Review

- Review of muscle so we can see how the neuromuscular system works

- This is not on today's note
Skeletal Muscle Cell: Cellular System

• A) Excitation System – Electrical Potential
  • muscle is an excitable tissue
  • sarcolemma (cell membrane)/ T-Tubules
  • action potential

• B) Ca^{2+} Regulation System
  • Sarcoplasmic Reticulum (SR)
  • storage, release, and uptake of Ca^{2+}

• C) Contractile System (Myofibrils)
  • Contractile Proteins (Actin & Myosin)
  • Regulatory Proteins (Troponin & Tropomyosin)
Skeletal Muscle Cell: Cellular System

D) Metabolic (Energy) System

- ATP → ADP + Pi + ENERGY
  - ATPase
- muscle cell needs a constant supply of ATP to contract and produce force.

E) Nucleus (Multinucleated)

- ability to regenerate (Satellite Cells)
- ability to adapt and be eliminated to physiological and environmental stimuli
Fig. 8.2

(a) Skeletal muscle fiber with myofibrils and Z lines separating sarcomeres.

(b) Cross-section of a sarcomere showing the H zone, M line, and Z line.

(c) Enlarged view of the myosin and actin filaments.
Orientation of Thin & Thick Filaments Within Skeletal Muscle

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This is healthy muscle tissue
THIS IS A DAMAGED TISSUE
Thick Filament: Myosin Molecule

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Muscle Fiber Types

**Fast fibers**
- Type IIx (IIb) fibers
  - Fast-twitch fibers
  - Fast-glycolytic fibers
- Type IIa fibers
  - Intermediate fibers
  - Fast-oxidative glycolytic fibers

**Slow fibers**
- Type I fibers
  - Slow-twitch fibers
  - Slow-oxidative fibers
Primary factor that differentiates muscle or muscle fiber types:

- The RATE (speed) of contraction
  - Vmax (maximal rate of shortening)
  - Fast-Twitch (Type II) – IIx > Ila
  - Slow-Twitch (Type I)
- TYPE II > TYPE I
FAST-TWITCH VS. SLOW-TWITCH

FIG 8.15 Powers
Figure 19.13 • Speed, force, and fatigue characteristics of motor units. “Phasic” motor neurons fire rapidly with short bursts; “tonic” motor neurons fire slowly but continuously.
Second factor that differentiates muscle or muscle fiber types:

- FATIGUE Characteristics
  - Fatigue Index
A third factor used to characterized muscle fiber types is the fiber metabolisms.

- **Metabolic Characteristics**
  - Glycolytic
  - Oxidative
  - measure enzyme activities of representative pathways (Glycolysis, Oxidative Phosphorylation)

- Fast-Glycolytic (FG)
- Fast-Oxidative-Glycolytic (FOG)
- Slow-Oxidative (SO)
A fourth factor used to characterize muscle fiber types is the morphological characteristics (form and structure of fiber).

**Morphological Characteristics**

- muscle fiber diameter (size)
- capillary density (muscle blood flow)
- myoglobin content (cellular O2 transport)
- organelle content (SR, Mitochondria)
## Muscle Fiber Types

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Fast fibers</th>
<th>Slow fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type IIb</td>
<td>Type IIa</td>
</tr>
<tr>
<td>Number of mitochondria</td>
<td>Low</td>
<td>High/moderate</td>
</tr>
<tr>
<td>Resistance to fatigue</td>
<td>Low</td>
<td>High/moderate</td>
</tr>
<tr>
<td>Predominant energy system</td>
<td>Anaerobic</td>
<td>Combination</td>
</tr>
<tr>
<td>ATPase activity</td>
<td>Highest</td>
<td>High</td>
</tr>
<tr>
<td>$V_{max}$ (speed of shortening)</td>
<td>Highest</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Specific tension</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Table. 8.1 Powers.
M-ATPase
\[ \text{pH}=4.6 \]

- Type IIa
- Type IIx
- Type I
Training-Induced Changes in Muscle Fiber Type

- Type IIa (+13%)
- Type I (no change)
- Type IIb (-13%)
- The interrelated workings of the nervous system and the muscles to bring about movement

- The brain and spinal cord control skeletal (voluntary) muscles through specialized nerves
Neurons are nerve cells, found in the nervous system.
These are specialized cells designed to stimulate other cells in the body in order to communicate.
Neurons are excitable, which means they function by using electrical stimulation.
Action Potential

- a short-lasting event in which the electrical membrane potential of a cell rapidly rises and falls, following a consistent trajectory
Action Potential

https://www.youtube.com/watch?v=ifD1YG07fB8
NEUROMUSCULAR JUNCTION
(WHERE THE SYNAPSE HAPPENS)
1. Action potential travels down the Axon and depolarizes the axon terminal
2. The depolarization opens voltage gated Ca$^{2+}$ channels and Ca$^{2+}$ enters the cell
NEUROMUSCULAR JUNCTION - STEPS

3. Calcium entry triggers exocytosis of synaptic vessels neurotransmitter (acetylcholine - ACh)
4. Neurotransmitter diffuses across the synaptic cleft and binds on receptors
EXCITATION – CONTRACTION COUPLING

- The physiological process of converting an electrical stimulus to a mechanical response.
- It is the link (transduction) between the action potential generated in the sarcolemma and the start of a muscle contraction.
1. Muscle action potential propagation into – T-tubules
2. $\text{Ca}^{2+}$ released from sarcoplasmic reticulum
3. $\text{Ca}^{2+}$ binds to troponin and removes blocking action for tropomyosin
4. Cross-bridges bind and generate force (muscle shortens)
5. Ca\textsuperscript{2+} taken back up
6, Ca\(^{2+}\) removal from troponin restores tropomyosin blocking agent.
1. Somatic motor neuron releases ACh at neuromuscular junction.

2. Net entry of Na\(^+\) through ACh receptor-channel initiates a muscle action potential.

(a)

- Muscle fiber
- Action potential
- T-tubule
- DHP receptor
- Motor end plate
- Sarcoplasmic reticulum
- Ca\(^{2+}\)
- Tropomyosin
- Troponin
- Actin
- Myosin thick filament
- Myosin head
- M line
- Z disk

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STEPS IN EXCITATION-CONTRACTION (RELAXATION) COUPLING

• Sites of peripheral fatigue (i.e. beyond the neuromuscular junction and in the muscle itself)
A motor unit consists of a motor neuron, axon, and the muscle fibres it stimulates.
Some motor units are attached to just a few muscle fibres while others in large muscles are attached to 100’s

In order to do a one rep max, all motor units must be recruited.
Nerve impulses come in waves.

Single wave and muscle contraction is called a twitch.
MOTOR UNITS

- Slow twitch muscle motor units generally are smaller as they have fewer muscle fibres.
**ALL-OR-NONE PRINCIPLE**

- When a motor unit is stimulated to contract, all the muscle fibres will contract to their fullest potential. Either they all fire or they all don’t fire.
MOTOR UNIT

- motor neuron and the muscle fibers it innervates
- smallest amount of muscle that can be activated voluntarily

- recruitment of motor units is the most important means of controlling muscle force

- To increase force:
  - Recruit more motor units
  - Increase frequency
• **Neural factors**
  - Increased ability to activate motor units
  - Strength gains in initial 4-20 weeks

• **Muscular enlargement**
  - Mainly due enlargement of fibers (hypertrophy)
  - Long-term strength training
HIGH INTENSITY – SHORT DURATION TRAINING

- Nerve–muscle connections
  - Increased recruitment of additional motor units, which respond in a simultaneous fashion to improve force production
  - There is an increased activation of synergistic muscles to assist force production for strength, power, speed and hypertrophy.
HIGH INTENSITY – SHORT DURATION TRAINING

- Nerve–muscle connections
  - Neural pathways linking to target muscles become more efficient at transmitting the message (stimulus).
High Intensity – Short Duration Training

- Timing of Neural Stimulus
  - The timing of contractions becomes more coordinated, especially with power, speed and strength training, in order to meet the force generation required to move loads.
HIGH INTENSITY – SHORT DURATION TRAINING

- Summation of motor units
- The ability to summate (fire a lot of impulses in target muscles all at once) is improved with strength and power training because they require maximum activation of target muscles to create maximum force.
LONGER DURATION TRAINING

- No real neural changes

- As the duration of training lengthens slow twitch (endurance) fibres become increasingly dominant. Aerobic fitness, anaerobic fitness and muscular endurance training all improve the function of slow twitch fibres.