one bone being more stationary than another in a given movement. Muscle movement bends the skeleton at moveable joints.
- Muscles are anchored firmly to bone by **tendons** made of dense fibrous connective tissue shaped like heavy cords. Though very strong and secure to muscle, tendons may be injured.
- Attachment to the more stationary bone by tendon closest to the body or muscle head or proximal is the **origin** and attachment to the more moveable bone by tendon at the distal end is the **insertion**.
- During movement, the origin remains stationary and the insertion moves.
- The force producing the bending is always a **pull of contraction**. Reversing the direction is produced by the contraction of a different set of muscles. As one group of muscles contracts, the other group stretches and then they reverse actions.
- Muscle contractions can be short, single contractions or longer ones.

## Skeletal Muscle: Attachments

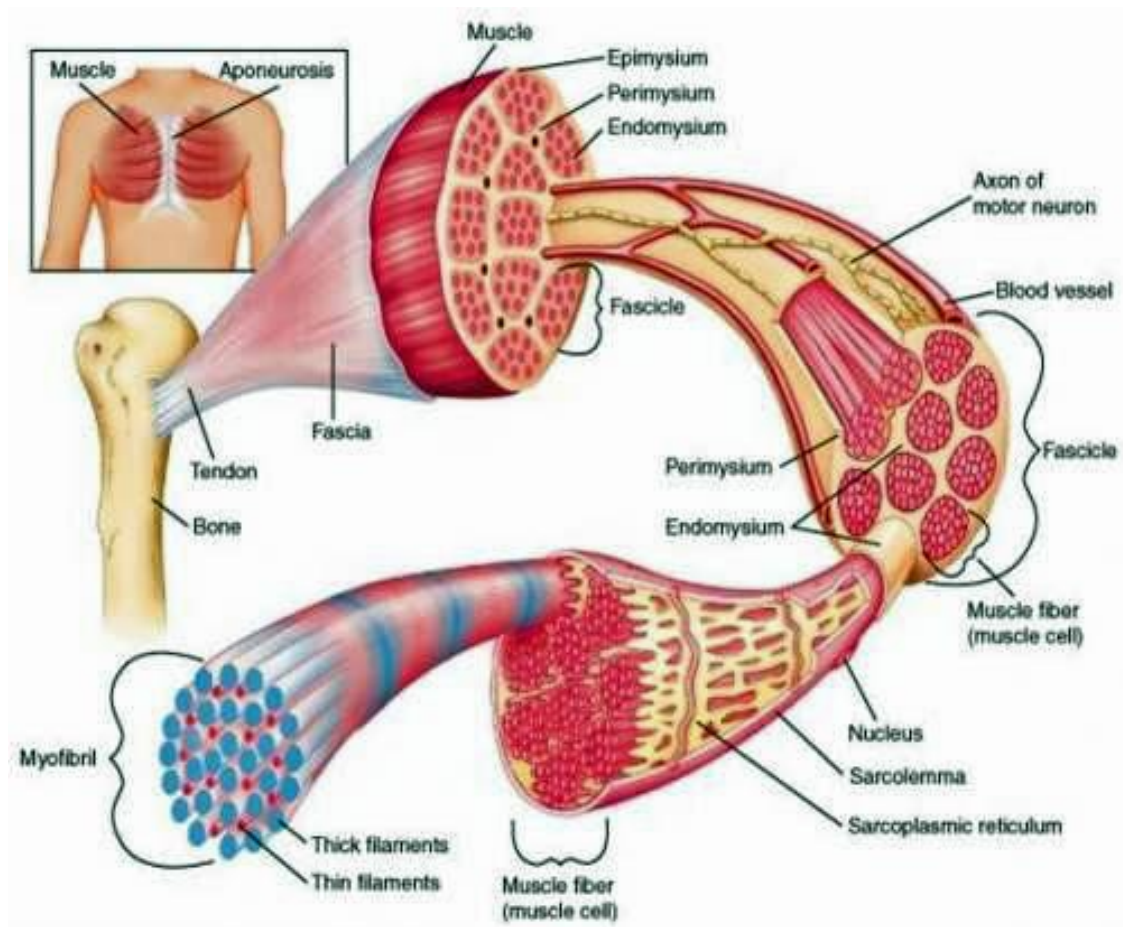
- Muscles span joints and are attached to bone in at least two places
- When muscles contract the movable bone, the muscle's insertion moves toward the immovable bone – the muscle's origin
- Muscles attach:
  - Directly – epimysium of the muscle is fused to the periosteum of a bone
  - Indirectly – CT wrappings extend beyond the muscle as a tendon or aponeurosis





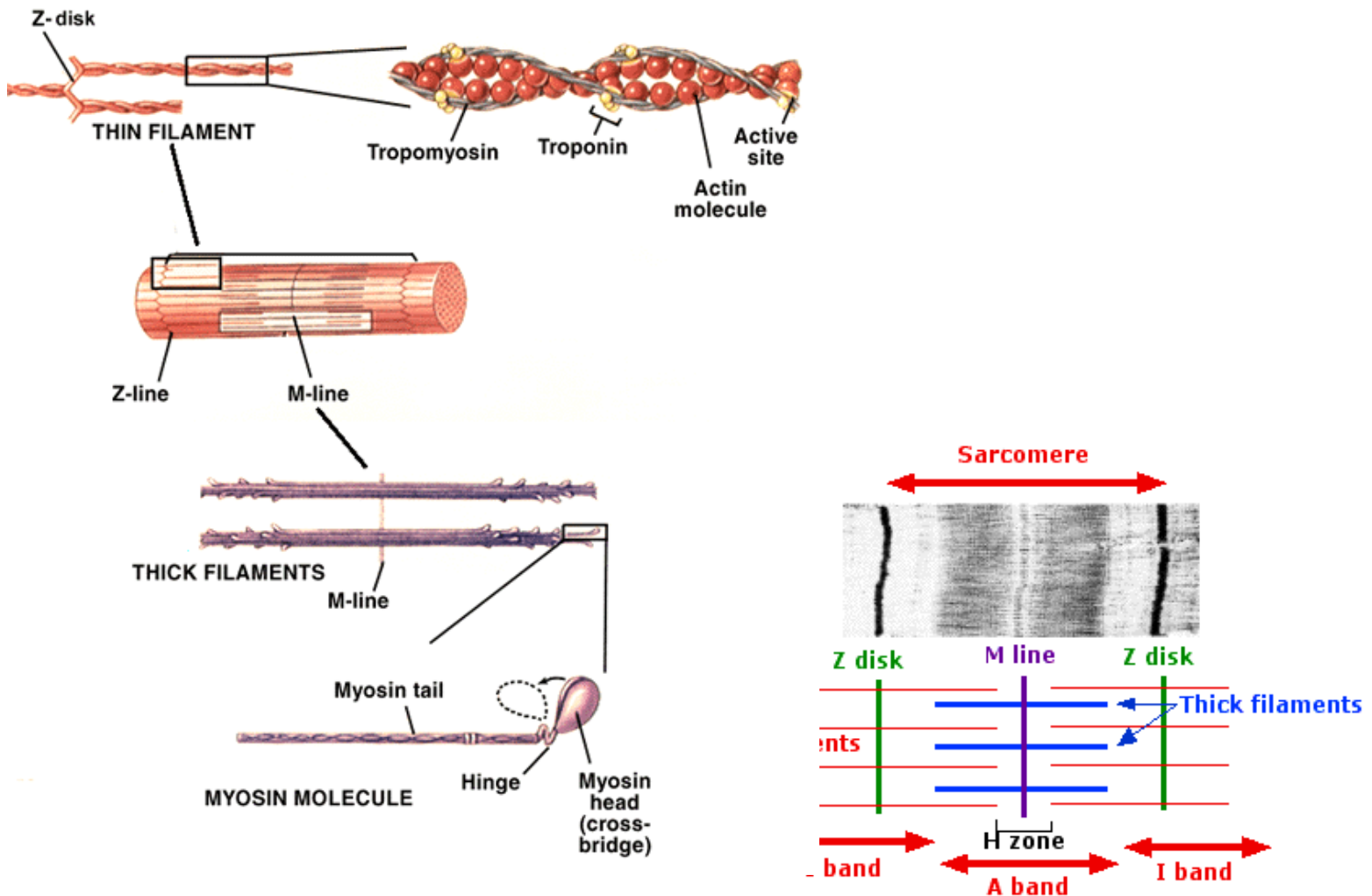
## Skeletal Muscle Anatomy

- Skeletal Muscle: Nerve and Blood Supply
  - Each muscle is served by one nerve, an artery, and one or more veins
  - Each skeletal muscle fiber is supplied with a nerve ending that controls contraction
  - Contracting fibers require continuous delivery of oxygen and nutrients via arteries
  - Wastes must be removed via veins
- Each muscle is a discrete organ composed of muscle tissue, blood vessels, nerve fibers, and connective tissue
- Each muscle has thousands of muscle fibers in a bundle running from origin to insertion bound together by connective tissue through which run blood vessels and nerves.
- Each muscle fiber contains many nuclei, an extensive endoplasmic reticulum or sarcoplasmic reticulum, many thick and thin myofibrils running lengthwise the entire length of the fiber, and many mitochondria for energy.
- The three connective tissue wrappings are:
  - **Epimysium** – an overcoat of dense regular CT that surrounds the entire muscle
  - **Perimysium** – fibrous CT that surrounds groups of muscle fibers called *fascicles*
  - **Endomysium** – fine sheath of CT composed of reticular fibers surrounding each muscle
- The basic functional unit of the muscle fiber is the **sarcomere** which consists of thick filaments with myosin (protein) molecules and thin filaments with actin (protein) molecules plus smaller amounts of troponin and tropomyosin.
- When viewed under the microscope, they appear as striations of **dark A bands** and **light I bands**. The A bands are bisected by the H zone with the M line or band running through the center of this H zone. The I bands are bisected by the Z disk or line.
- A **sarcomere** consists of the array of thick and thin filaments between two Z disks.



## Sliding-Filament Model

- In the thick filaments, myosin molecules contain a globular subunit, the **myosin head**, which has binding sites for the actin molecules of the thin filaments and ATP.
- Activating the muscle fiber causes the myosin heads to bind to actin molecules pulling the short filament a short distance past the thick filaments.
- The linkages break and reform (using ATP energy) further along the thick filaments. Thus the thin filaments are pulled past the thick filaments in a ratchet-like action. No shortening, thickening or folding of individual filaments occurs.
- As the **muscle contracts**, the width of the I bands and H zones decrease causing the Z disks to come closer together, but there is no change in the width of the A band because the thick filaments do not move. As the **muscle relaxes or stretches**, the width of the I bands separate as the thin filaments move apart but the thick filaments still do not move.



### **Motor Unit: The Nerve-Muscle Functional Unit**

- A motor unit is a motor neuron and all the muscle fibers it supplies
- The number of muscle fibers per motor unit can vary from four to several hundred
- Muscles that control fine movements (fingers, eyes) have small motor units
- Large weight-bearing muscles (thighs, hips) have large motor units
- Muscle fibers from a motor unit are spread throughout the muscle; therefore, contraction of a single motor unit causes weak contraction of the entire muscle

### **Sequential Events of Contraction**

- Cross bridge attachment – myosin cross bridge attaches to actin filament
- Working (power) stroke – myosin head pivots and pulls actin filament toward M line
- Cross bridge detachment – ATP attaches to myosin head and the cross bridge detaches
- “Cocking” of the myosin head – energy from hydrolysis of ATP cocks the myosin head into the high energy state

### **Regulation of Contraction**

In order to contract, a skeletal muscle must:

- Be stimulated by a nerve ending
- Propagate an electrical current, or action potential, along its sarcolemma
- Have a rise in intracellular  $\text{Ca}^{2+}$  levels, the final trigger for contraction
- Linking the electrical signal to the contraction is excitation-contraction coupling

### **Nerve Stimulus of Skeletal Muscle**

- Skeletal muscles are stimulated by motor neurons of the somatic nervous system
- Axons of these neurons travel in nerves to muscle cells
- Axons of motor neurons branch profusely as they enter muscles
- Each axonal branch forms a neuromuscular junction with a single muscle fiber

### **Muscle Fatigue**

- Muscle fatigue – the muscle is in a state of physiological inability to contract
- Muscle fatigue occurs when:
  - ATP production fails to keep pace with ATP use
  - There is a relative deficit of ATP, causing contractures
  - Lactic acid accumulates in the muscle
  - Ionic imbalances are present

### **Oxygen Debt**

- Vigorous exercise causes dramatic changes in muscle chemistry
- For a muscle to return to a resting state:
  - Oxygen reserves must be replenished
  - Lactic acid must be converted to pyruvic acid
  - Glycogen stores must be replaced
  - ATP and CP reserves must be resynthesized
- Oxygen debt – the extra amount of  $\text{O}_2$  needed for the above restorative processes

### **Heat Production During Muscle Activity**

- Only 40% of the energy released in muscle activity is useful as work
- The remaining 60% is given off as heat
- Dangerous heat levels are prevented by radiation of heat from the skin and sweating

## Muscle and Tendon Injuries

**Strains** – injuries from overexertion or trauma which involve stretching or tearing of muscle fibers. They often are accompanied by pain and inflammation of the muscle and tendon. If the injury is near a joint and involves a ligament, it is called a sprain.

**Cramps** – painful muscle spasms or involuntary twitches.

**Stress-induced muscle tension** – may cause back pain and headaches.

## Muscular Disorders:

**Poliomyelitis** – viral infection of the nerves that control skeletal muscle movement.

**Muscular Dystrophies** – most common caused by mutation of gene for the protein **dystrophin** which helps in attaching and organizing the filaments in the sarcomere. Duchenne Muscular Dystrophy and Becker muscular dystrophy are the two most common types. The gene for dystrophin is on the X chromosome so the disorder is sex-linked. Muscle function is impaired.

**Myasthenia gravis** – autoimmune disease affecting the neuromuscular junction. Patients have smaller end plate potentials due to the antibodies being directed against the receptors. It affects the ability of the impulse to cause the muscle contraction. Administering an inhibitor of acetylcholinesterase can temporarily restore contractibility.

**Tetanus** - a serious bacterial disease that affects your nervous system, leading to painful muscle contractions, particularly of your jaw and neck muscles - Tetanus can interfere with your ability to breathe and, ultimately, threaten your life. Tetanus is commonly known as "lockjaw."

## Homeostatic Imbalance: Age Related

- With age, connective tissue increases and muscle fibers decrease
- Muscles become stringier and more sinewy
- By age 80, 50% of muscle mass is lost (sarcopenia)
- Regular exercise reverses sarcopenia
- Aging of the cardiovascular system affects every organ in the body
- Atherosclerosis may block distal arteries, leading to intermittent claudication and causing severe pain in leg muscles

## Effects of Exercise on Muscular System

- Exercise helps muscles become more effective and efficient.
- Tendons will become thicker and able to withstand greater force
- High intensity exercise for short duration produces strength, size and power gains in muscles
- Low intensity exercise for long durations will give endurance benefits
- Trained muscles have better tone or state of readiness to respond
- Exercise promotes good posture enabling muscles to work effectively and helps prevent injury
- During exercise the muscle cells use up more oxygen and produce increased amounts of carbon dioxide.
- The lungs and heart have to work harder to supply the extra oxygen and remove the carbon dioxide.
- Heart rate also increases in order to transport the oxygenated blood to the muscles.
- Muscle cell respiration increases - more oxygen is used up and levels of carbon dioxide rise.
- The brain also tells the heart to beat faster so that more blood is pumped to the lungs for gaseous exchange. More oxygenated blood is gets to the muscles and more carbon dioxide is removed.