Muscle Physiology
Adapted from Human Physiology with Vernier

Skeletal muscle is composed of bundles of muscle fibers, each of which can receive a stimulus from **somatic motor neurons**. The junction between a muscle fiber and the somatic motor neuron that synapses onto it is called a **neuromuscular junction**. At the neuromuscular junction with skeletal muscles the somatic motor neuron releases the neurotransmitter **acetylcholine (ACh),** which binds to **nicotinic cholinergic receptors** on the muscle fiber (Fig 1). Binding of the receptor with ACh causes an action potential to form in the muscle fiber allowing **calcium (Ca+2)** release from the muscle's **sarcoplasmic reticulum**. At the microscopic level of the muscle there are repeating units called sarcomeres containing myofilaments called **actin** (the thin filament having active sites, troponin, and tropomyosin) and **myosin** (the thick filament). This Ca+2 released from the sarcoplasmic reticulum binds to the protein **troponin**. Binding of troponin allows another protein, **tropomyosin**, to expose **active sites** on the actin. Once active sites on actin are exposed **myosin** grabs onto them and pull on actin (Fig. 2). The pulling of the actin and myosin filaments is the basis for the sliding filament theory of muscle contraction. The sliding filaments cause the muscle fiber to shorten (contract). When muscle fibers respond to ACh stimulation they respond by contracting to their maximum potential. The strength of the muscle contraction depends on the number of individual muscle fibers that are stimulated by a motor neuron. If more muscle fibers are stimulated by a motor neuron a greater contractile force is produced and when fewer muscle fibers are stimulated a lesser contractile force is produced. Once a muscle is contracted it must relax before it can contract again.
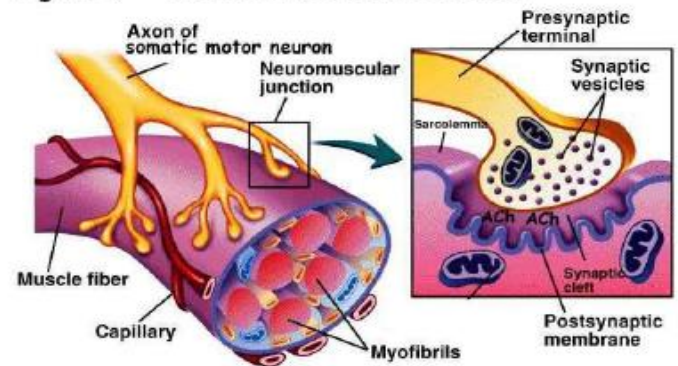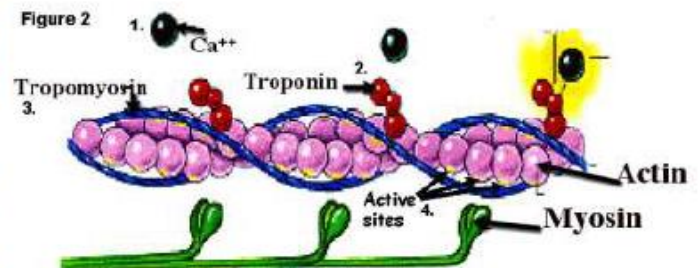

Figure 1   Neuromuscular Junction

Figure 2

Muscles undergo two main types of contractions**: isotonic contraction** (*iso* = same; *tonic* = strength). When you lift your textbook from the table, the force generated by your arm muscles is greater than the force of gravity on the book, and therefore your muscle will shorten and lift the book. An opposing force that is sufficiently large (such as attempting to lift a car off the ground by yourself) will prevent the muscle from shortening even when it is exerting tension. This situation, where muscle tension does not result in muscle shortening, is called an **isometric contraction** (*iso* = same; *metric* = length).

Muscle fatigue occurs with prolonged or repetitive use of a muscle group and is familiar to anyone who has ever carried a heavy suitcase or walked up a long flight of stairs. With fatigue, there is a sense of weakness and even discomfort, which eventually leads one to discontinue the activity that is causing it. The mechanism of fatigue is multifactorial and not fully understood, but is felt to involve the central nervous system, peripheral nervous system, muscle units and individual muscle fibers. At the level of muscle cells, depletion of energy stores may be important. Regular exercise improves muscular function and delays the onset of fatigue, thus increasing the amount and duration of work that can be performed. Exercise is important for optimal athletic performance, prevention of injury in athletes and non-athletes, and the maintenance of good general

health. In this experiment, you will examine the effect of fatigue on muscle action by performing sustained and repetitive isometric contractions of muscles of the arm and hand using a Vernier Hand Dynamometer.

Important: Inform your instructor of any possible health problems (arthritis, carpal tunnel syndrome) that might be exacerbated if you participate in this exercise.

PART 1: Grip Strength Comparison Between Dominant and Non-Dominant Hands

1. Have the subject sit with back straight and feet flat on the floor. The elbow should be at a right angle and arm unsupported as shown in Figure 3. The hand dynamometer should be held in the non-dominant hand as shown in Figure 4. Eyes should be closed or averted – the subject may not look at the computer screen!
2. Under the "Experiment" tab, set the data collection time to 10 seconds.
3. Have the subject grasp the hand dynamometer as tightly as possible.
4. Click on the green arrow on the upper screen to start data collection.
5. After 10 seconds, data collection will stop.
6. Position the cursor at 0 s on the graph. Click and drag to highlight the 0-10 seconds segment of the graph. Click the "stats" tab at the top of the screen.
7. Record the mean force in table 1.
8. REPEAT procedures in 1-7 for the dominant hand.
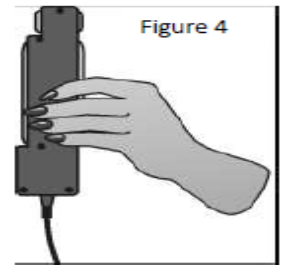9. Repeat for each member in the group.

Figure 3

Figure 4

PART 2: Pinch Strength Comparison – Dominant Hand

1. Have the subject sit as for the previous exercise (Figure 3). The pinch end of the hand dynamometer should be held with the index finger and thumb of the dominant hand (Figure 5). Eyes should be closed or averted – subject may not look at the computer screen!
2. Under the "Experiment" tab, set the data collection time to 10 seconds.
3. Have the subject pinch the hand dynamometer as tightly as possible.
4. Click on the green arrow on the upper screen to start data collection.
5. After 10 seconds, data collection will stop.
6. Position the cursor at 0 s on the graph. Click and drag to highlight the 0-10 seconds segment of the graph. Click the "stats" tab at the top of the screen.
7. Record the mean force in the data table for grip strength comparison.
8. Repeat the procedure in 1-7 for your middle finger and thumb.
9. Repeat the procedure in 1-7 for your ring finger and thumb.
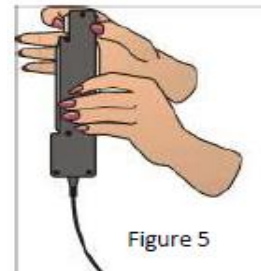10. Repeat the procedure in 1-7 for your pinky finger and thumb.

Figure 5

Table 1. Grip Strength Comparison

10 second test	Mean Force (N)
PART 1: Dominant hand grip strength	
PART 1: Non-dominant hand grip strength	
PART 2: Dominant hand index finger pinch strength	
PART 2: Dominant hand middle finger pinch strength	
PART 2: Dominant hand ring finger pinch strength	
PART 2: Dominant hand little finger pinch strength	

PART 3: Muscle fatigue with continuous grip (100 sec of continuous holding!)

1. Have the subject sit as for the previous exercises. The hand dynamometer should be held with the dominant hand, elbow at a right angle, arm unsupported, eyes closed or averted – **subject may not look at the computer screen!**
2. Under the "Experiment" tab, set the data collection time to 100 seconds.
3. Instruct the subject to grip the sensor with full strength and click the green arrow at the top of the screen to begin data collection. The subject should exert maximum effort throughout the data collection period.
4. **At 80 seconds, the group should encourage the subject to grip even harder.** Data collection will stop after 100 seconds. This is analogous to "cheerleading" for your partner. What we want to see is if encouragement helps the subject overcome muscle fatigue in the last 20 seconds of the experiment.
5. Analyze and record statistical information:
a. Position the cursor at 0 seconds on the graph. Click and drag to highlight the 0-20 seconds segment of the graph. Click the "stats" tab at the top of the screen.
b. Record the the mean force for that interval in Table 2.
c. Click the "X" in the statistics box to close the box, and click once on the graph to remove the highlighted section.
d. Repeat steps a-c for the 20-40, 40-80, 60-80, and 80-100 second intervals.
6. Optional: Calculate the change in mean for each time interval by subtracting the mean grip strength of the previous interval from the mean grip strength of the current interval. A negative change in mean indicates the average force of the current interval is less than the average force during the previous interval.

Table 2. Muscle Fatigue Comparison

100 second test	Time Interval	Mean grip strength (N)	Change (Δ) in mean
PART 3: Continuous grip strength without visual feedback	0-20 s		
	20-40 s		
	40 -60 s		
	60-80 s		
	80-100 s		