Muscles & Muscular Tissue

• Terminology
  • “__________________” refers to muscles.
  • myopathy = disease of muscle (e.g., cardiomypathy)
  • electromyography = recording of electrical or activity of muscle.
  • myoblasts = cells that produce or become muscle cells.
  • “__________________” = "flesh" sarcomere, sarcoplasmic reticulum and sarcolemma.
  • Sarcophagus = "flesh eating."

• Muscle is a principal tissue type, Specialized for contraction.
• Like neurons, muscle is an __________ tissue, in that it can conduct or transmit electrical impulses (respond to stimuli).
• 3 muscle types:

Functions

1) Skeletal muscle: Movement of skeleton
Cardiac muscle: Movement (contraction) of heart
Smooth muscle: Regulation of blood vessel diameter, bronchiole diameter, movement of material in gastrointestinal tract.

2) 

3)
General structure of skeletal muscle

• Tendon ---- Body of Muscle ----- Tendon
• Tendon Histology: connective tissue

Aponeurosis

• _______ that is broad or sheet-like.
• Aponeurosis of Galen
• Lumbar aponeurosis: origin of the latissimus dorsi.

Levels of Organization

• _______ : a collection of fascicles
• _______ : a collection of muscle cells
• _______ : collection of myofibrils plus other cell organelles.
• _______ : series of sarcomeres
• _______ : Basic unit of muscle structure and function.
• _______ : Thick and thin filaments
Filament Structure

- Tropomyosin
- G-actin
- Thin filament
- Thick filament
- Z-disc
- I band
- A band
- H zone
- M line

Associated Connective Tissue Organizes Muscle Tissue

- Bundles of muscle fibers are grouped or bundled together by connective tissue.
- ______________: surrounds fibers
- ______________: surrounds fascicle
- ______________: surrounds fascicles
- Superficial fascia: layer adjacent to hypodermis. Deep fascia: binds muscles together.
Blood and Nerve Supply

- Muscles are highly vascular organs — high rate of metabolic activity.
- Nerves control or modify muscle contraction.
- A "_____________" nerve is any nerve that innervates a muscle.
- Skeletal muscles require input from a nerve in order to contract. They are _______________________.
- Cardiac and smooth muscle can contract on their own (they have an intrinsic spontaneous contraction rate and are _______________________), but the rate is controlled by nerves and hormones.

Sensory nerves are abundant in muscle also—supply nervous system with information on muscle contraction and joint position.
- Muscle Spindles: monitor ___________ within muscles.

Electrical Nature of Membrane

- Resting Membrane Potential (RMP)
  - The cell membrane is electrically polarized
  - Voltage difference across cell membrane is - -50 to -90 mV. Unequal conc. of ions.
  - __________: 10X more concentrated outside
  - __________: 15X more concentrated inside
  - “Fixed” Anions
  - Chloride

Excitable Cells

- Excitable cells (neurons and muscle cells) do something with the electrical difference across the membrane.
- ______________: potential > RMP
- ______________: return to RMP
- ______________: potential < RMP
- ______________: voltage at which impulse (action potential) is triggered.
Excitation-Contraction Coupling

- Mechanism by which excitation of muscle cell membrane stimulates muscle cell contraction.

Action Potential
- Depolarization
- Propagation
- Repolarization

Neuromuscular Junction
3 components

1) ____________________
   Motor neuron terminal has synaptic vesicles that contain the neurotransmitter acetylcholine (ACh). ACh is released by nerve stimulation (nerve action potential).

2) ____________________ Gap thru which transmitter diffuses.

3) ____________________: Area specialized for reception of neurotransmitter.
   - ACh binds to Ach receptors -- causes endplate potential (EPP). Membrane potential reaches threshold and then a muscle action potential is triggered.
   - ____________________: enzyme on endplate that breaks down ACh -- initiation of muscle impulse ends.
Sequence of Events at Neuromuscular Junction and Excitation-Contraction Coupling.

1. Nerve impulse (action potential) arrives at terminal and induces the entry of Calcium into terminal via voltage-gated calcium _____________.

2. Calcium entry stimulates _____________ of ACh filled vesicles.

3. ACh diffuses across synaptic cleft and binds onto ________________ on muscle endplate.

4. ACh receptors activate Na/K ion channels. Sodium entry depolarizes endplate -- generates an _______________ _______________ (EPP).

5. Endplate membrane is brought to threshold voltage and adjacent muscle cell membrane generates an action potential (muscle impulse).

6. Muscle Impulse: travels down sarcolemma and then into myofibrils via the ___________ _______________

7. Transverse tubules transmit signal to Sarcoplasmic Reticulum (S.R.)
   - S.R. releases calcium to myofibrils (initiates contraction).

8. Actin and myosin filaments interact -- they slide past each other and muscle cell shortens.
   - Calcium binds to ________________ - pulls ________________ away from active site on actin -- myosin can now bind to actin -- myosin head moves actin filaments.
   - This is the _______________ _______________ theory of muscle contraction.
Roles of ATP

• ATP provides ___________________. Myosin head is an ATPase in that it cleaves ATP to form ADP and Pi, yielding energy for movement.
• ATP is also need to ___________ from myosin head.
• Lack of ATP -- rigor mortis sets in. Muscles are stiff because actin and myosin filaments are cross-linked.

Muscle Relaxation

1. ACh is broken down by __________
2. S.R. pumps calcium back inside -- this uses ATP!
3. Without calcium present, troponin and tropomyosin block active site on actin preventing cross-bridge formation between actin and myosin.
4. Actin and myosin filaments return to their original positions.

Muscle Contraction

• Functional unit of muscle contraction is the ___________ : one motor neuron & all the muscle cells it innervates
• To increase force of contraction, more motor units need to be __________

Tension Developed is Proportional to Overlap of Filaments
Resting muscle uses _________ _______ pathway to supply ATP. Prime energy sources are fatty acids and glucose (from glycogen via glycogenolysis).

Glucose converted to pyruvic acid, which is broken down by citric acid cycle (in___________________, aerobic) to produce ATP.
Aerobic and Anaerobic Metabolism of Glucose

- Advantage of Aerobic respiration:
  – ______________________

- Disadvantage of Aerobic respiration:
  – ______________________

- Exercising muscle uses ATP, but use soon outweighs ATP production. Muscle respires anaerobically (glycolysis -- lactic acid produced).
- ATP is also generated from creatine phosphate

Creatine Phosphate

- Creatine Phosphate + ADP → ATP + Creatine
- Muscle has large stores of creatine phosphate but it is rapidly used up during sustained contraction.

Oxygen Debt*

- As a result of heavy exercise, lactic acid accumulates from anaerobic respiration. Lactic acid then travels to the liver, which converts it to glucose. Conversion to glucose requires ATP and oxygen. During exercise, available oxygen is used primarily by muscle, so less is available for use by liver.
- The "oxygen debt" created is equal to the amount of oxygen needed by liver to convert accumulated lactic acid into glucose, plus the amount needed by muscle for ATP and CP regeneration. Total process may take hours.
- (*Note: Exercise physiologists prefer to call oxygen debt "EPOC" for "Excess post-exercise oxygen consumption.")

Muscle Fatigue

- Accumulation of _________ _______ and low _______ results in fatigue (reduction in ability to contract).
- Other factors include: change in pH, interruption of blood supply, depletion of acetylcholine.
- Tolerance to fatigue from athletic training is due to increased ___________ & ___________.
- Energy use of muscles can be modified as a result of exercise.
Effects of Resistance Training

- __________________ is from increase in Number and Size of Myofibrils.
- "_________________" is from increase in Number of Fibers -- not from mitosis in this case, but from splitting of muscle cells.

Responses to Endurance Training

- Numerous factors related to aerobic metabolism

Loss of Muscle Mass

- _____________ wasting away of muscle tissue. E.g., disuse atrophy, in which muscle mass is lost because of inactivity.
- Also from loss of motor neurons.
- _____________ literally, "defective nutrition." Tissue fails to develop correctly or thrive. Usually congenital or genetic in cause.
- _____________ means "vanishing flesh." Age-related loss of muscle with replacement by fat.

Skeletal Muscle Fiber Types

1) ____________ (Type I) -- e.g., soleus.
   - 100 msec for contraction.
   - "_________________" muscle fibers -- due to myoglobin & blood supply.
   - High resistance to fatigue, aerobic metabolism.

2) _______________ (Type IIA) e.g., gastrocnemius. Fast twitch. "Pink fibers" intermediate to high resistance to fatigue.

3) _______________ (Type IIB) -- e.g., extraocular muscles. 7.3 msec for contraction.
   - _____________ fibers.
   - Low resistance to fatigue, anaerobic metabolism.
• Fiber type dictated by ________________ (experimentally demonstrated) and by genetics.
• Effect of training? Twitch type (fast or slow) stays the same. Aerobic capacity/fatigue resistance can be increased in fast-twitch muscles. (Fast-twitch fatigable become intermediate).
• Fibers also differ in: Myoglobin content (oxygen supply), Vascularization and Myosin ATPase activity.
• Ratio of fast to slow fibers varies among individuals.
• Gastrocnemius muscles of runners for example: Sprinters have more fast twitch fibers, long distance runners have more slow twitch fibers.

Cardiac Muscle
• Striated, but differs from skeletal muscle in the following ways:
  1. ________________
  2. ________________
  4. Arrangement of sarcoplasmic reticulum and transverse tubules is different.
  5. Strictly ________________.
  6. Autorhythmic (has automaticity)

Smooth Muscle
• Typically associated with "viscera" and "involuntary" systems (circulatory, respiratory, digestive, urinary, reproductive and integumentary).
  1. ________________ Actin and myosin have diffuse organization.
  2. Spindle-shaped cells with _________. ___________ nucleus.
  3. Actin is anchored at "dense bodies" scattered along the sarcolemma. Dense bodies link adjacent cells.
  4. When the muscle contracts, it may twist or corkscrew as it shortens.

  5. ________________ is calcium binding protein (rather than troponin).
  6. Little internal stores of calcium -- most calcium enters from outside of cell.
  7. Functions over large range of muscle lengths.
  8. Motor neuron connections are variable (____________ and ____________ subtypes).
  9. Sensitive to a number of hormones and neurotransmitters.
Muscular Diseases

- **Muscular Dystrophy:**
  1. Group of diseases - not a single disease
  2. Progressive skeletal muscle degeneration and increase in fat and connective tissue.
  4. Gene Therapy for some forms of MD has begun.

  - Protein called "dystrophin" is either lacking or defective. Dystrophin helps organize the structure of the muscle fiber.

- **Myasthenia Gravis:**
  - Fatigue is rapid.
  - Antibody attack on ______________

- **Botulism:** Botulinum toxin comes from *Clostridium botulinum*, a soil bacterium. The toxin inhibits the release of ACh from motor nerve terminals, causing ______________ paralysis.

- **Tetanus or Lockjaw:** Severe muscle spasms from toxin produced by the bacterium *Clostridium tetani*. Not a direct muscle effect. The toxin blocks inhibitory neurotransmitters in ______________, so motor neurons are inhibited less.

- **Dystrophin & Muscular Dystrophy**

  - **Dystrophin**
    - Located at periphery of muscle cells
    - Duchenne’s MD
    - No Dystrophin

- **Muscular Dystrophy** is a related disease in which dystrophin is present in low amounts.