

WHAT'S THE CONNECTION?

Directions for Teachers

SYNOPSIS

Students elicit and observe reflex responses and distinguish between types of reflexes. They then design and conduct experiments to learn more about reflexes and their control by the nervous system.

LEVEL



Exploration, Concept/Term Introduction Phases



Application Phase

Getting Ready

See sidebars for additional information regarding preparation of this lab.

Directions for Setting Up the Lab

General:

- Make an "X" on the chalkboard for the teacher-led introduction.
- Photocopy the **Directions for Students** pages.

Teacher Background

A reflex is an involuntary neural response to a specific sensory stimulus that threatens the survival or homeostatic state of an organism. Reflexes exist in the most primitive of species, usually with a protective function for animals when they encounter external and internal stimuli. A primitive example of this protective reflex is the gill withdrawal reflex of the sea slug *Aplysia*. In humans and other vertebrates, protective reflexes have been maintained and expanded in number. Examples are the gag reflex that occurs when objects touch the sides

or the back of the throat, and the carotid sinus reflex that restores blood pressure to normal when baroreceptors detect an increase in blood pressure. A second type of reflex, the stretch reflex, has evolved to help maintain muscle tone that is important for posture and movement.

An understanding of the neural circuitry underlying each type of reflex also has clinical significance. When physicians test for potential damage to various components of the nervous system, they often begin by attempting to elicit reflex responses to the appropriate stimuli. Examples of reflexes with protective and diagnostic importance are the flexor withdrawal reflex, the corneal (blink) reflex, and the accommodation reflex. The loss of the pupillary light reflex in a comatose patient, described under the section **Protective reflex**, often indicates extreme damage deep in the brain. Loss of the knee-jerk response may indicate problems with muscle tone, chronic diabetes, or damage at the L2, L3, or L4 vertebral level.

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STUDENT PRIOR KNOWLEDGE

Before participating in this activity students should be able to:

- Describe the parts of a neuron and explain their functions.
- Distinguish between sensory and motor neurons.
- Describe briefly the organization of the nervous system.

INTEGRATION

Into the Biology Curriculum

- Health
- Biology I, II
- Human Anatomy and Physiology
- AP Biology

Across the Curriculum

- Mathematics
- Physics
- Psychology

OBJECTIVES

At the end of this activity, students will be able to:

- Identify common reflexes of the human body and the neural circuitry involved in these reflexes.
- Distinguish between stretch and protective reflexes.
- Describe the role of reflexes.

LENGTH OF LAB

A suggested time allotment follows:

Day 1

- E** 5 minutes — Teacher introduction.
- 40 minutes — Conduct the activity and assign research.

Day 2

- C** 40 minutes — Analyze data and develop hypotheses.
- 5 minutes — Select a hypothesis for experimental design.

Day 3

- A** 45 minutes — Design and conduct experiments.

Day 4

- A** 45 minutes — Analyze and discuss results of experiments.

MATERIALS NEEDED

You may need one or more of the following for the teacher-led introduction:

- 1 book
- 1 balloon
- 1 pin
- 1 watch/clock with a second timer
- C** You will need the following for each group of four students in a class of 24:
 - 1 rubber percussion hammer or a 30-cm ruler
 - 1 utility flashlight or penlight
 - 1 pair safety goggles
 - 1 square of light cardboard (5 x 5 cm)
 - 1 marker

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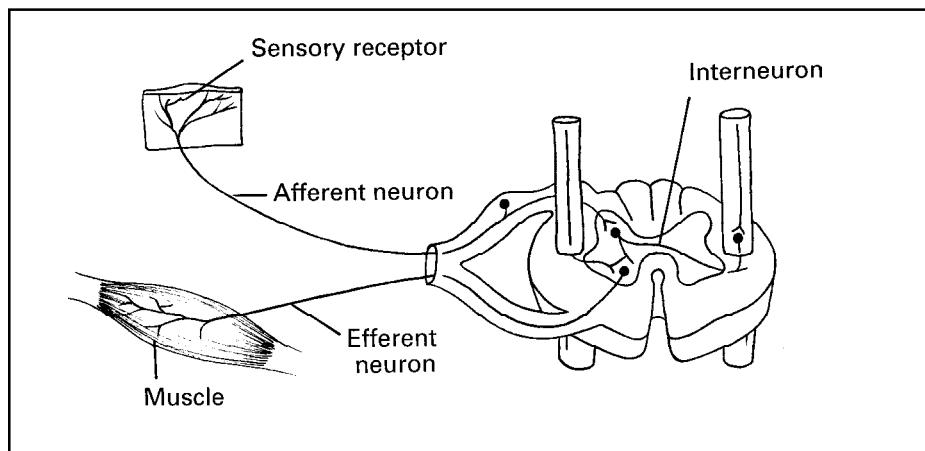


Figure 1. Components of neural circuitry of reflexes.

For each reflex resulting in a specific motor output, the neural pathway linking the sensory receptor to the central nervous system (CNS) may be studied. In this activity, components of the neural circuitry of reflexes will be studied. These components include a sensory receptor, a sensory (*afferent*) neuron, a reflex center in the CNS that may involve one or more levels of integration, a motor (*efferent*) neuron, and a muscle (*effector*). See Figure 1.

Students will investigate the following reflexes to learn about these components:

- **Stretch reflex:** the knee-jerk (patellar) reflex. See Figure 2. Tapping the patellar tendon stretches striated muscle fibers in the quadriceps, resulting in activation of specialized sensory receptors within the muscle called *muscle spindles*. Sensory neurons connected to the muscle spindles are activated and carry the stimulus to the spinal cord, where they synapse onto a motor neuron. These motor neurons are triggered by a neurotransmitter and release a neurotransmitter back at the quadriceps muscle in a synaptic area of the striated muscle membrane called the *neuromuscular junction*. This results in shortening the length of the muscle fibers and knee extension. The knee-jerk and other tendon reflexes differ significantly from other types of reflexes in that no central nervous system interneurons are involved in the knee-jerk reflex. Under normal circumstances, brain pathways descend onto the same motor neurons, constantly modulating the strength of stretch reflexes. This modulation of muscle tone keeps muscles from being damaged during everyday movements. This process occurs not only in the quadriceps muscle, but also in other areas of the body as well. If students experience mild discomfort while participating in this activity, it is important to emphasize that this discomfort was felt only after the reflex response. Pain perception is processed by the brain and cannot be experienced until the message has had enough time to travel to the brain.

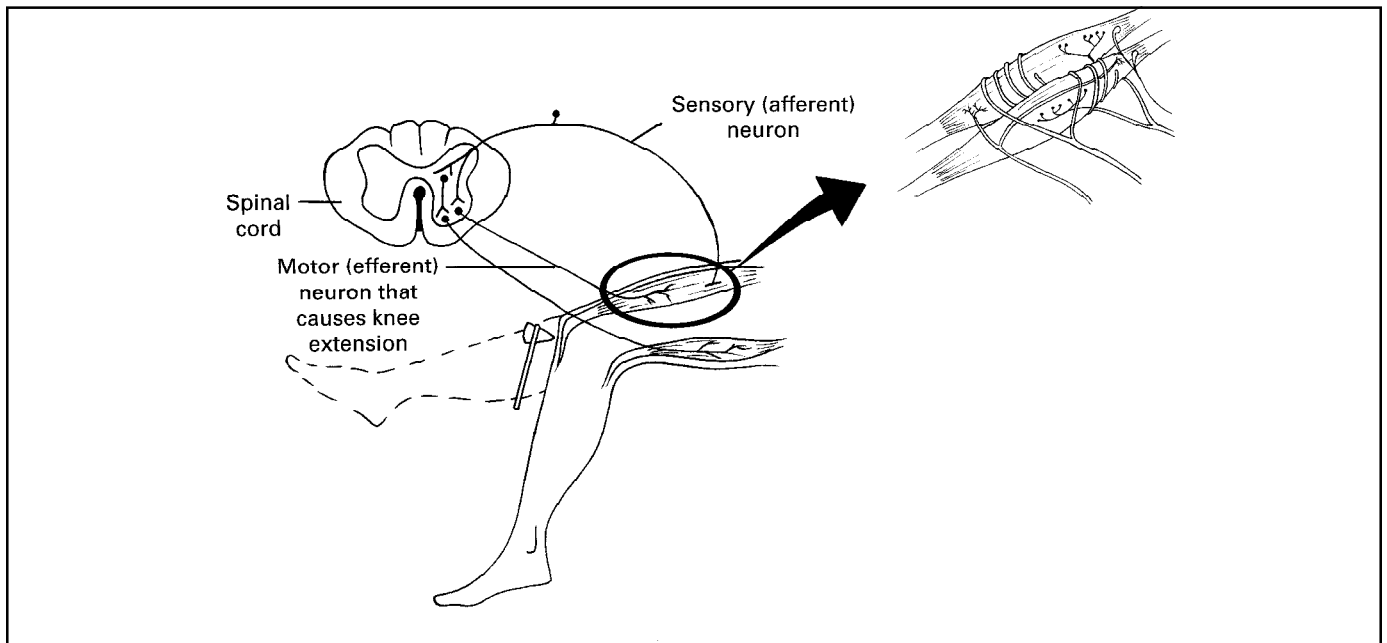


Figure 2. Stretch reflex.

■ **Protective reflex:** the pupillary light reflex. Shining a light into one eye activates sensory receptors in the retina of that eye, eventually stimulating output cells of the retina called *ganglion cells*. Refer to the lab “Is Seeing Believing?” on p. 239 for more information about ganglion cells. The ganglion cells respond to brightness in the eye and send the signals via the optic nerve to the midbrain, located in the brainstem. Some optic nerve fibers synapse in the midbrain on the same side that the eye was stimulated, while others cross and synapse in the midbrain on the opposite side. As a result, the neurons in the midbrain process the signal on both sides of the brain. See Figure 3. Outflow from these neurons exits the brain within both *oculomotor nerves*, but does not go to the relay centers in the thalamus that send signals to the cerebral cortex for visual processing. Components of these nerves devoted to the pupillary light reflex synapse on *parasympathetic* neurons outside of the eye, activating the smooth muscle cells of the pupillary sphincter muscle. Pupils of both eyes constrict due to the bilateral processing in the midbrain. There is a *direct pupillary light reflex* in the eye that was originally stimulated and a *consensual pupillary light reflex* in the other eye. One cannot suppress consciously this protective reflex. See Figure 4. This lab activity could lead to discussions of the somatic versus autonomic nervous systems, control of skeletal versus smooth muscle, and downstream modulation/control of neural pathways by the cerebral cortex.

MATERIALS

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- 1 piece of poster board (70 x 55 cm)
- 1 protractor (optional)

PREPARATION TIME REQUIRED

E 30 minutes to locate and obtain materials, if the hammers and penlights are available

SAFETY NOTES

- Supervise students carefully to ensure that they are tapping their partners' knees lightly with the percussion hammers.
- The penlights should be brought only within 5 to 10 cm of the eye and should not shine on the eye for more than 3 to 5 seconds.
- Safety goggles should be worn.

TEACHING TIPS

- Percussion hammers are available from science education supply catalogs; 30-cm rulers are an acceptable substitute.
- Many students probably have small flashlights at home that they can bring to school.
- Some students may need to practice with the hammer a few times to find the appropriate place to tap their partner's knee in order to elicit the correct knee-jerk action. Some students may experience mild discomfort from the knee tap.

SAMPLE HYPOTHESIS

The knee-jerk reflex can be suppressed consciously by an individual.

SAMPLE PROCEDURE

Repeat Steps 1 through 7 of the **Exploration** section of this activity. The only change will be that the subject will try consciously to keep the leg from responding to the light tap of the hammer.

SUGGESTED MODIFICATIONS FOR

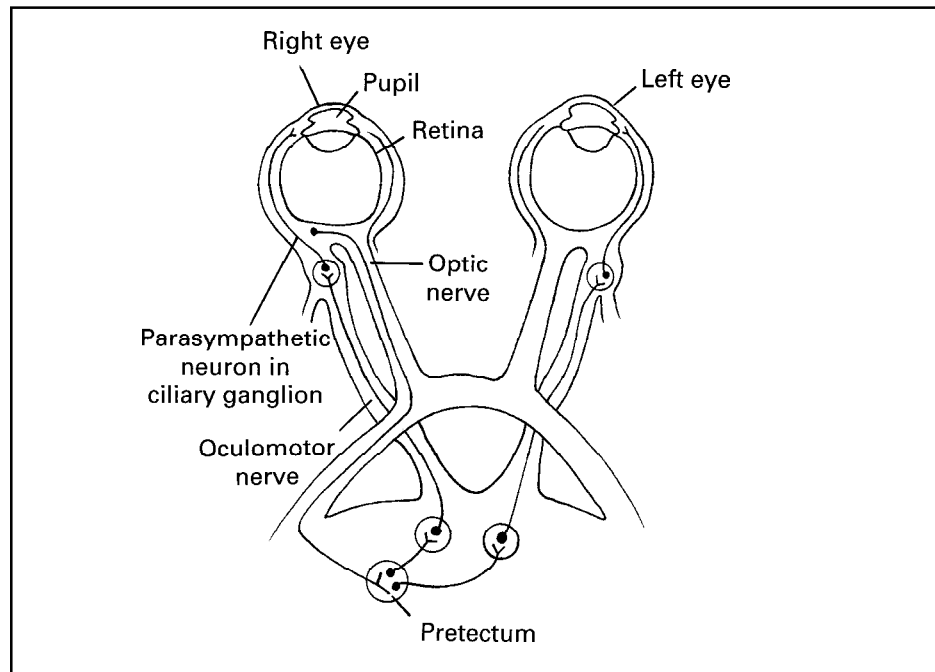


Figure 3. Reflex pathway mediating pupillary light reflex.

Procedure

Some suggestions follow for introducing this activity:

- Have students stare at an “X” drawn on the chalkboard for as long as they can before blinking.
- Drop a book on the floor.

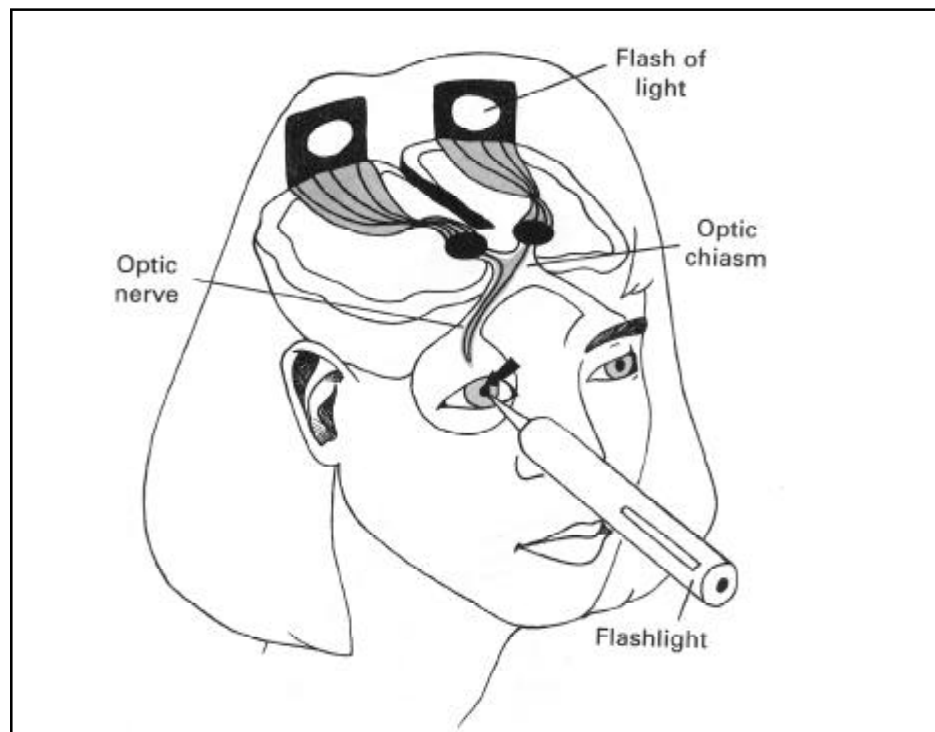


Figure 4. Diagram of bilateral processing in the midbrain.

- Close a book with a loud smack.
- Pop a balloon that is sitting on the teacher’s demonstration table.
- Pretend to throw an imaginary object at the class.

Whatever stimulus you choose to use, take care not to compromise the safety of your students. Immediately following the reflex response, ask questions suggested in the list below:

- What was your reaction to the stimulus?
- How did your body respond?
- How quickly did it respond?
- Can you control your reaction?
- What is the function of this response?
- What is this response called? If students use the word “reflex” in answering this question, ask them to name other reflexes.

Tell students they are going to do activities examining this phenomenon.

Exploration

The **Exploration** activity demonstrates the concept of the reflex arc. The student procedures for conducting the activity with small groups are listed below.

1. Divide the class into six groups of four students each and have each group conduct the activity. If possible, give each student the opportunity to be the subject.
2. Assign each student in the group one of the following roles:
 - Subject
 - Experimenter
 - Timer
 - Data recorder.
3. Have each group do the knee-jerk reflex. The subject should relax and sit on a desk or table with his/her legs dangling loosely over the edge.
4. The experimenter should apply the stimulus by tapping, firmly but carefully, the area just below the kneecap with a percussion hammer. He/she should do this when the data recorder tells the timer to begin timing the reaction.
5. The data recorder should indicate to the timer when the subject has responded and the timer should note the time.
6. The data recorder should describe the response and record the time.
7. The group should repeat Steps 4–5 with the other leg.
8. Have the timer and data recorder exchange roles with the subject and the experimenter to do the pupillary light reflex.
9. In a dimly lit room, the subject should look out toward a wall until his/her eyes dilate. The experimenter should place a 5 x 5 cm square of light cardboard on the bridge of the subject’s nose to separate each eye’s field of vision. See Figure 5. Then the experimenter should bring a flashlight

STUDENTS WHO ARE EXCEPTIONAL

Below are possible ways to modify this specific activity for students who have special needs, if they have not already developed their own adaptations. General suggestions for modification of activities for students with impairments are found in the *AAAS Barrier-Free in Brief* publications. Refer to p. 19 of the introduction of this book for information on ordering **FREE** copies of these publications. Some of these booklets have addresses of agencies that can provide information about obtaining assistive technology, such as Assistive Listening Devices (ALDs); light probes; and talking thermometers, calculators, and clocks.

Blind or Visually Impaired

- Using a Sewell Drawing Kit, provide raised line drawings of the stretch reflex and protective reflex for students who are blind. Use photo-enlarged copies of these diagrams for students with reduced vision.
- Assign a student with a visual impairment to act as either the subject or experimenter for the stretch reflex exercise. For the protective reflex activity, the student probably would be most comfortable as an observer aided by a sighted partner who carefully describes the events.
- Use one of the *auditory* stimuli to introduce the activity if the class includes a student with limited vision.

Deaf or Hard-of-Hearing

Introduce the activity with one of the *visual* stimuli that are suggested. If the student
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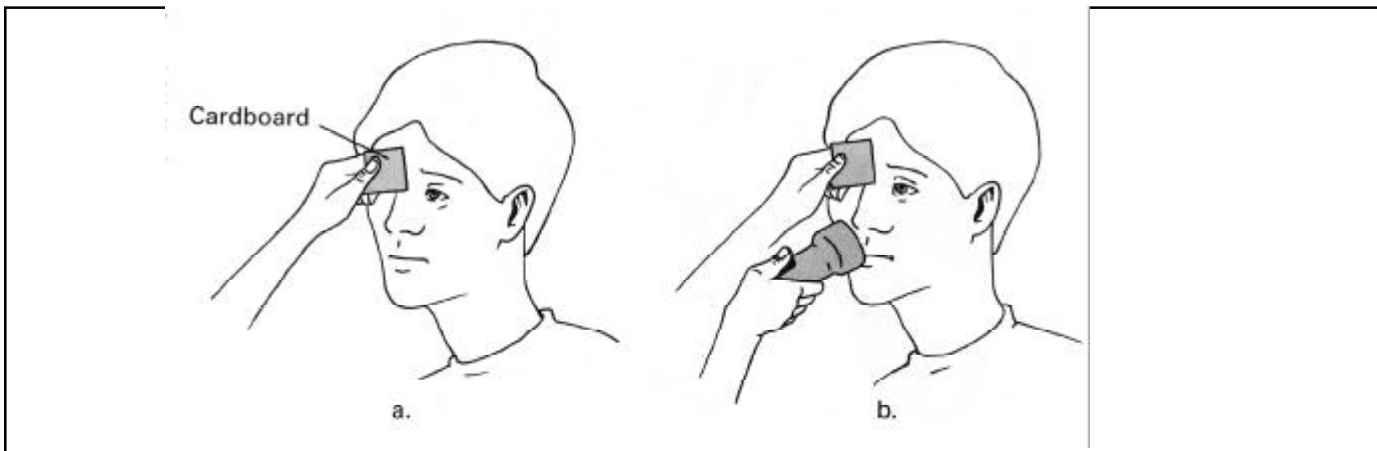


Figure 5. Administration of pupillary reflex test: (a) placing cardboard against the nose; (b) turning on light placed 5 to 10 cm from subject's face.

SUGGESTED MODIFICATIONS — Continued

acts as an observer, make sure that he/she is close enough to the activity to view the events.

Gifted

Have students research answers to the following:

- Why do you think some people have exaggerated responses when their knee or arm tendons are tapped?
- Over time, as humans gradually became more intelligent, why did we need to keep our reflex responses?
- Maybe humans will live on the moon someday. If they do, will they need to have reflex responses there? If so, would they have different ones? Explain.
- How could you design an animal with reflex responses to live safely aboard a space station in Earth's orbit? Draw and

— Continued

from the side to within 5 to 10 cm of the subject's face. The timer should note the time and signal the experimenter to turn on the light. After 3 to 5 seconds, he/she should tell the experimenter to turn off the flashlight.

10. The data recorder should observe the response of the pupil in the eye that is stimulated and the one that is not and record the results.
11. After allowing the subject's eyes to return to the pre-dilated state, the test should be repeated with the other eye. Note the response in both eyes.
12. Students should research reflexes for the next class.

C Concept/Term Introduction

Students should work in their groups and follow **Directions for Students** for this section. As part of each group discussion, you may want to follow the suggested procedure below:

- Have students diagram the neural circuitry of each response.
- Check the student diagrams.
- Listen to the group discussions to be sure students do not have misconceptions about reflexes.

A Application

Students can now build on their previous experiences and learn more about reflexes. Have them work in their groups to design and conduct their experiments, and analyze their data. As they conduct these investigations, encourage students who did not serve as the subject in the original activities to do so as time allows. Afterwards, each group should share its results with other members of the class. Students can quantify their data by measuring the distance the foot moved during the knee reaction by marking the starting and ending points on a poster board. Alternatively, they could measure the angle of change in the knee with a protractor. Eye pupil data may be scored as a plus or minus to indicate whether the reaction occurred. The reflex times for the class may be pooled to establish a class average reflex time to use as a baseline for further experiments.

Suggested questions students may wish to investigate include the following:

- Can you suppress the knee-jerk reflex consciously? The eye reflex?
- How is each of the following reactions controlled by the nervous system? In each case can the reflex be controlled consciously by the nervous system?
 - Flexor (biceps) withdrawal reflex
 - Corneal (blink) reflex
 - Gag reflex
 - Accommodation reflex
- Does the timing or intensity of each of the reflexes vary among individuals? Do these characteristics change with age?
- Is the response different between males and females?
- What factors affect the timing and intensity of the withdrawal reflex of the land snail, *Helix*, sp.?
- How are the reflexes of other invertebrate animals, such as the cockroach, controlled by their nervous systems?
- Your students probably will develop other questions related to reflexes. In the sidebar on p. 62 is a sample hypothesis and procedure that students might derive related to this activity. This example has been included as a suggested outcome of the activity and is not meant to be given to the students. Students should develop their own hypotheses and procedures. Make sure they understand that there is not just one correct hypothesis and procedure.

Answers to Questions in “Directions for Students”

Concept/Term Introduction

Focus Questions

1. Protection and survival.
- 2a. Yes, in the pupillary reflex.
- 2b. In the pupillary reflex, some fibers of the optic nerve cross over in the nervous system, while others stay on the same side; midbrain processing of mixed signals results in the pupils on both sides of the body responding instead of one.
- 3a. Both are involuntary.
- 3b. The pupillary response is a protective reflex and the knee-jerk reaction is a stretch reflex.
- 4a. You would not be able to plan and execute complex activities. You would only be able to respond to the environment.
- 4b. You would have to think consciously about every action and function of your body. For example, blinking your eyes to maintain moisture, yawning, making the heart pump, breathing. All of your time would be spent with basic survival. You also would lack the ability to measure and react to many stimuli.

SUGGESTED MODIFICATIONS

— Continued

label your animal and its reflex arcs. Explain how the various reflexes enable your animal to survive (Solomon, Schmidt & Adragna, 1990).

Mobility Impaired

- Use a large flashlight that is easy to hold and turn on for students with certain physical impairments so that they can participate as experimenters in the eye reflex activity.
- Assign one of several roles, depending upon the type of impairment. A student with limited use of his/her legs could assume any role except subject for the knee-jerk stimulus. One with limited use of his/her arms might need a larger flashlight that can be grasped easily to act as the experimenter for the protective response activity. A student with a physical impairment should be able to assume roles of subject, timer, or data recorder for the latter activity.

- 5a. No; they both occurred immediately after the stimulus was given. (Note: There are measurable differences, but these cannot be detected by the techniques used in this lab. The pupillary response has more synapses, so it is slower, but the neurons are shorter than those of the knee-jerk reflex.)
- 5b. Both are involuntary and involve a reflex arc of the nervous system.
- 6. Yes; protection and survival.
- 7. The nervous system.
- 8a. It helps them react quickly to potential danger.
- 8b. An insect running into a dark area of the room when a person enters and turns on the light.

A Application

Analysis

1–5. Answers will vary depending on experiments students conduct.

References

Solomon, E.P., Schmidt, R.R. & Adragna, P.J. (1990). *Human anatomy and physiology*. 2nd ed. Ft. Worth, TX: Saunders College Publishing.

Suggested Reading

Kandel, E.R., Schwartz, J.H. & Jessell, T.M. (Eds.). (1991). *Principles of neural science*. 3rd ed. New York: Elsevier Science Publishing Company.

WHAT'S THE CONNECTION?

Directions for Students

Introduction

The door slams and you jump!

You blink as a tennis ball comes your way.

You are getting ready for an important date. As you look in your closet for something to wear, you notice that your favorite shirt has somehow made its way to the bottom of your closet. Quickly, you go downstairs and set up the iron and impatiently wait for the iron to heat up. As you pick it up, you touch the iron lightly to see if it is ready. Immediately, your hand pulls away, as though it has a will of its own.

What did you just experience? This lab will help you develop an understanding of what just took place.

Procedure

E Exploration

After your teacher introduces the activity, you will begin by performing two simple tests. Follow the directions your teacher gives you.

C Concept/Term Introduction

1. Analyze the data and brainstorm ideas about what occurred in the tests and why. As you do, answer the **Focus Questions** on page 68 in your groups.

During your discussion, your teacher may suggest that you diagram what took place.

MATERIALS

Materials will be provided by your teacher and consist of the following per group:

- 1 rubber percussion hammer or a 30-cm ruler
- 1 utility flashlight or penlight
- 1 pair safety goggles
- 1 square of light cardboard (5 x 5 cm)

SAFETY NOTES

- Safety goggles should be worn.
- Tap lightly with the percussion hammer to prevent injury.
- The penlights should be brought only within 5 to 10 cm of the eye, and they should not shine on the eye for more than 3 to 5 seconds.

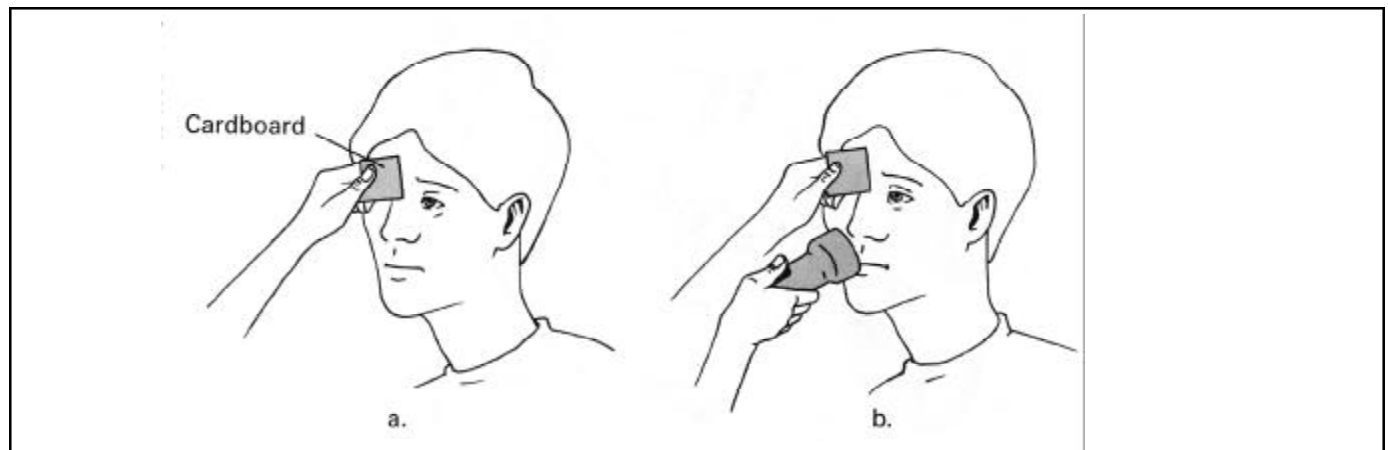


Figure 1. Administration of pupillary reflex test: (a) placing cardboard against the nose; (b) turning on light placed 5 to 10 cm from subject's face.

FOCUS QUESTIONS

1. What functions do the responses in this test serve?
- 2a. Was more than one side of the body involved in either or both responses?
- 2b. Explain.
- 3a. How are these two responses similar?
- 3b. How are they different?
- 4a. What would your life be like if you were only capable of responding in this fashion?
- 4b. What would life be like without these types of responses?
- 5a. Did the speed of the two responses vary?
- 5b. Explain.
6. Does the speed of the response perform a special function?
7. What system of the body is involved in this response?
- 8a. How does this system contribute to the survival of other animals?
- 8b. Give an example.
2. Make a list of possible hypotheses to explain what the data showed

or to gather further information. Then select the hypothesis you feel is best to share with the rest of the class.

3. Research individually the group hypothesis and return to the class with information for developing a procedure to test the hypothesis.

A Application

Think of questions that arose as you conducted your **Exploration** activity, discussed your results as a class, and answered the **Focus Questions**. You may wish to draw on information you gathered to develop your hypothesis. Decide as a group what question you wish to test. Then design a simple experiment to test that question. Write your procedure in a numbered list. Make sure that your group does the following:

- Writes the question as a hypothesis or in the form of an “if... then” statement.
- Gathers quantifiable data.
- Decides what variables must be controlled, and plans how to control those variables.

**Teacher approval must be obtained
before you begin this activity!**

Analysis

1. Did your group obtain the results you expected? How do you explain your results in terms of what you learned during group sharing?
2. Draw a concept map to explain your results.
3. How did you express your data quantitatively?
4. If you were to repeat this experiment, what would you do differently?
5. What might have been sources of error in your experiment?

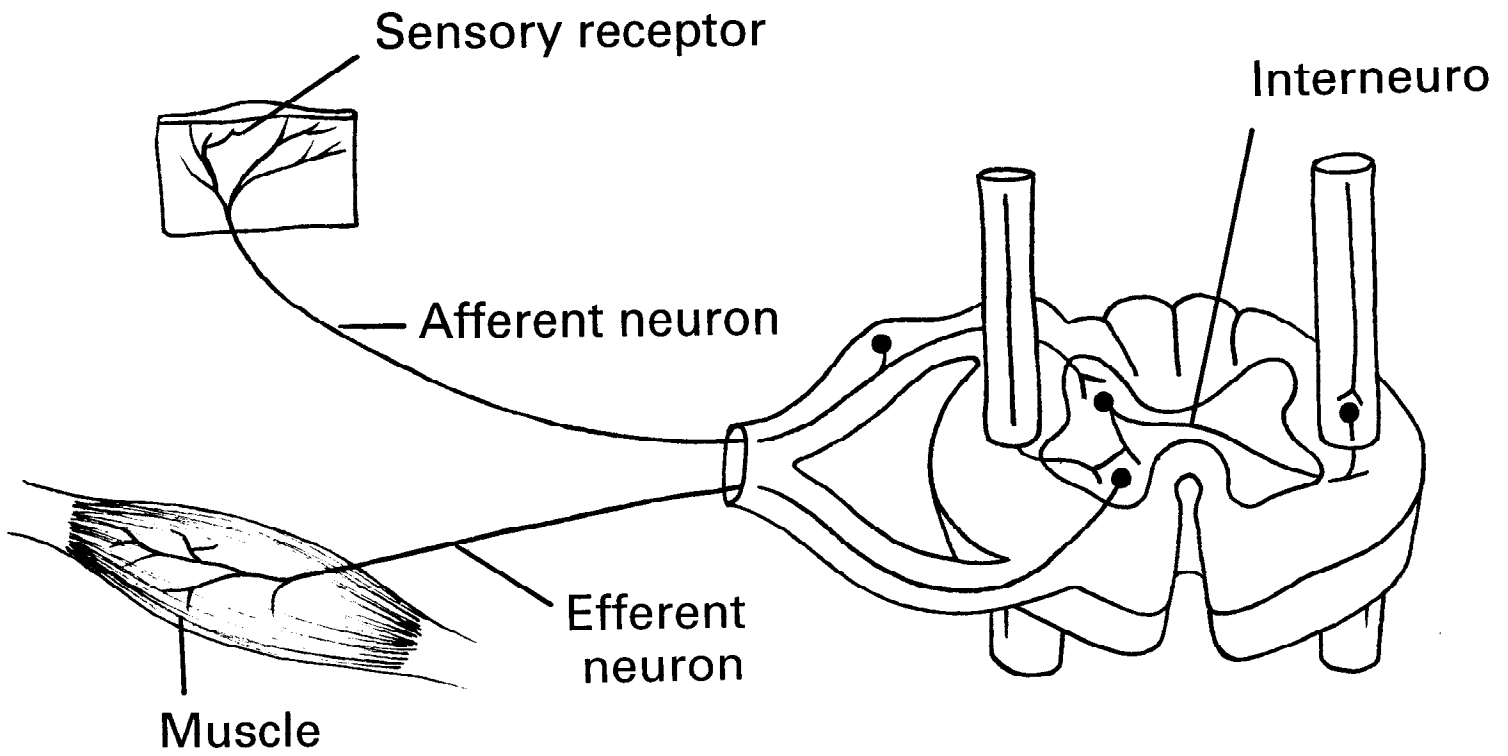


Figure 1. Components of neural circuitry of reflexes.

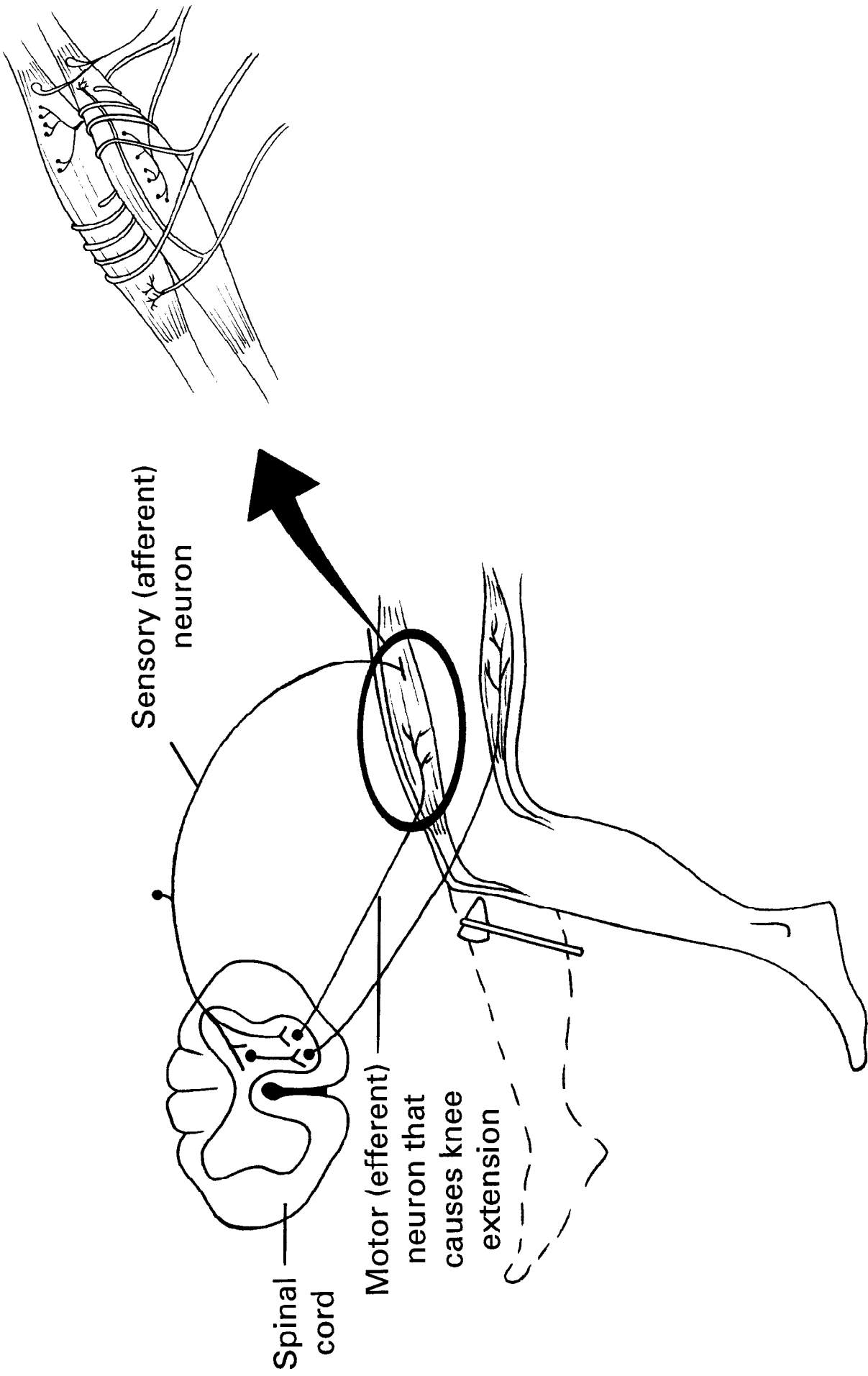


Figure 2. Stretch reflex.

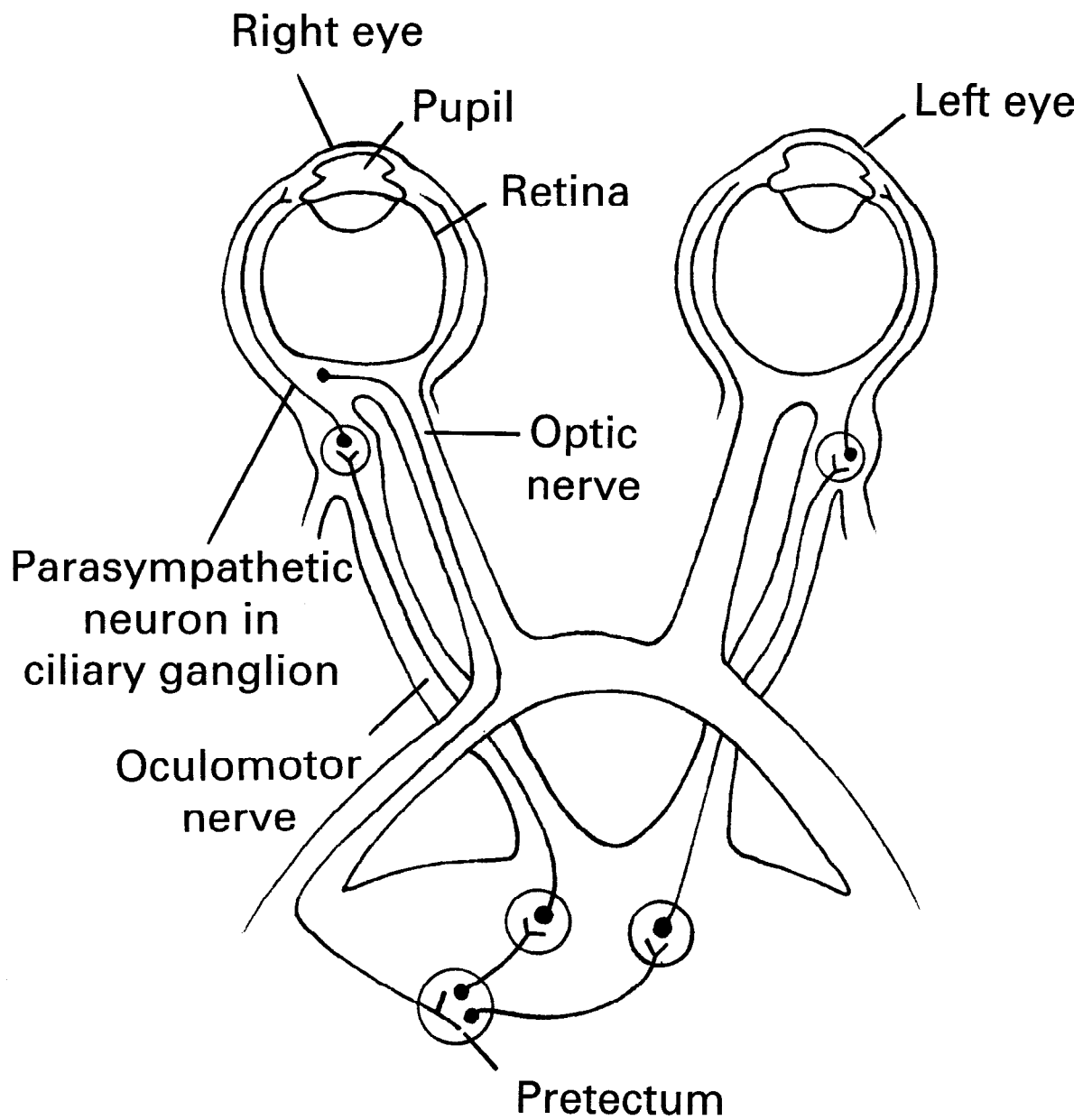


Figure 3. Reflex pathway mediating pupillary light reflex.

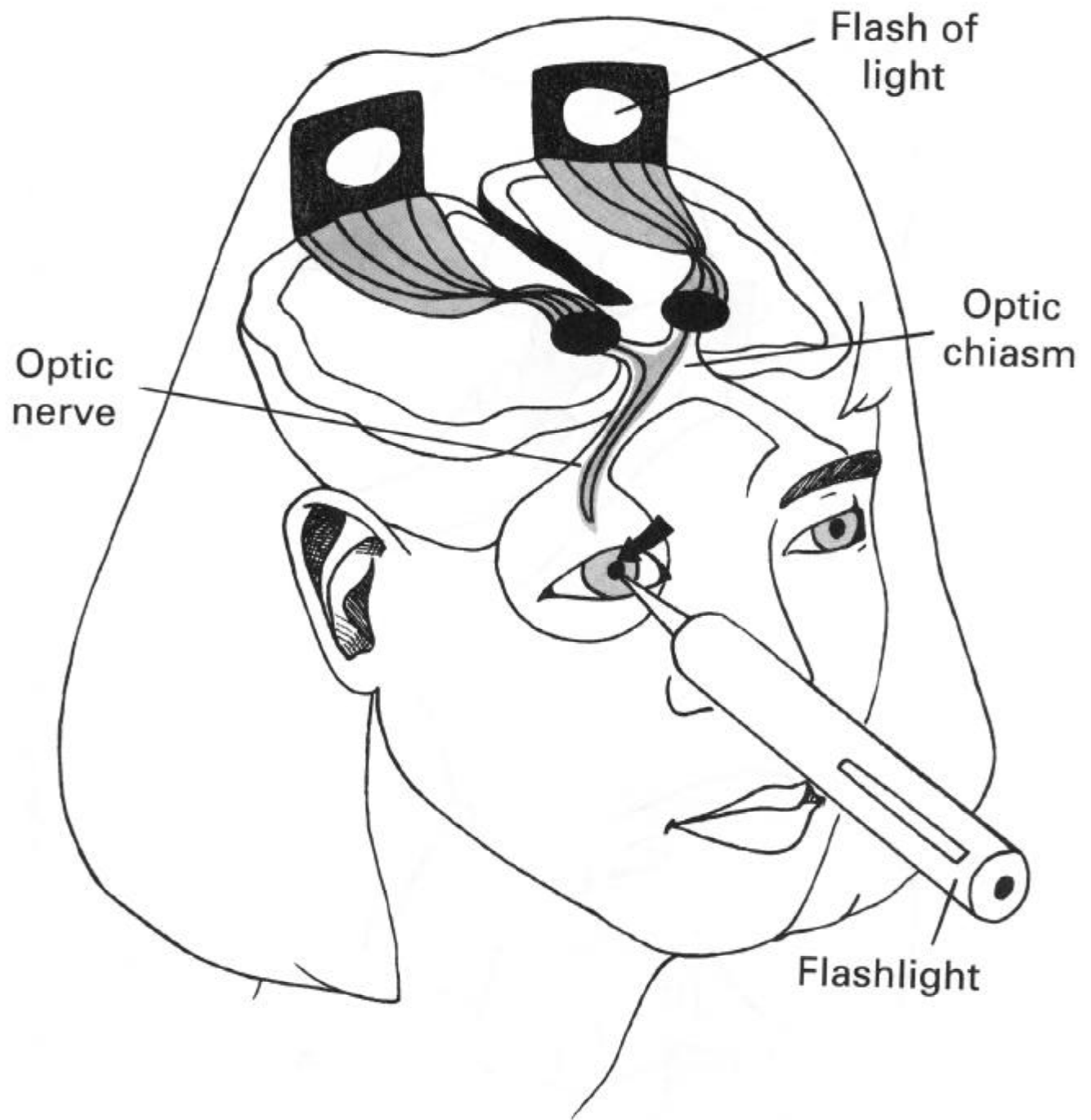
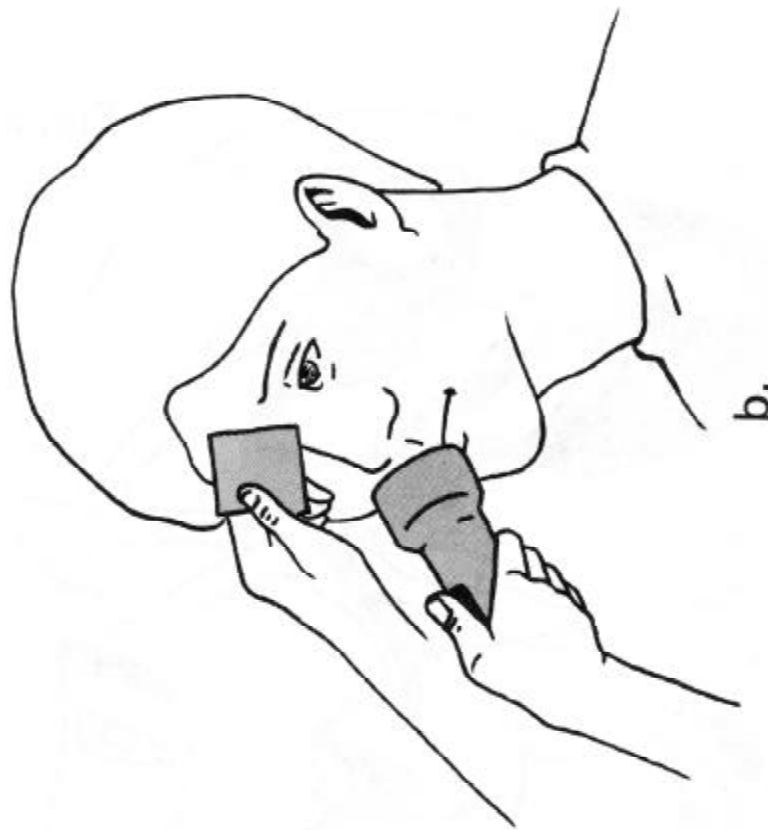
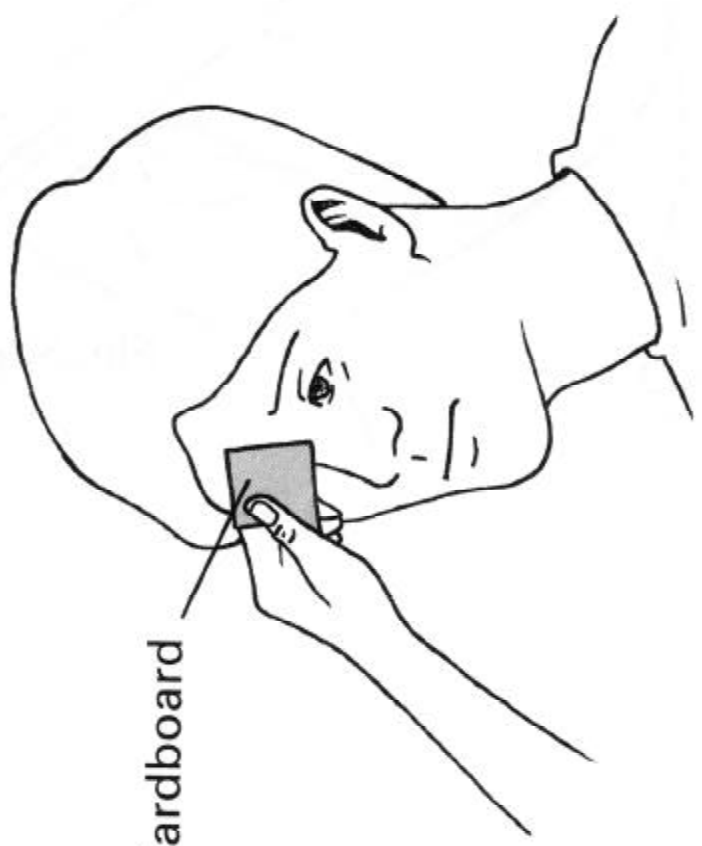


Figure 4. Diagram of bilateral processing in the midbrain.



b.



a.

Cardboard

Figure 5. Administration of pupillary reflex test: (a) placing cardboard against the nose; (b) turning on light placed 5 to 10 cm from subject's face.