Chapter 9 - Muscle and Muscle Tissue

I. Overview of muscle tissue

A. Three muscle types in the body:

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>SKELETAL</th>
<th>CARDIAC</th>
<th>SMOOTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body location</td>
<td>Attached to bones or (some facial muscles) to skin</td>
<td>Walls of the heart</td>
<td>Unitary muscle in walls of hollow visceral organs (other than the heart); multi unit muscle in intrinsic eye muscles, airways, large arteries</td>
</tr>
<tr>
<td>Cell shape and appearance</td>
<td>Single, very long, cylindrical, multinucleate cells with obvious striations</td>
<td>Branching chains of cells; uni- or binucleate; striations</td>
<td>Single, fusiform, uninucleate; no striations</td>
</tr>
</tbody>
</table>

B. Special characteristics
   1. Excitability: able to receive and respond to a stimulus
   2. Contractility: ability to shorten
   3. Extensibility: ability to be stretched
   4. Elasticity: ability to resume normal after stretching

C. Functions
   1. Movement
   2. Posture maintenance
   3. Joint stability
   4. Heat generation
II. Skeletal muscle tissue

A. Gross anatomy of skeletal muscle

1. Nerve and blood supply

2. Connective tissue sheaths
   a. Endomysium: *surrounds each muscle cell*
   b. Perimysium: *surrounds fascicle*
      1) Fascicles: *bundles of muscle cells*
         Fascicle (a portion of the muscle)
   c. Epimysium: *envelops the entire muscle*

3. Attachments to bones or other structures
   a. Definitions
      1) Origin: *attachment point to the stationary bone*
2) **Insertion:** attachment point to the moving bone
   b. **Direct attachment:** tendon to the periosteum of a bone
c. **Indirect:** attachment to other connective tissues

B. **Microscopic anatomy of skeletal muscle**
   1. **Sarcolemma:** muscle cell outer membrane
   2. **Sarcoplasm:** special name for cytoplasm of the muscle cell
   3. **Myoglobin**
   4. **Myofiber:** muscle cell

a. **Myofibrils:** rod like protein structures filling the muscle cell

b. **Myofilaments:** protein strands that make up myofibrils
c. Sarcomeres: *small segment of the myofibril*

1) Z-disc: *the ends of sarcomere unit*

2) Myofilaments – 2 types:
   a) Thick filament
b) Thin filament

(1) Tropomyosin: thread-like protein that reinforces thin filaments

(2) Troponin complex: binds to actin, tropomyosin, and calcium

3) Banding pattern: due to myofilament overlap

a) A band

b) I band

c) H zone
5. Sarcoplasmic reticulum (SR): sac-like membrane complex that stores calcium

C. Contraction of a skeletal muscle fiber: the sliding filament model of contraction

1. Requirements
   a. Motor neuron must stimulate muscle cell
   b. Muscle cell must propagate an action potential
   c. Voltage change in sarcolemma opens Ca^{++} gates in S.R.
   d. Ca^{++} floods the sarcoplasm: binds to troponin complex
e. Troponin complex pulls tropomyosin out of way
f. Sequence of events:

2. Diagrams of sarcomeres (described in the stages below)
3. Cross bridge attachment
4. Power stroke
5. Cocking the myosin head

6. Remove calcium

7. Rigor mortis

D. Regulation of contraction
1. Nerve stimulus and the neuromuscular junction
   a. Motor neuron: stimulates muscle cells
   b. Neuromuscular junction: where muscle cell and neuron join (one per muscle cell)

   1) Synaptic cleft: tiny space between neuron and muscle cell
   2) Axonal endings: endings of axon of the motor neuron
   3) Neurotransmitter: chemical that causes transmission of impulse from neuron to muscle cell

   4) Synaptic vesicles: contain neurotransmitter
   5) Events of action potential propagation
      a) Voluntary impulse from the brain
      b) Electrical impulse causes exocytosis of ACh
      c) Receptors on muscle cell bind the ACh
d) Causes flood of Na\(^+\) into muscle cell

e) Electrical impulse causes SR to release all stored Ca\(^{++}\)

f) In mean time, enzyme AChE is rapidly destroying ACh

g) When action potential stops, ACh rapidly destroyed

h) Na\(^+\) gates close causing Ca\(^{++}\) gate closure
6) **Latent period**: period of time between the action potential reaching the synapse and initiation of muscle cell shortening

**E. Contraction of whole muscle**

1. **Motor unit**: motor neuron plus all the muscle cells it innervates
a. Each muscle possesses at least one motor nerve
b. One motor neuron may have 4 to 150 muscle fibers it controls
c. Examples: (Which has the best control over force?)
   1) Muscle A has 1000 motor neurons each attached to a single muscle cell
   2) Muscle B has one motor neuron attached to all 1000 muscle cells

2. The muscle twitch: *the response of whole muscle to a single threshold stimulus*

   ![Diagram of muscle twitch](image)

   a. Threshold: *the minimum stimulus necessary to cause slightest visible motion of the muscle*
   b. Myogram: *the recording of a muscle twitch*
      1) Latent period: *a few msec*
      2) Period of contraction: *30 msec*
      3) Period of relaxation: *100 msec*

3. Graded muscle response: *a smooth gradual increase in muscle force production*
   a. Frequency (wave summation): *2 or more successive stimuli rapidly delivered*
1) **Tetanus:** frequency of stimulation is so great that muscle does not have a chance to relax

b. Recruitment (motor unit summation): increasing the number of motor units activated will increase the force produced

4. **Isometric and isotonic contractions**
   a. Isotonic
   b. Isometric

5. **Muscle fatigue:** mostly due to potassium and calcium imbalances
   a. Lactic acid: glucose is being utilized anaerobically
   b. Oxygen debt: how much O2 is "owed" to restore muscle function

F. **Force velocity and duration of muscle contraction**
   1. Force is affected by:
      a. Number of fibers contracting
      b. Relative size of muscle fibers
      c. Frequency of stimulation
      1) Series elastic elements
      d. Degree of muscle stretch

![Diagram of muscle stretch at 75%, 100%, and 170%](image)

2. Velocity and duration of contraction
   a. Load
   b. Recruitment
   c. Muscle fiber type
d. Proportions of fibers: *all muscles have all 3 types*

3. Effect of exercise on muscle
   a. Aerobic exercise
      1) Increased blood supply, mitochondria, myoglobin
      2) Not much change in cell diameter
   b. Resistance exercise
      1) More myofilaments means larger fiber diameter
      2) More glycogen, connective tissue
   c. Disuse atrophy

**III. Smooth muscle**: *visceral muscle – found in the walls of hollow organs*

A. **Microscopic structure**: *long tapered cells with a single nucleus*
1. Myofilaments
   a. Actin/myosin arranged diagonally
   b. No troponin
   c. No sarcomeres
   d. Intermediate filaments
   e. Dense bodies
      1) Anchors actin and intermediate filaments

2. Diffuse junctions: dump neurotransmitter in general vicinity of muscle cells

B. Contraction of smooth muscle

1. Gap junctions: link single-unit smooth muscle cells together
2. Works similar to a sarcomere
3. Myosin ATPase is 1/10 as active as in skeletal
4. 2 types of NT activate smooth muscle:
   a. ACh: causes contraction
   b. Norepinephrine: causes relaxation when on some cells. contraction when on others

C. Special features of smooth muscle contraction
1. Stress-relaxation response: allows hollow organs to fill slowly without vigorous expulsive contractions
2. No true sarcomeres: allows a wider range of contraction efficiency
3. Hyperplasia: some smooth muscle cells are able to divide

D. Types of smooth muscle
1. Unitary (single unit): the most common type
2. Multiunit: regulated like skeletal muscle