Exercise 16

Human Reflex Physiology

Laboratory Objectives

On completion of the activities in this exercise, you will be able to:

- Describe the organization of the motor homunculus.
- List the fiber connections between the cerebellum and other parts of the central nervous system.
- Describe the function of the cerebellum.
- Indicate why reflexes are important to day-to-day functioning.
- Assess basic functions of coordination and balance.
- Describe the function of each element of the reflex arc.
- Perform spinal reflex tests for the upper and lower extremities.

Materials

- Reflex hammers
- Chalk
- Labeling or masking tape

Motor neurons in the precentral gyrus of the frontal lobe initiate all voluntary motor function. This region, known as the **primary motor area**, can be divided into body regions represented by a **motor homunculus** that illustrates the correspondence between the cortical regions and the body parts it controls (Figure 16.1). The organization of the motor homunculus is related to the number of motor units that are present in muscles, not the size of the body region. For example, the muscles of the hands and face contain many small motor units that make complex and specific motor skills possible, so the motor areas that control these body regions are relatively large. Conversely, the motor area that controls the more expansive torso of the body is relatively small, because the muscles in this area contain larger but fewer motor units that are designed for less specific functions.

The descending motor pathways, which originate in the primary motor area, descend through the brainstem and spinal cord before distributing motor fibers to cranial and spinal nerves. Since most descending pathways cross over to the opposite side either in the brainstem or spinal cord, the motor area on the right side of the brain directs motor function on the left side of the body, and vice versa.

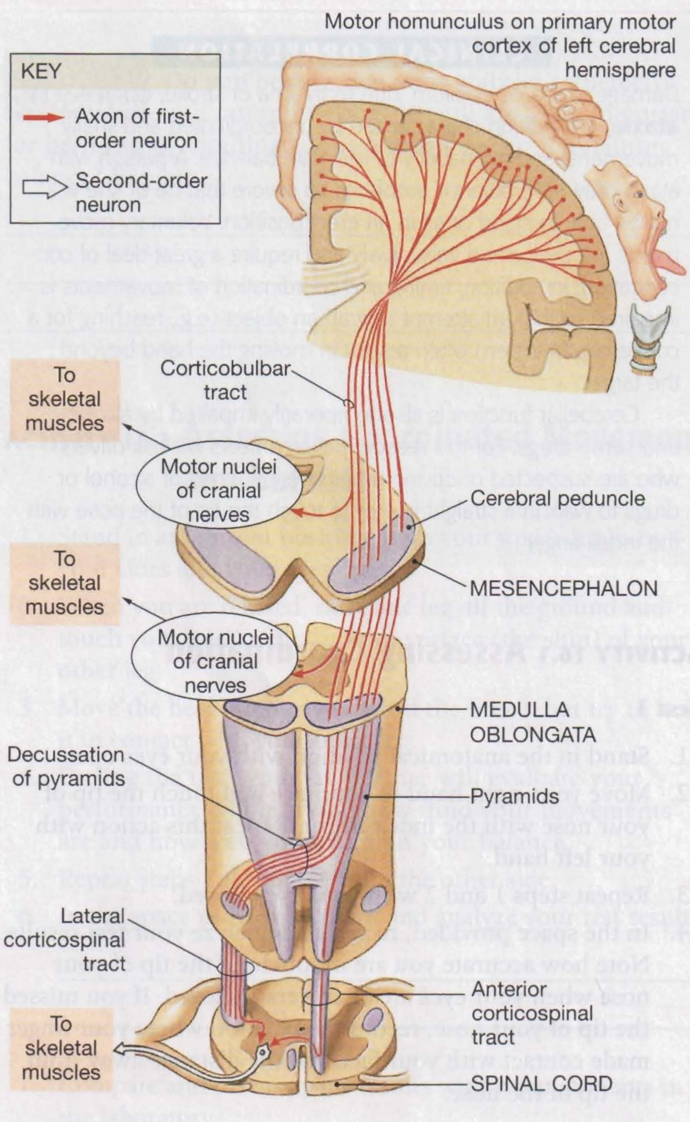

Figure 16.1 Descending motor pathways. The pathways begin in the primary motor area in the precentral gyrus of the frontal lobe and travel to the brainstem or spinal cord. Note the body parts map (motor homunculus) in the primary motor area and the crossing over of the motor fibers.

Coordinated Movement and Balance

The cerebellum interacts with the motor areas by ensuring that all movements are smooth and well coordinated. It receives inputs for motor commands from the cerebrum, for equilibrium (balance) from the inner ear, for visual stimuli from the retinas of the eyes, and for proprioception (body position in space) from receptors called proprioceptors in muscles and joints. After analyzing this input, the cerebellum sends information that fine-tunes the motor activity back to the cerebrum. Thus, normal cerebellar function gives us the ability to maintain normal balance and posture, and allows us to perform highly specialized motor functions (e.g., playing a musical instrument, typing on a keyboard, climbing a ladder) gracefully and efficiently.

WHAT'S IN A WORD The term *proprioception* is derived from two Latin words: *proprius*, meaning "one's own," and *capio*, meaning "to take." Proprioception is a general sensory awareness of the position and movement of one's own body parts. ■

CLINICAL CORRELATION

Damage to the cerebellum, due to trauma or stroke, can result in **ataxia,** a condition characterized by uncoordinated and shaky movements and an inability to maintain balance. A person with ataxia may have balance problems so severe that he or she will not be able to stand or sit in an erect position. Voluntary movements are performed very slowly and require a great deal of concentration. In addition, timing and coordination of movements is impaired so that an attempt to grab an object (e.g., reaching for a coffee cup or a pen) often results in moving the hand beyond the target.

Cerebellar function is also temporarily impaired by alcohol and some drugs. For this reason, police officers will ask drivers who are suspected of driving under the influence of alcohol or drugs to walk in a straight line or to touch the tip of the nose with the index finger.

ACTIVITY 16.1 Assessing Coordination

Test 1

1. Stand in the anatomical position with your eyes open.
2. Move your right hand to your face and touch the tip of your nose with the index finger. Repeat this action with your left hand.
3. Repeat steps 1 and 2 with your eyes closed.
4. In the space provided, record and analyze your test results. Note how accurate you are in touching the tip of your nose when your eyes are open versus closed. If you missed the tip of your nose, record the position where your finger made contact with your face and the distance away from the tip of the nose.

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Test 2

1. Stand in the anatomical position with your eyes open.
2. Abduct your upper extremities so that they are parallel to the floor.
3. With each index finger extended, move your upper extremities forward and attempt to bring the fingertips together.
4. Repeat steps 1 through 3 with your eyes closed.
5. In the space provided, record and analyze your test results. Note the accuracy in your ability to touch your fingertips with your eyes open versus closed. If your fingertips do not make contact, record the distance between the two fingers as they pass by each other.

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QUESTIONS TO CONSIDER

1. Discuss the importance of visual stimuli in performing the tests in Activity 16.1.

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2. When your eyes are closed, what other sensory stimuli do you rely on to successfully complete the exercises?

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3. When your eyes are closed, is it more or less difficult to perform the exercises? Explain.

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4. Compare and discuss your results with the results of other students in the laboratory.

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ACTIVITY 16.2 Assessing Balance

Test 1

1. With tape, mark off a line along the floor that is 6 m (20 ft) in length.
2. With your eyes open, walk slowly along the tape, heel to toe, without losing your balance. Have your lab partner record the time that it takes to walk the entire length of the tape.
3. Repeat step 2 several times, increasing your speed for each turn. Record the time after each turn. Stop the test when you no longer can maintain your balance.

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4. Repeat steps 2 and 3 with your eyes closed. Record the time at each turn. (*Important: For safety, two people should*

remain to the sides of the subject to act as spotters while he or she performs this activity.)

5. Compare and discuss your results with the results of other students in the laboratory.

Test 2

1. Draw a vertical line on a chalkboard, or position a piece of tape in a vertical line on a wall in the laboratory.
2. Stand in an erect position, adjacent to the chalk or tape line, with your upper limbs by your sides and your eyes open. Remain standing for at least 2 minutes.
3. Your laboratory partner will time the exercise and record any body movements that you make during the test. Use the chalk or tape line as a reference position for recording movements.
4. When the 2-minute period is completed, sit comfortably for a short time.
5. When you are rested and comfortable, stand in an erect position, adjacent to the vertical reference line, but this time close your eyes. Remain standing for 2 minutes.
   Form a Hypothesis **Before you begin, make a prediction about the results.**
6. Your laboratory partner should, once again, note any body movements that you make during the test.
7. **Assess the Outcome** **Make comparisons of the results from the two tests. In particular, contrast the number and type of movements that were made and note any evidence that a loss of balance had occurred when the eyes were open versus closed. Did your results support or refute your hypothesis?**
8. Compare and discuss your results with those of others in the laboratory.

QUESTION TO CONSIDER Do you believe that your abilities to perceive and interpret visual stimuli are more important for performing coordinated movements or for maintaining balance? Explain.

ACTIVITY 16.3 Assessing Coordinated Movement and Balance

1. Stand in an upright position, with your upper limbs by your sides and your eyes open.
2. When you are relaxed, raise one leg off the ground and touch your heel to the anterior surface (the shin) of your other leg.
3. Move the heel inferiorly (toward the floor), but try to keep it in contact with your other leg.
4. During the test, your lab partner will evaluate your performance by observing how fluid your movements are and how well you maintain your balance.
5. Repeat steps 1 through 4 from the other side.
6. In the space provided, record and analyze your test results.
7. Compare and discuss your results with other students in the laboratory.

QUESTION TO CONSIDER Discuss why well-coordinated muscle contractions and maintenance of balance and posture are important for performing complex actions (e.g., dancing, running, climbing).

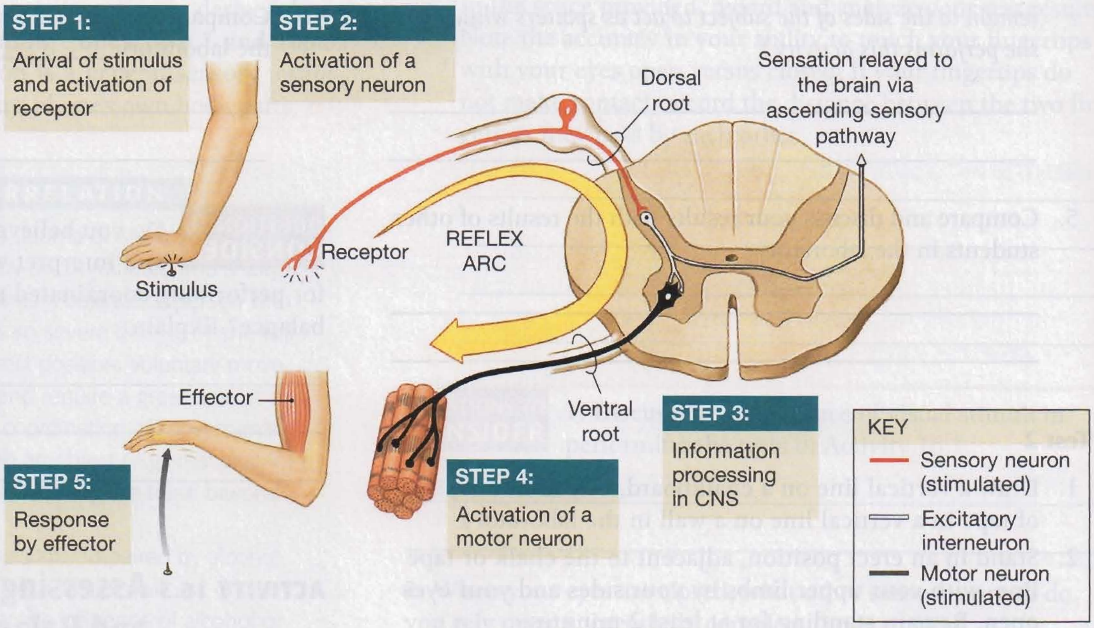

Figure 16.2 The components of a reflex arc. Step 1: A sensory receptor responds to a stimulus. **Step 2:** A sensory neuron transmits sensory impulses to the CNS. **Step 3:** An integration center in the CNS (either the spinal cord or the brainstem) receives and transfers sensory information to a motor neuron. **Step 4:** A motor neuron transmits motor impulses to an effector organ. **Step 5:** An effector organ receives motor impulses and acts in response to the stimulus. Effector organs can be muscle fibers (skeletal, smooth, or cardiac muscle) or glands.

The Reflex Arc

A **reflex** is an automatic, involuntary response to a change that can occur inside or outside the body. Many reflexes play a critical role in protecting the body by regulating homeostasis. The neuronal pathway of a reflex, known as a **reflex arc**, contains five elements (Figure 16.2).

- **Sensory receptor** that responds to a stimulus
- **Sensory neuron** that delivers sensory impulses to the CNS
- **Integration center** in the CNS (either the spinal cord or the brainstem) where the sensory information is received and transferred to motor neurons
- **Motor neuron** that delivers motor impulses from the CNS to an effector organ
- **Effector organ** that receives motor impulses and acts in response to the stimulus; effector organs can be muscle fibers (skeletal, smooth, or cardiac muscle) or glands

Reflexes are classified according to the location of the integration center, the type of effector organ that is activated, and the number of synapses between the sensory and motor neurons in the reflex arc. Table 16.1 identifies the various types of reflexes based on these criteria.

Assessing the Function of Spinal Reflexes: The Reflex Arc

The spinal reflexes that you will observe in the laboratory are examples of **stretch reflexes** (Figure 16.3a). They involve the activity of receptors called **muscle spindles** that are embedded between muscle fascicles in skeletal muscles. When a muscle is stretched, muscle spindles are elongated. As a result, a reflex muscle contraction will occur, and excessive stretching of the muscle will be prevented.

Table 16.1 Classification of Nerve Reflexes

Criterion	Type of reflex
A. Location of integration center	
1. Brainstem	Cranial reflex
2. Spinal cord	Spinal reflex
B. Type of effector organ	
1. Skeletal muscle	Somatic reflex
2. Cardiac muscle, smooth muscle, glands	Visceral reflex
C. Number of synapses between sensory and motor neurons in the reflex arc	
1. One synapse (sensory neuron synapses directly with motor neuron)	Monosynaptic reflex
2. Two or more synapses (one or more interneurons intervene between the sensory and motor neurons)	Polysynaptic reflex

Other spinal reflexes include the **deep tendon reflex, withdrawal reflex** (Figure 16.3b), and **crossed extensor reflex** (Figure 16.3c). These are described in Table 16.2.

CLINICAL CORRELATION

Stretch reflexes play a critical role in reducing the possibility of muscle damage due to overextension. They are also important for maintaining normal upright posture. Accordingly, they are very active in the muscles of the lower extremities. In a clinical setting, stretch reflex tests are performed to check normal function of spinal nerves.

With a lab partner, perform the reflex tests described in the following activities. Conduct the tests on both the right and left sides. For most of these tests, the reflex contractions are very subtle, so, careful observations are required to see the results.

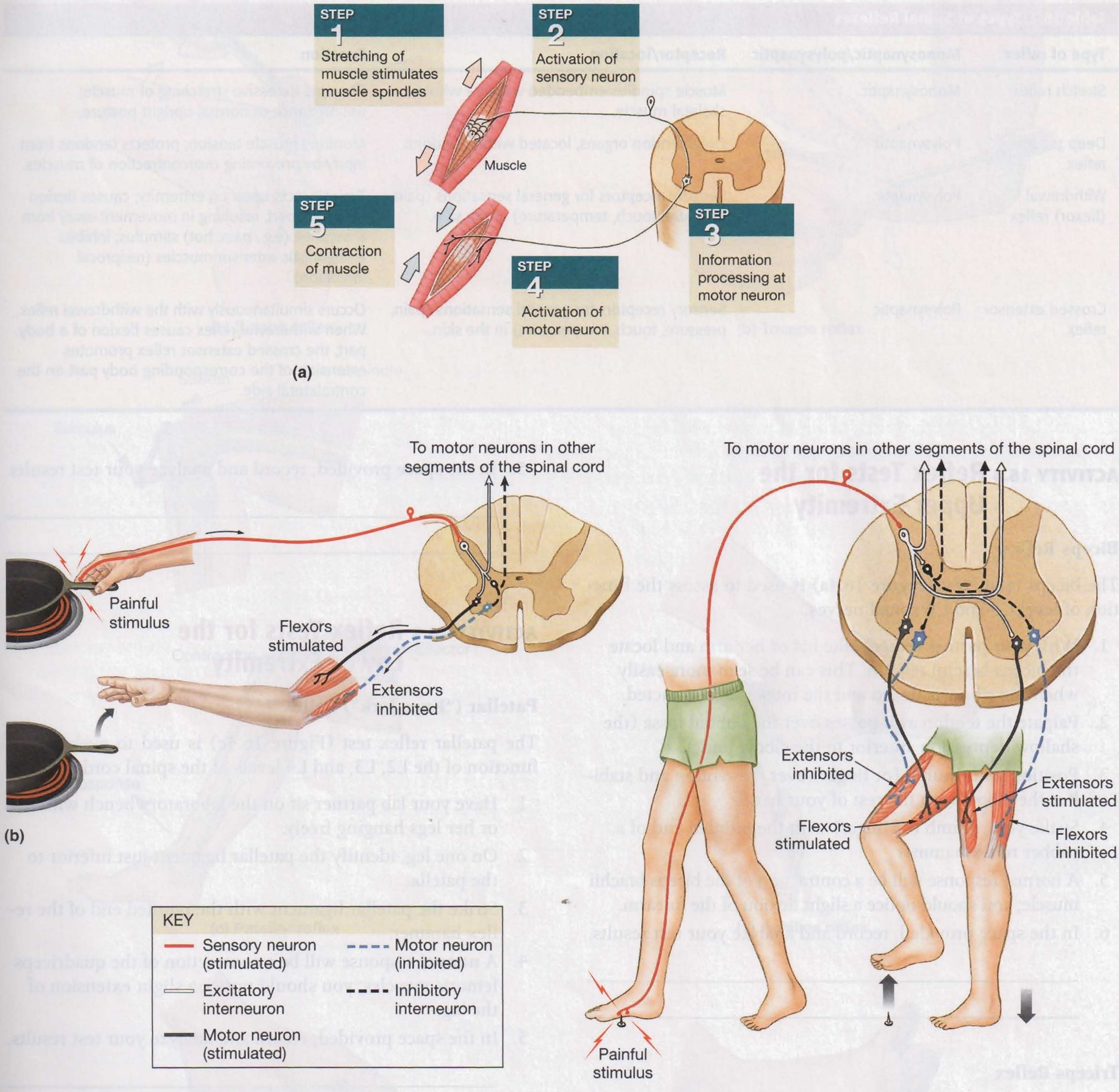

Figure 16.3 Types of spinal reflexes. a) Stretch reflex; **b)** withdrawal (flexor) reflex; **c)** crossed extensor reflex. The stretch reflex is monosynaptic. Withdrawal and crossed extensor reflexes are polysynaptic.

Table 16.2 Types of Spinal Reflexes

Type of reflex	Monosynaptic/polysynaptic	Receptor/location	Function
Stretch reflex	Monosynaptic	Muscle spindles embedded within a whole skeletal muscle.	Prevents excessive stretching of muscle; maintenance of normal upright posture.
Deep tendon reflex	Polysynaptic	Golgi tendon organs, located within tendons.	Monitors muscle tension; protects tendons from injury by preventing overcontraction of muscles.
Withdrawal (flexor) reflex	Polysynaptic	Sensory receptors for general sensations (pain, pressure, touch, temperature) in the skin.	Typically acts upon an extremity; causes flexion of a body part, resulting in movement away from a negative (e.g., pain, hot) stimulus; inhibits antagonistic extensor muscles (reciprocal inhibition).
Crossed extensor reflex	Polysynaptic	Sensory receptors for general sensations (pain, pressure, touch, temperature) in the skin.	Occurs simultaneously with the withdrawal reflex. When withdrawal reflex causes flexion of a body part, the crossed extensor reflex promotes extension of the corresponding body part on the contralateral side.

ACTIVITY 16.4 Reflex Tests for the Upper Extremity

Biceps Reflex

The biceps reflex test (Figure 16.4a) is used to assess the function of level C5 and C6 spinal nerves.

1. With your partner seated, take his or her arm and locate the biceps brachii tendon. This can be seen more easily when the elbow is flexed and the muscle is contracted.
2. Palpate the tendon as it passes over the cubital fossa (the shallow depression anterior to the elbow joint).
3. Position your thumb (or finger) over the tendon and stabilize the elbow with the rest of your hand.
4. Strike your thumb (or finger) with the pointed end of a rubber reflex hammer.
5. A normal response will be a contraction of the biceps brachii muscle; you should notice a slight flexion of the forearm.
6. In the space provided, record and analyze your test results.

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Triceps Reflex

The triceps reflex test (Figure 16.4b) is used to evaluate the function of the C7 and C8 levels of the spinal cord.

1. Palpate your lab partner's triceps brachii muscle in the posterior arm.
2. Follow the muscle inferiorly until you can feel the triceps tendon just superior to the elbow joint.
3. Strike the triceps tendon with the pointed end of the reflex hammer and observe the response.
4. A normal response will be a contraction of the triceps brachii muscle; you should notice a slight extension of the forearm.
5. In the space provided, record and analyze your test results.

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ACTIVITY 16.5 Reflex Tests for the Lower Extremity

Patellar ("Knee Jerk") Reflex

The patellar reflex test (Figure 16.4c) is used to evaluate the function of the L2, L3, and L4 levels of the spinal cord.

1. Have your lab partner sit on the laboratory bench with his or her legs hanging freely.
2. On one leg, identify the patellar ligament just inferior to the patella.
3. Strike the patellar ligament with the pointed end of the reflex hammer.
4. A normal response will be a contraction of the quadriceps femoris muscles; you should notice a slight extension of the leg.
5. In the space provided, record and analyze your test results.

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Ankle Jerk Reflex

The ankle jerk reflex test (Figure 16.4d) assesses the function of the S1 and S2 levels of the spinal cord.

1. Have your lab partner sit on the laboratory bench with his or her legs hanging freely.
2. On one side, identify the calcaneal (Achilles) tendon as it passes posterior to the ankle joint.

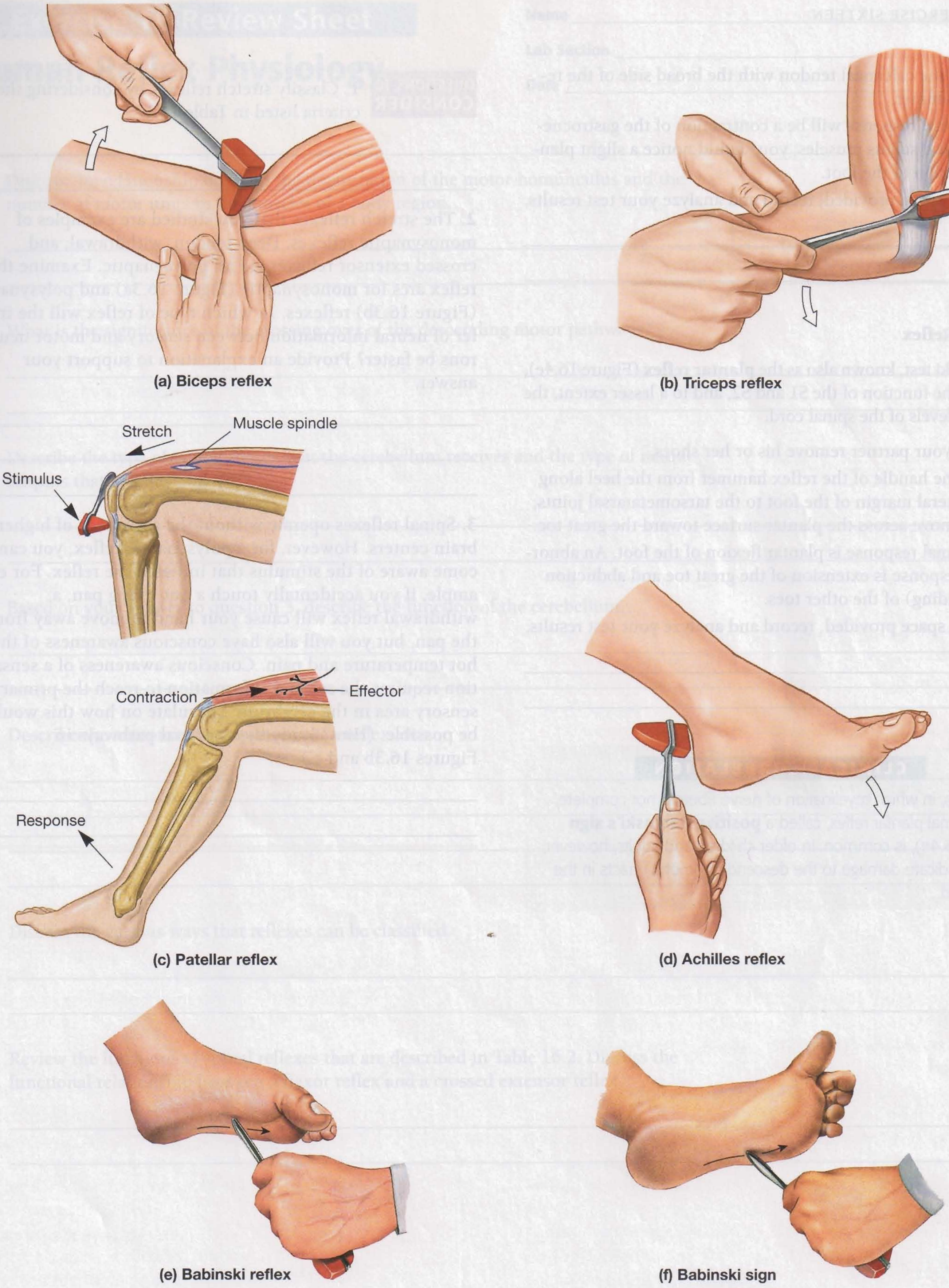

Figure 16.4 Various types of stretch reflexes. All stretch reflexes are monosynaptic. **a)** Biceps reflex; **b)** triceps reflex; **c)** patellar (knee jerk) reflex; **d)** Achilles (ankle jerk) reflex; **e)** Babinski (plantar) reflex and **f)** the Babinski sign.

3. Strike the calcaneal tendon with the broad side of the reflex hammer.
4. A normal response will be a contraction of the gastrocnemius and soleus muscles; you should notice a slight plantar flexion of the foot.
5. In the space provided, record and analyze your test results.

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Babinski Reflex

The Babinski test, known also as the **plantar reflex** (Figure 16.4e), examines the function of the S1 and S2, and to a lesser extent, the L4 and L5 levels of the spinal cord.

1. Have your partner remove his or her shoes.
2. Run the handle of the reflex hammer from the heel along the lateral margin of the foot to the tarsometatarsal joints; then move across the plantar surface toward the great toe.
3. A normal response is plantar flexion of the foot. An abnormal response is extension of the great toe and abduction (spreading) of the other toes.
4. In the space provided, record and analyze your test results.

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CLINICAL CORRELATION

For infants, in which myelination of nerve fibers is not complete, an abnormal plantar reflex, called a **positive Babinski's sign** (Figure 16.4e), is common. In older children and adults, however, it could indicate damage to the descending (motor) tracts in the spinal cord.

QUESTIONS TO CONSIDER

1. Classify stretch reflexes by considering the criteria listed in Table 16.1.

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2. The stretch reflexes that you studied are examples of monosynaptic reflexes. Deep tendon, withdrawal, and crossed extensor reflexes are all polysynaptic. Examine the reflex arcs for monosynaptic (Figure 16.3a) and polysynaptic (Figure 16.3b) reflexes. In which type of reflex will the transfer of neural information between sensory and motor neurons be faster? Provide an explanation to support your answer.

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3. Spinal reflexes operate without the assistance of higher brain centers. However, for a polysynaptic reflex, you can become aware of the stimulus that initiated the reflex. For example, if you accidentally touch a hot frying pan, a withdrawal reflex will cause your hand to move away from the pan, but you will also have conscious awareness of the hot temperature and pain. Conscious awareness of a sensation requires the sensory information to reach the primary sensory area in the cerebrum. Speculate on how this would be possible. (Hint: Study the neuronal pathways in Figures 16.3b and c.)

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Exercise 16 Review Sheet

Human Reflex Physiology

Name ______________________

Lab Section ______________________

Date ______________________

1. Discuss the relationship between the organization of the motor homunculus and the number of motor units in the muscles of a body region.

2. What is the significance of the crossing over of the descending motor pathways?

3. Describe the type of neural inputs that the cerebellum receives and the type of neural outputs that it sends out.

4. Based on your answer to question 3, describe the function of the cerebellum.

5. Describe the anatomical components of a reflex arc.

6. Discuss the various ways that reflexes can be classified.

7. Review the functions of spinal reflexes that are described in Table 16.2. Discuss the functional relationship between a flexor reflex and a crossed extensor reflex.