



Human Physiology Experiments



HSB-HP



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Equipment Used in Experiments

		EKG	Force	Hand Dynamometer	Heart Rate	Oxygen Gas	Respiration	Surface Temperature
1	Body Temperature							X
2	Limb Position and Grip Strength			X				
3	Introduction to Electromyography	X		X				
4	Simple Neuromuscular Reflexes	X	X*					
5	Balance		X					
6	Homeostasis and Autonomic Reflexes				X			
7	Effect of Exercise on Heart Rate				X			
8	Introduction to Electrocardiography	X						
9	Blood Flow and Skin Temperature							X
10	Respiration and Ventilation						X	
11	Ventilation and Heart Rate				X		X	
12	Oxygen Extraction During Respiration					X		
13	Effect of Exercise on Oxygen Usage					X**		
14	Heart Rate and Calories				X			

* Requires the Reflex Hammer Accessory Kit (order code: RFX-ACC)

** Requires the BioChamber 250 (order code: BC-250)

Simple Neuromuscular Reflexes

The automatic response of a muscle to a stimulus is called a reflex. The patellar reflex can be initiated by tapping the patellar tendon below the knee with a reflex hammer. The tap on the tendon stretches the muscle, activating a stretch receptor that sends nerve impulses to the spinal cord. In the spinal cord, the incoming impulses activate motor neurons that travel back to the muscle and result in a contraction of the quadriceps muscle and extension of the leg. This reflex arc is primarily a spinal reflex, but is influenced by other pathways to and from the brain (Figure 1).

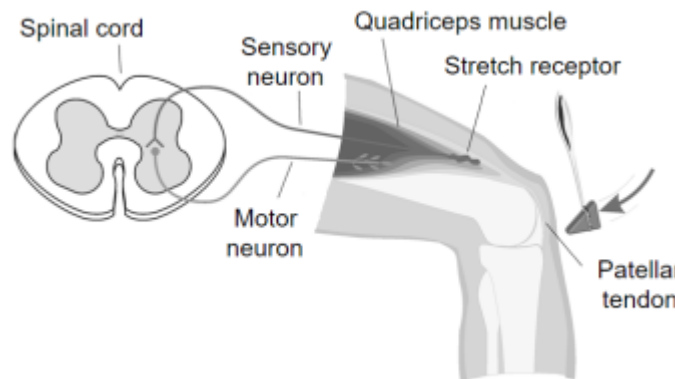


Figure 1

A reflex may be *reinforced* (a term used by neurologists) by slight voluntary contraction of muscles other than the one being tested. For example, voluntary activation of arm muscles by motor neurons in the central nervous system “spills over” to cause a slight activation of the leg muscles as well. This results in the enhancement of the patellar reflex. There are other examples of central nervous system influences on reflexes. Health care professionals use knowledge of these influences to aid in diagnosis of conditions such as acute stroke and herniated lumbar disk, where reflexes may be absent; and spinal cord injury and multiple sclerosis, which may result in exuberant reflexes.

In this experiment, you will use an EKG sensor to compare the speed of a voluntary muscle action versus a reflex muscle action as well as to measure the relative strength (amplitude) of the impulse generated by a stimulus with and without reinforcement. Using data generated by a force sensor mounted on a reflex hammer in conjunction with the EKG sensor, you will make a calculation of nerve impulse speed.

OBJECTIVES

- Graph the electrical activity of a muscle activated by a reflex arc through nerves to and from the spinal cord.
- Compare the relative speeds of voluntary and reflex muscle activation.
- Associate muscle activity with involuntary activation.
- Observe the effect of central nervous system influence on reflex amplitude.

Simple Neuromuscular Reflexes

- Calculate the approximate speed of a nerve impulse.
- Compare reflex response and electrical amplitude in different subjects.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct EKG
Go Direct Force and Acceleration
Reflex Hammer Accessory Kit
electrode tabs
cloth tape
measure
pen

PROCEDURE

Select one person from your lab group to be the subject. **Important:** Do not attempt this experiment if you have pain in or around the knee. Inform your instructor of any possible health problems that might be exacerbated if you participate in this exercise.

Part I Voluntary activation of the quadriceps muscle

1. Attach the Reflex Hammer Accessory Kit to the Go Direct Force and Acceleration (see Figure 2) according to the assembly instructions.
2. Connect and set up the sensors.
 - a. Launch Graphical Analysis.
 - b. Connect Go Direct EKG to your Chromebook, computer, or mobile device.
 - c. Click or tap Sensor Channels. Deselect the EKG channel and select the EMG Rectified channel.
 - d. Connect Go Direct Force and Acceleration to your Chromebook, computer, or mobile device. The default channel is correct for this experiment.
 - e. Click or tap Done.
 - f. Click or tap the Force meter and enable Reverse. Dismiss the menu; this will switch the coordinate system so a press on the force sensor hook will generate positive force values.
3. Set up the data-collection mode.
 - a. Click or tap Mode to open data-collection settings.
 - b. Change Rate to 100 samples/s and End Collection to 30 s.
 - c. Click or tap Done.
4. Have the subject sit comfortably in a chair that is high enough to allow his or her legs to dangle freely above the floor.

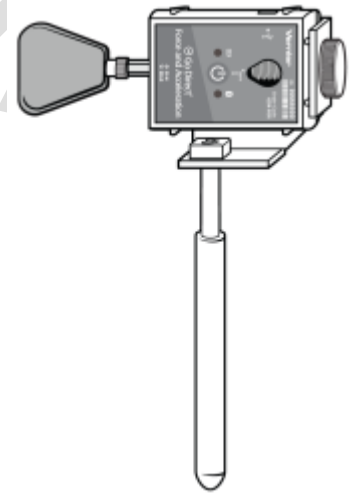


Figure 2

5. Attach two electrode tabs above one knee along the line of the quadriceps muscle between the knee and the hip (see Figure 3). The tabs should be 5 cm and 13 cm from the center of the patella. Place a third electrode tab on the lower leg.
6. Attach the red and green EKG leads to the electrode tabs above the knee with the red electrode closest to the knee. Attach the black lead (ground) to the electrode tab on the lower leg.

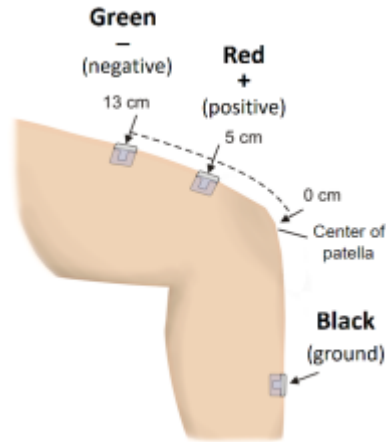


Figure 3

7. Click or tap Collect to start data collection. If the graph has a stable baseline as shown in Figure 4, click or tap Stop to stop data collection and continue to Step 8. If your graph has an unstable baseline, click or tap Stop and collect a new set of data by clicking or tapping Collect. Repeat data collection until you have obtained a stable baseline for 5 s. **Note:** The previous data set is automatically saved each time.

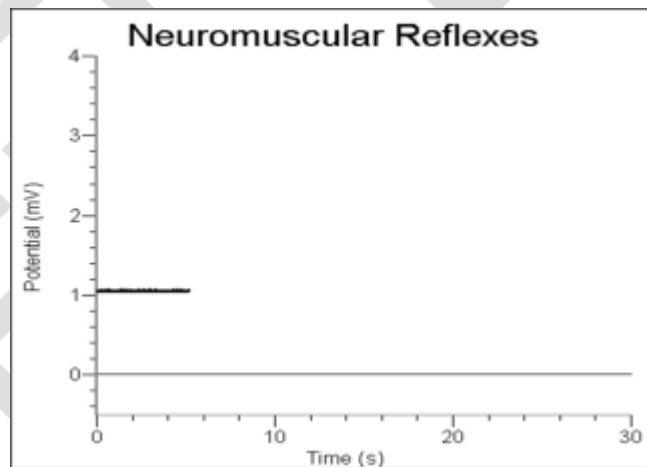


Figure 4

8. Collect voluntary muscle activation data. **Note:** Read the entire step before collecting data to become familiar with the procedure.
 - a. Have the subject close his or her eyes, or avert them from the screen.
 - b. Click or tap Collect to start data collection.
 - c. After recording 5 s of stable baseline, swing the reflex hammer briskly to contact the table or other surface that generates a sound.

Simple Neuromuscular Reflexes

- d. The subject should kick his or her leg out immediately upon hearing the sound.
 - e. Continue obtaining reflexes (repeat parts c and d of this step) so that you record 5 to 10 kicks during the data-collection period.
9. Determine the time elapsed between striking the table surface with the reflex hammer and the contraction of the quadriceps muscle.
- a. On the force graph, click or tap the first peak (which corresponds to the first kick). This peak indicates the time at which the table surface was struck. Record this time in Table 1.
 - b. On the EMG graph, click or tap the first high peak (Kick 1). This peak indicates the time at which the quadriceps muscle contracted. Record this time in Table 1.
 - c. Repeat this process of determining the time of the hammer strike and reflex for a total of five stimulus-kick pairs.
 - d. Calculate the change in time between the hammer strike and reflex for the five stimulus-kick pairs and then calculate the average change in time for all five pairs. Record the values in Table 1.

Part II Patellar reflex

10. Locate the subject's patellar tendon by feeling for the narrow band of tissue that connects the lower aspect of the patella to the tibia. Use a pen to mark a horizontal line in the center of the tendon (see Figure 5). The tendon can be identified by its softness compared with the bones above and below.



Figure 5

11. Click or tap Collect to start data collection. If your graph has a stable baseline as shown in Figure 4, click or tap Stop and continue to Step 12. If your graph has an unstable baseline, click or tap Stop and repeat data collection until you have obtained a stable baseline for 5 s.
12. Collect patellar reflex data. **Note:** Read the entire step before collecting data to familiarize yourself with the procedure.
- a. Have the subject close his or her eyes or avert them from the screen.
 - b. Click or tap Collect to start data collection.
 - c. After recording 5 s of stable baseline, swing the reflex hammer briskly to contact the mark on the subject's tendon. If this does not result in a visible reflex, aim toward other areas of the tendon until the reflex is obtained.

- d. Continue obtaining reflexes so that you record 5 to 10 reflexes during the collection period. If necessary, repeat this step until you have a data set with 5–10 reflexes.
13. Determine the time elapsed between striking the patellar tendon with the reflex hammer and the contraction of the quadriceps muscle.
 - a. On the force graph, click or tap the first peak (which corresponds to the first kick). This peak indicates the time at which the tendon was struck. Record this time in Table 2.
 - b. On the EMG graph, click or tap the first high peak (Kick 1). This peak indicates the time at which the quadriceps muscle contracted. Record this time in Table 2.
 - c. Repeat this process of determining the time of the hammer strike and reflex for a total of five stimulus-kick pairs.
 - d. Calculate the change in time between the hammer strike and reflex for the five stimulus-kick pairs and then calculate the average change in time for all five pairs. Record the values in Table 2.


Part III Reflex reinforcement

14. With the subject sitting comfortably in a chair, start data collection. If your graph has a stable baseline, click or tap Stop and continue to Step 15. If your graph has an unstable baseline, click or tap Stop and repeat data collection until you have obtained a stable baseline for 5 s.
15. Collect patellar reflex data without and with reinforcement. **Note:** Read the entire step before collecting data to familiarize yourself with the procedure.
 - a. Have the subject close his or her eyes or avert them from the screen.
 - b. Click or tap Collect to start data collection.
 - c. After recording a stable baseline for 5 s, swing the reflex hammer briskly to contact the mark on the subject's tendon. If this does not result in a visible reflex, aim toward other areas of the tendon until the reflex is obtained.
 - d. After 5 or 6 successful reflexes have been obtained, have the subject *reinforce* the reflex by hooking together his/her flexed fingers and pulling apart at chest level, with elbows extending outward (see Figure 6).
 - e. Continue obtaining reflexes until data collection is completed at 30 s. A total of 10–15 reflexes should appear on the graph.



Figure 6

Simple Neuromuscular Reflexes

16. Determine the minimum, maximum, and Δy for the depolarization events.
 - a. Select the first area of increased amplitude (depolarization) on the EMG graph (see Figure 7).
 - b. Click or tap Graph Tools, , on the EMG graph and choose View Statistics.
 - c. Record the minimum and maximum for this depolarization in Table 3, rounding to the nearest 0.01 mV.
 - d. Determine and record the Δy value (amplitude) as the ΔmV .

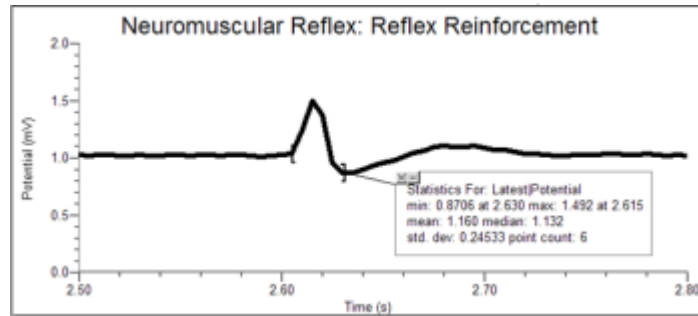


Figure 7

17. Repeat this process for each of five *unreinforced* and five *reinforced* depolarization events, using the EMG graph to identify each primary reflex. Ignore rebound responses. Record the appropriate values in Table 3.
18. Determine the average amplitude of the reinforced and unreinforced depolarization events examined. Record these values in Table 3.

DATA

	Kick 1	Kick 2	Kick 3	Kick 4	Kick 5	Average
Time of muscle contraction (s)						
Time of stimulus (s)						
Δt (s)						

	Reflex 1	Reflex 2	Reflex 3	Reflex 4	Reflex 5	Average
Time of muscle contraction (s)						
Time of stimulus (s)						
Δt (s)						

Reflex response	Reflex without reinforcement			Reflex with reinforcement		
	Max (mV)	Min (mV)	ΔmV	Max (mV)	Min (mV)	ΔmV
1						
2						
3						
4						
5						
Average values						

DATA ANALYSIS

1. Compare the reaction times between voluntary and involuntary activation of the quadriceps muscle. What might account for the observed differences in reaction times?
2. Using data from Table 2, calculate speed at which a stimulus traveled from the quadriceps muscle to the spinal cord and back to the quadriceps muscle (a complete reflex arc). To do this, you must estimate the distance traveled. Using a cloth tape measure, measure the distance in centimeters (cm) from the mark on the patellar tendon to the spinal cord at waist level (straight across from the anterior-superior iliac spine—see Figure 8). Multiply the distance by two to obtain the approximate total distance traveled in the reflex arc. Once this value has been obtained, divide by the average Δt from Table 2 and divide by 100 to obtain the speed, in m/s, at which the stimulus traveled.

Simple Neuromuscular Reflexes

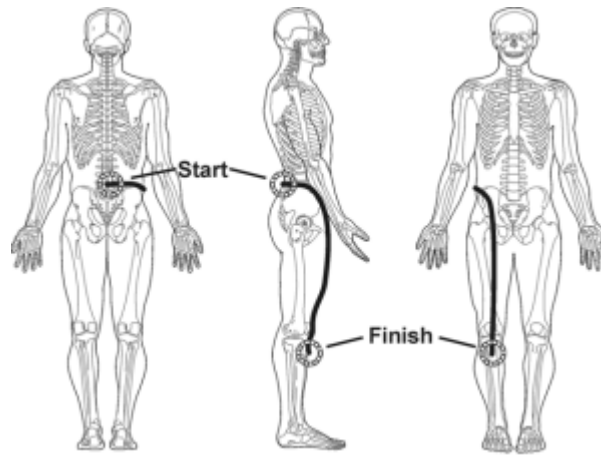


Figure 8

3. Nerve impulses have been found to travel as fast as 100 m/s. What could account for the difference between your answer to Question 2 and this value obtained by researchers?
4. Assume the speed of a nerve impulse is 100 m/s. How does this compare to the speed of electricity in a copper wire (approximately 3.00×10^8 m/s)?
5. Compare the data you obtained in this experiment with other members of your group/class. Can individual differences be attributed to any physical differences (e.g., body shape/size, muscle mass, physical fitness level)?

EXTENSIONS

1. Explore the Achilles tendon and brachioradialis reflexes.
2. Perform the experiment with the subject watching the reflex hammer as it hits the patellar tendon. Compare this data to data gathered while the subject is focusing on an object elsewhere in the room.

Blood Flow and Skin Temperature

Homeostasis refers to the body's ability to maintain internal conditions (e.g., temperature, pH, hydration) within the narrow limits that are optimal for the continuation of metabolic processes. When these optimal conditions are disturbed by a change in the environment, body systems work to return them to normal.

Many of the chemical reactions and cellular processes necessary to sustain human life occur most readily at a body temperature of approximately 37.0°C (98.6°F). Homeostatic mechanisms work to maintain this temperature, regardless of changes in the external environment. Changes in temperature are sensed by the skin, which is well designed to counteract these changes. Beneath the protective epidermal layer of the skin lies the dermis, which contains sweat and oil glands and a rich blood supply (see Figure 1).

The dermal tissues influence body temperature by either allowing or diverting the flow of blood to the surface of the skin. When an area is exposed to the cold, small arterioles in the dermis constrict, reducing blood flow to that area and protecting core body temperature. When cold is removed, the blood supply to the skin increases again as the arterioles dilate.

Exposure to heat also causes blood vessels to dilate, allowing heat to dissipate from the skin's surface, and resulting in a flushed or red appearance. Other examples of the regulation of body temperature through the action of the skin's blood supply include the dilatation seen with embarrassment and the constriction and resulting paleness that occurs with fear. Dilatation also occurs with the ingestion of alcohol.

Human skin temperature is maintained at approximately 33°C (91°F). This temperature can be referred to as the skin temperature *set point*. Regions of skin with higher *vascularity* (containing more blood vessels) will return more quickly to the set point after a disturbance than regions with less vascularity. In this experiment, you will compare the rate of recovery from cold in two different skin regions and draw conclusions about the vascularity of these areas.

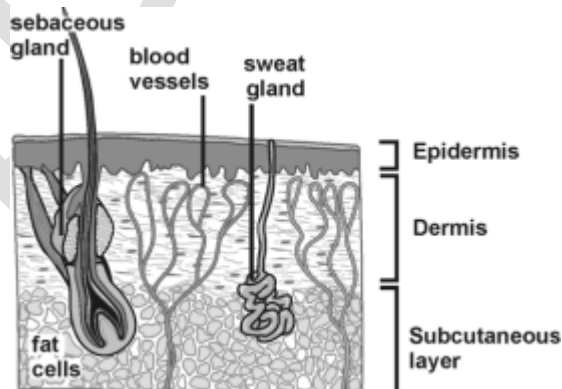


Figure 1

Blood Flow and Skin Temperature

OBJECTIVES

- Compare the rate of recovery from cold in two different skin regions.
- Correlate rate of recovery with vascularity.

MATERIALS

Chromebook, computer, **or** mobile device
Graphical Analysis 4 app
Go Direct Surface Temperature
tape
ice
soap and water or rubbing alcohol
towel (paper or cloth)

PROCEDURE

Important: Inform your instructor of any possible health problems that might be exacerbated if you participate in this exercise.



Part I Temperature recovery by skin of upper arm

1. Launch Graphical Analysis. Connect Go Direct Surface Temperature to your Chromebook, computer, or mobile device.
2. Set up the data-collection mode.
 - a. Click or tap Mode to open Data Collection Settings.
 - b. Change End Collection to 120 s.
 - c. Click or tap Done.
3. Remove excess oil from the skin over the biceps brachii with soap and water or alcohol. Tape the temperature sensor to the upper arm, over the area of the biceps. Be sure to tape the thermistor end (the tip) of the sensor directly to the arm (see Figure 2).



Figure 2

4. Click or tap Collect to start data collection. Collect data for 50 s to obtain a baseline recording of the temperature. Click or tap Stop to stop data collection after 50 s.

5. Determine the baseline temperature.
 - a. Examine the graph and identify the region of the graph where the temperature was constant (baseline region).
 - b. Select the data in the baseline region of the graph.
 - c. Click or tap Graph Tools, , and choose View Statistics.
 - d. Record the mean temperature value in your data table as the baseline temperature.
6. Remove the temperature sensor from the arm. Obtain a piece of ice and hold the ice over the area of the upper arm to which the sensor was affixed. Hold the ice cube in place for 30 s.
7. Remove the ice and quickly blot the area dry with a towel. **Important:** Do not rub as friction can cause an increase in skin temperature.
8. Tape the sensor to the upper arm again, in the same area of the biceps where the ice was held.
9. Click or tap Collect to start data collection. Data will be collected for 120 s.
10. Determine the rate of recovery.
 - a. Select the data collected from 0–50 s.
 - b. Click or tap Graph Tools, , and choose Apply Curve Fit.
 - c. Choose Linear as the Curve Fit. Click or tap Apply.
 - d. Record the slope, m , in Table 1.

Part II Temperature recovery by facial skin

11. Tape the temperature sensor to the face, below the cheek bone, approximately 3 cm from the corner of the mouth, looping the sensor wire over the ear for stability (see Figure 3). Remove excess oil from the skin with soap and water or alcohol to improve the adhesion of the tape to the skin. Be sure to tape the thermistor end (the tip) of the sensor directly to the cheek.

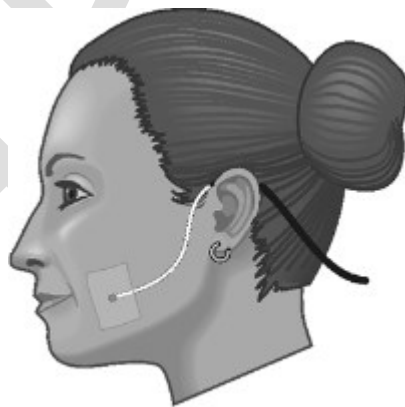



Figure 3

12. Click or tap Collect to start data collection. Collect data for 50 s to obtain a baseline recording of the temperature. Determine the baseline temperature and record the value in Table 1.

Blood Flow and Skin Temperature

13. Remove the temperature sensor from the face. Obtain a piece of ice and hold the ice over the area of the cheek to which the sensor was affixed. Avoid placing the ice cube on the cheek bone, as this may cause headache. Hold the ice cube in place for 30 s.
14. Remove the ice and quickly blot the area dry with a towel. **Important:** Do not rub as friction can cause an increase in skin temperature.
15. Tape the sensor to the face again, in the same area where the ice was touching.
16. Click or tap Collect to start data collection. Data collection will continue for 120 s.
17. Determine the rate of recovery.
 - a. Select the data collected from 0–50 s.
 - b. Click or tap graph Tools, , and choose Apply Curve Fit.
 - c. Select Linear as the Fit Equation. Click or tap Apply.
 - d. Record the slope, m , in Table 1.

DATA

	Baseline temperature (°C)	Slope, or rate (°C/s)
Part I: Upper arm		
Part II: Cheek		

DATA ANALYSIS

1. Is the baseline temperature recovered within the 2 minutes during which data were collected? Estimate how long it would take for full recovery to be achieved for each of the two parts. Relate this to everyday experiences where you have been exposed to cold.
2. Which area of skin tested (upper arm or face) had the most rapid recovery of temperature after cooling? Explain this result.
3. Alcohol causes dilatation of arterioles and a sensation of warmth. Would you recommend that someone who is stranded in the snow drink alcohol to keep warm? Why or why not?
4. A condition called hyperthermia (heat prostration) can result when the body's homeostatic mechanisms are no longer adequate to counter the effect of high external temperatures. On the basis of what you know about vasoconstriction and vasodilation as methods of temperature regulation in the body, describe the skin color of someone who is in the first stages of hyperthermia.

EXTENSIONS

1. Perform the procedure on different areas of the body (i.e., over large muscles, such as the thigh and calf muscles; over areas with little subcutaneous fat, such as the palm, kneecap, and shin; or extremities (hands and fingers). Compare your results with the result obtained in the original experiment.
2. Perform the procedure placing a blanket over the area on which the sensor is attached. Does this alter the recovery time?