NO PAIN, NO GAIN

Directions for Teachers

Stephanie Collins
Orchard Park High School
4040 Baker Road
Orchard Park, NY 14172

SYNOPSIS

Students pinch the web of skin between their index and middle fingers in order to learn about pain pathways. They also discuss their experiences with pain, draw diagrams of pain pathways, and describe ways to stop or reduce pain. Finally, they make predictions about how methods of reducing pain work, and how pain-related phenomena occur.

LEVEL

Exploration Phase

Concept/Term Introduction, Application Phases

Getting Ready

See sidebars for additional information regarding preparation of this lab.

Directions for Setting Up the Lab

Concept/Term Introduction

- Make overhead transparencies of Figures 1 and 2. Photocopy these figures for students.

Application

- Schedule a class visit to the school library (optional).
- Make photocopies of Figure 3 (optional).
- Obtain a copy of the *NIH Image* computer program (optional). (See **Teaching Tips**.)
- Locate and set up the computer (optional).

Teacher Background

Pain is very important to our survival. Although pain is defined as the perception of a noxious (i.e., tissue damaging) stimulus, pain can also occur in the absence of injury or long after an injury has healed.

Pain provides humans with information about tissue-damaging stimuli, and thus enables them to protect themselves from greater damage. Pain is protective in two ways. First, it removes a person from stimuli that cause tissue damage through withdrawal reflexes. Second, learning associated with pain causes the person to avoid stimuli that previously caused pain. In humans, pain often initiates the search for medical assistance and helps us to pinpoint the underlying cause of disease. In addition, pain facilitates recovery from injury because sensitive body regions are protected from further injury.

STUDENT PRIOR KNOWLEDGE

Before participating in this activity students should be able to:

- Define or describe the function of the following terms: noxious stimulus, sensory neuron, neuron, synapse, neurotransmitter, spinal cord, thalamus, cerebral cortex.
- Explain how neurons carry impulses.

INTEGRATION

Into the Biology Curriculum

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

Across the Curriculum

- Computer Science
- Psychology

OBJECTIVES

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

- Define pain and describe its protective function.
- Describe pathways involved in the transmission and perception of pain.
- Explain how pain can be reduced or stopped.

LENGTH OF LAB

A suggested time allotment follows:

Day 1

[E] *15 minutes* — Conduct ***Exploration I.***

10 minutes — Conduct ***Exploration II.***

[C] *20 minutes* — Draw and correct pain pathways.

Day 2

[A] *15 minutes* — Make predictions for ***Application I.***

30 minutes — Conduct library research to check predictions (optional).

Day 3

[A] *15 minutes* — Make predictions for ***Application II*** (optional).

30 minutes — Conduct library research to check predictions (optional).

TEACHING TIPS

MATERIALS NEEDED

[A] You will need the following optional materials for the ***Application*** phase of this activity:

- 1 Macintosh computer with two megabytes of RAM, hard drive, mouse, and a color monitor.
- 1 *NIH Image* computer program (See **Teaching Tips** for information on how to obtain this.)

Although acute pain, that associated with acute disease or injury, has a protective function in that it prevents further tissue damage, occasionally persistent pains that have no useful purpose can develop. Persistent pain is not simply a symptom of injury — it persists long after recovery from injury and long after pain has a useful function. Such pain syndromes are a widespread medical problem. According to the Society for Neuroscience, "Each year, more than 97 million Americans suffer chronic, debilitating headaches, a bout with a bad back or the pain of arthritis — all at a total cost of some $80 billion" (Society for Neuroscience, 1990, p.19).

Messages about tissue damage are transmitted from the skin or other site of injury to the spinal cord by specialized sensory neurons called nociceptors. See Figure 1. Nociceptors respond exclusively to stimuli that damage the skin and other tissues.

Two things happen once the message reaches the spinal cord. Spinal interneurons transmit the message to motor neurons that synapse with muscles involved in withdrawal reflexes. This reflex circuit removes the injured limb from the stimulus. Simultaneously, a message travels to the thalamus, which relays the message to the somatosensory cortex. Because of the difference in distance in these two pathways, nociceptive reflexes occur before the pain message reaches the brain. Although much is known about the pathways from injured tissue to the brain, the interpretation of pain in the brain is not completely understood (Guyton, 1991).

Students should discover during ***Exploration II*** that there are different types of neurons that carry information about painful stimuli to the spinal cord

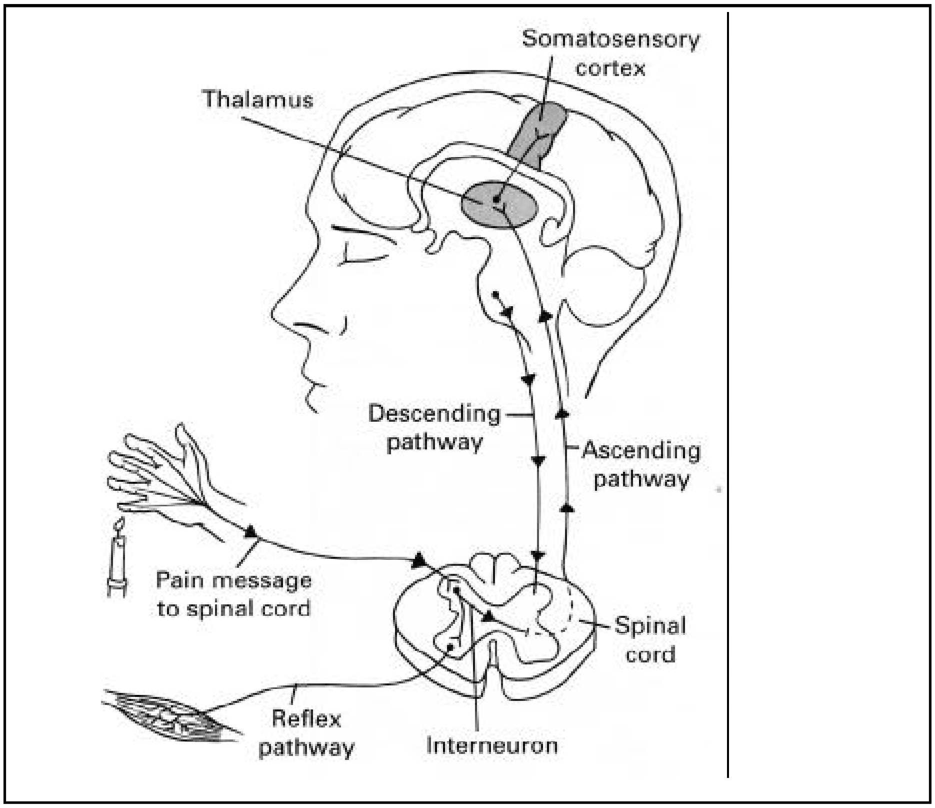

Figure 1. Transmission of pain messages to the brain.

(Martin & Jessell, 1991, pp. 349–351). When students pinch the finger web, they experience two types of pain, as shown in Figure 2.

It is hypothesized that these two types of pain are carried by different types of nociceptors. Small, myelinated fibers (A delta fibers) are believed to carry sharp, pricking sensations, whereas unmyelinated fibers (C fibers) are believed to carry a diffuse, throbbing pain. A delta fibers carry messages at a velocity of 6 to 30 m/second and C fibers at a velocity of 0.5 to 2.0 m/second (Guyton, 1991, p. 522). The long-lasting throbbing pain is probably the result of prolonged activity in C fibers. Students who have hit a finger with a hammer or dropped something on a toe have probably experienced these two types of pain.

What is life like for a person who cannot feel pain? The protective value of pain is demonstrated easily by examining individuals who are insensitive to pain. People with a rare condition called congenital insensitivity to pain lack the neural apparatus for detecting harmful stimuli. They repeatedly injure themselves because they do not avoid hot objects, intense pressure, extreme twisting, or corrosive substances, and, thus, end up with burns, pressure sores, missing digits, and damaged joints. Specific examples of some of these injuries are mentioned below:

- The little girl who poked a pencil through her cheek.
- A baby girl who bit off the tip of one of her fingers and watched it bleed.

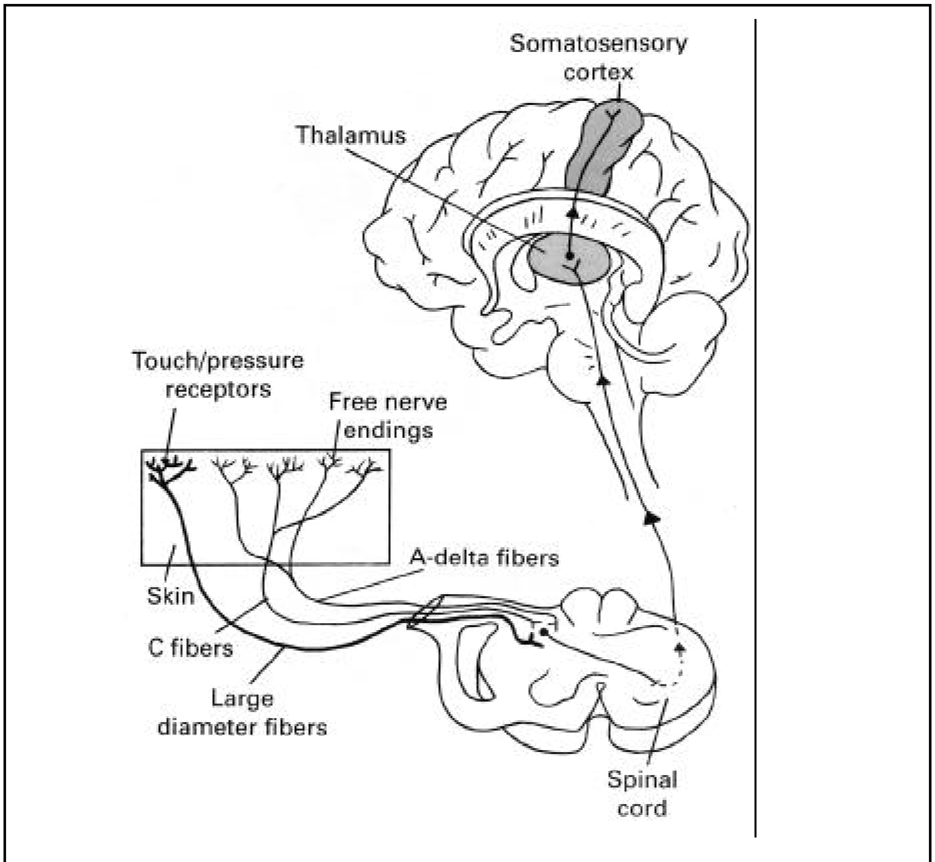

Figure 2. Different types of nerve fibers carrying pain sensations.

PREPARATION TIME REQUIRED

C *45 minutes* — Make overhead transparencies and photocopies of Figures 1 and 2.

A *15 minutes* — Schedule a class visit to the school library (optional).

15 minutes — Make photocopies of Figure 3 (optional).

3 hours — Obtain a copy of the *NIH Image* computer program (optional).

30 minutes — Locate and set up computer (optional).

SAFETY NOTES

- Students should pinch only their own finger webs, using only their fingers. Their hands and fingernails should be clean.
- Students should pinch their finger webs on a voluntary basis only. Students who do not pinch their finger webs can listen to descriptions of the pain from other students.
- Demonstrate the finger web pinching procedure before students perform the activity.
- If students use the computer program in the ***Application*** section, have them sit at least 75 cm from the monitor to reduce the effects of radiation.

- You can give your students an additional opportunity for exploration and discovery by using the technology of image processing to investigate digital imagery from neuroscience and using the free software, *NIH Image,* on your school computers. For help getting started with image processing, contact the Image Processing for Teaching (IPT) project at the University of Arizona. IPT provides imagery and curriculum materials for all science subjects, including image-processing activities in neural structure and brain physiology. IPT also supports educators nationwide with workshops, technical support, and linkage to other users. Information from IPT, including access to the public-domain *NIH Image* software, is available on the Internet at http://ipt.lpl.arizona.edu (E-mail: IPTCIPE@ aol. com), or call the Center for Image Processing in Education at 1(800)322-9884.

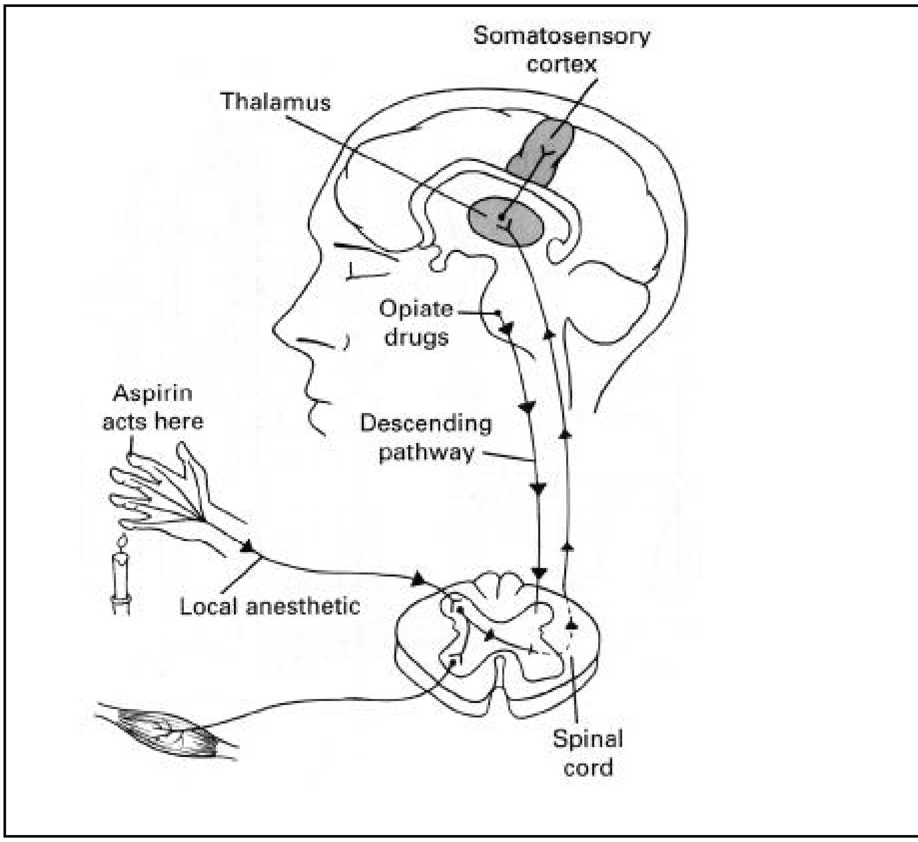

Figure 3. Sites of action of different painkillers.

- A young woman who died of spine damage because she did not receive the normal discomfort signals from her joints telling her to change her posture—she never moved in her sleep, for example (Fields, 1987).

Pain is an unpleasant sensory experience associated with actual or potential damage to the body, or perception of such damage. It is a subjective experience. The perception of pain varies with the intensity of the stimulus and the affective or emotional state of the individual. Memories of events associated with extreme pain persist for a long time. This persistence should become evident to students during ***Exploration I*** as they look at the ages listed when their worst pain occurred.

Mental state is known to have a powerful influence over pain. For example, an athlete may not notice a twisted ankle until after the competition is over. Similarly, soldiers in battle often continue to fight even after sustaining serious injury, and they may report afterwards that they experienced no pain until after battle. The scientific explanation for this phenomenon is that the brain not only receives pain messages, but also has a descending system of neurons that suppresses pain messages, as shown in Figure 1. This system inhibits cells in the spinal cord that transmit pain signals. The descending system is thus a natural pain modulation pathway. Naturally occurring opioids such as the endorphins are important neurotransmitters in some of these descending pathways (Carola, Harley & Noback, 1990, p. 432). Endorphins appear to be released by the brain in times of stress (e.g., attack from a predator) in order to minimize pain that may detract from an organism's ability to escape. Extreme exercise may also cause the release of endorphins, leading to the "natural high" experienced by serious runners (Carola, Harley & Noback, 1990, p. 432).

Physicians make use of these endogenous pain modulatory systems by treating severe pain with opioids derived from plants such as morphine or codeine (Society for Neuroscience, 1990, pp. 19–20). These drugs bind to endogenous opioid receptors in the central nervous system (CNS) to relieve pain much as naturally occurring opioids do. See Figure 3. Physicians can also treat pain by blocking nerve conduction with anesthetics or by surgically cutting a nerve. Cutting a nerve is not recommended, however, because this causes a permanent loss of all sensations carried by the cut nerve, and, yet, surgery often does not alleviate persistent pain problems.

In contrast, mild pains often are reduced by simply rubbing the injury, applying ice, or taking aspirin or other over-the-counter painkillers. These mechanisms work by reducing neural transmission either indirectly via inhibiting inflammation (e.g., aspirin, cold water) or via interfering with nociceptive messages in the spinal cord (e.g., rubbing the skin activates touch fibers that inhibit nociceptive neurons in the spinal cord).

Procedure

E Exploration

Exploration I: Pain

Divide the students into groups of four. Have them read the **Introduction** in **Directions for Students** and do the ***Exploration*** below:

1. Discuss with your group the worst pain that you have ever experienced. Make a list of these pains. Record the following data:
   - The age when the pain occurred.
   - The cause of the pain.
   - The location on the body where the pain occurred.
   - The method used to relieve the pain. Pain relief could be what you did, such as take aspirin or rub the injury, or what a doctor did, such as administer opioids or other painkillers.
2. Make another list of any pains that you have experienced in the last day or two. Record the following data:
   - The cause of the pain.
   - The location on the body where the pain occurred.
   - The method used to relieve the pain.

Lead students in a class discussion once these lists are completed. Questions you might ask during the discussion include the following:

- What ages are listed in each group indicating the time when the worst pain occurred?
- What do these ages tell you, if anything, about the persistence of memories of pain?

SUGGESTED MODIFICATIONS FOR 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

- For students who are blind, prepare raised line drawings of Figures 1 through 4 using the Sewell Drawing Kit or prepare tactile diagrams using string or glue. Have the student prepare his/her pain pathway in the same manner. Provide an audiotaped or brailled copy of the text for the students.
- For students with low vision, provide photo-enlarged copies of text and figures.

—Continued

SUGGESTED MODIFICATIONS *— Continued*

Mobility Impaired

- A student with limited or no use of his/her arms may have difficulty with the pinching activity in ***Exploration II*** due to the inability to pinch and/or feel pain in the finger web. This student can listen to descriptions by other students of the sensations experienced.

- What would have happened if the worst pain you ever experienced had not been perceived?
- What would have happened if the pain you experienced in the last day or two had not been perceived?
- Were the methods used to relieve pain different for severe pain and recent mild pains?
- Why do we have pain?
- What would your life be like if you were insensitive to pain?

Exploration II

This activity requires careful teacher guidance. Demonstrate the finger web pinching before students perform it. Instructions for pinching finger webs are given below. Refer to Figures 4a and 4b as you read these directions.

1. Extend your hand out in front of you and find the webbing between your first and second fingers.
2. Place your thumbnail on one side of the web. Place the opposing finger on the other side.
3. Pinch quickly and forcefully. Have all students pinch at the same time. Students must pinch firmly enough to reach the pain threshold. If they do not pinch hard enough, they will feel only pressure, not pain.

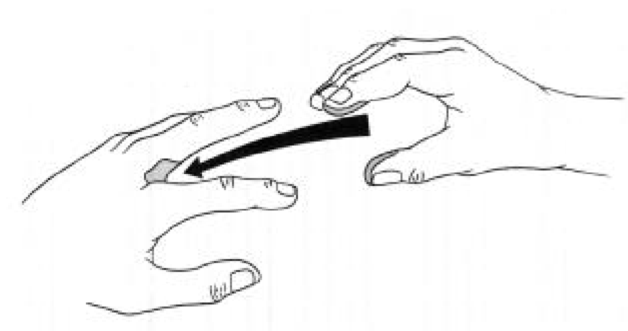

Figure 4a. Tec

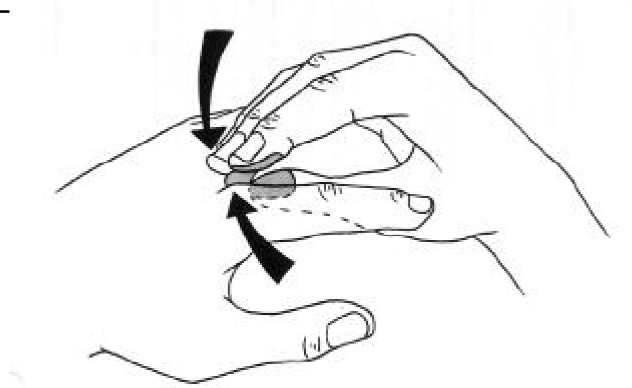

Figure 4b. Technique for pinching finger web.

4. As soon as students have pinched, ask them what they feel.
5. Students should pay attention to the sensation in the finger web for 15 seconds after the pinch. After 15 seconds, ask them to describe what they feel now. Is the second feeling different from the first? How?
6. Have students work in their groups to answer the focus questions in the ***Exploration*** section in **Directions for Students.**

Concept/Term Introduction

You may need to review terms such as neuron, neurotransmitter, synapse, spinal cord, thalamus, and cerebral cortex. Then, 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:

1. Have students follow **Directions for Students** as they diagram pain pathways to show what happens after a painful stimulus. See Sample Pain Pathways in Figures 1 and 2.
2. Check the student diagrams.
3. Listen to the group discussions to be sure students do not have misconceptions about pain pathways, such as: *A message travels directly from a receptor to the brain*. Address and try to correct any student misconceptions you hear.
4. After students have drawn and compared their diagrams, have them present and discuss their pain pathways.
5. Show students overhead transparencies and/or photocopies of correct pain pathways (Figures 1 and 2). Be sure students correct any errors they made on the pain pathways they drew themselves.

Application

Students can now build on their previous experiences and learn more about methods for reducing pain and other pain-related phenomena. Have them follow the instructions in **Directions for Students** for the ***Application*** section for one or both of the ***Application*** activities. You might want to give the students copies of Figure 3 after they have made their predictions for ***Application I***. If available, you might also have students work on investigating neuroscience imagery using the *NIH Image* computer program. (See **Teaching Tips** for more information.)

Answers to Questions in “Directions for Students”

Exploration

Focus Questions

1. Students should first experience a sudden, sharp pain. Soon after, students should feel a second pain — dull, more diffuse, throbbing. Students who do not feel these two pains in sequence have probably not pinched hard enough and should try again.
2. Different types of neurons carry information about the first and second pains. A noxious, or tissue-damaging, stimulus activates two types of

neurons. One type, myelinated neurons (A delta fibers), carries messages very quickly. This is the first sharp pain. The second type, the unmyelinated neurons (C fibers), carries messages more slowly than the A delta fibers, but remains active for a longer time. This is the second throbbing pain.

3a. through 3d. Refer to the answers for Questions 1 and 2 and the **Teacher Background** information.

4. The function of pain from a finger pinch may be protection of the body from pinching stimuli, and may help a person learn to avoid such stimuli. If the pain did not occur, the person would not be likely to avoid these stimuli, and tissue damage could result.

A Application

Application I: Modulating Pain

Focus Questions

1. Yes, mental state is known to have a powerful influence over pain, as in the case of an injured athlete. Refer to the **Teacher Background** for more information.
2. Pain is a necessary warning signal, but it is also unpleasant. People want to reduce what is unpleasant. Also, in cases of chronic pain, pain no longer has any useful function, so it should be stopped if possible.
3. Methods of blocking severe pain include:
   - Doctors blocking nerves with *anesthetics*.
   - Doctors prescribing *opioids*. These drugs act on the CNS to block pain messages.
   - Surgically *cutting* the nerve to block nerve conduction.

   Methods of blocking mild pain include:
   - *Aspirin* or other over-the-counter painkillers (ibuprofen, acetaminophen) that reduce pain by alleviating inflammation at the site of injury.
   - *Rubbing* the injured area to activate touch fibers that reduce pain sensation.
   - *Cooling* the injured area to block nerve conduction or reduce inflammation.
4. Answers will vary, depending on the method of pain treatment students choose. Refer to Figure 3 and the answers to Question 3.
5. Answers will vary.
6. Answers will vary. Students should correct any mistakes they made on the pain pathways they might have drawn for Question 4.

Application II: Pain-Related Phenomena

Focus Questions

1. Answers will vary.
2. Answers will vary, depending on the questions chosen by students.

3. Answers will vary. Students should correct any mistakes they made in their predictions.

References

Carola, R., Harley, J.P. & Noback, C.R. (1990). *Human anatomy and physiology.* New York: McGraw-Hill Publishing Company.

Fields, H.L. (1987). *Pain*. New York: McGraw-Hill Book Company.

Guyton, A.C. (1991). *Textbook of medical physiology*. 8th ed. Philadelphia, PA: W.B. Saunders Company: Harcourt Brace Jovanovich, Inc.

Martin, J.H. & Jessell, T.M. (1991). *Modality coding in the somatic sensory system*. In Kandel, E.R., Schwartz, J.H. & Jessell, T.M. (Eds.), *Principles of neural science.* 3rd ed. New York: Elsevier Science Publishing Company.

Society for Neuroscience. (1990). *Brain facts: A primer on the brain and nervous system*. J. Carey (Ed.). Washington, DC: Society for Neuroscience.

Acknowledgments

The author acknowledges invaluable help from Michael Morgan, Ph.D., Washington State University, and Robert Foreman, Ph.D., University of Oklahoma.

Suggested Reading

Chapman, C.R. & Bonica, J.J. (1985). *Chronic pain*. The Upjohn Company.

Foreman, R.D. (1989). Organization of spinothalamic tract as a relay for cardiopulmonary sympathetic afferent fiber activity. *Progress in Sensory Physiology*, *9*, 1–51.

Melzack, R. & Wall, P. (1988). *The challenge of pain*. London: Penguin Books.

Schmidt, R.F. (1986). *Nociception and pain.* In R.F. Schmidt (Ed.), *Fundamentals of sensory physiology* (pp. 117–143). New York: Springer-Verlag.

Society for Neuroscience. (1991). *Brain concepts: What is pain?* J. Carey (Ed.). Washington, DC: Society for Neuroscience.

Thies, R. (1992). *Physiology.* 3rd ed. New York: Springer-Verlag.

NO PAIN, NO GAIN

Directions for Students

Introduction

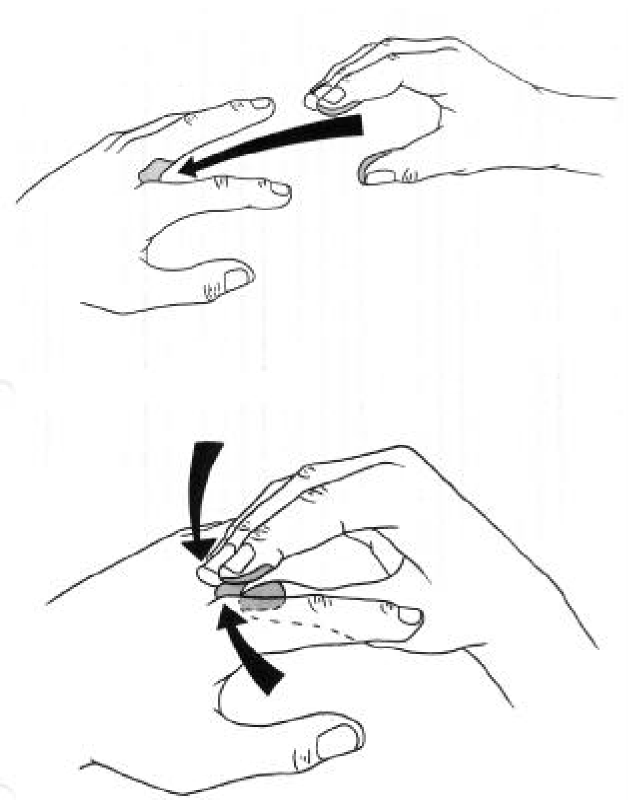

Figure 1

Figure 1b. Technique for pinching finger web.

Pain is a mysterious sensation. Sometimes pain is so severe as to prevent leaving your bed. At other times you may break a bone and feel almost no pain. Have you ever had the experience of injuring yourself, but not feeling the pain until later? In this activity, you will gain a better understanding of pain. You will consider the subjective nature of pain, analyze different types of pain, and study ways to reduce pain.

Procedure

E Exploration

Your teacher will lead you through two exploration activities. Follow the directions your teacher gives you.

MATERIALS

Optional materials may be provided by your teacher and consist of the following per group:

- 1 Macintosh computer with at least two megabytes of RAM, hard drive, mouse, and color monitor
- 1 *NIH Image* program disk, non-FPU version with the following images:
  - MRI — human skull, sagittal section
  - mu opioid receptors — rat brain horizontal cross section, below the eyes, including olfactory bulbs

SAFETY NOTES

- Pinching your finger web is voluntary.
- Watch your teacher's demonstration of finger web pinching before you try it.
- Pinch only your own finger web, using only your fingers. Your hands and fingernails should be clean.
- If you use the computer program in the *Application* section, sit at least 75 cm from the monitor to reduce the effects of radiation.

FOCUS QUESTIONS

Answer the following **Focus Questions** in your group after the finger web pinching exercise:

1. Describe what happened when you pinched the finger web.
2. How do you think this occurred?
3. Did you experience more than one pain? If you did, answer these questions:
   a. When was each pain experienced—immediately after the pinch, or a short time later?
   b. How did each pain feel?
   c. How long did you feel each pain after you initially experienced it?
   d. How do you explain the differences in the two pains?
4. In the case of finger web pinching, what would be the consequences if there were no pain?

C Concept/Term Introduction

Work with your teacher and other students to learn more about how pain occurs. Your teacher may suggest that you work in your groups and draw diagrams of what took place. Choose a specific pain to be the focus of your diagram. You may choose one of the pains from the lists your group made in ***Exploration I***, or you may choose one of the pains you felt during ***Exploration II***. On a separate sheet, draw and label a picture of the pain pathway in your body that carried information about the painful stimulus to your brain. Use the information you have learned about pain to sketch how you think this process occurs. Remember to use what you know about neurons and how they transmit information.

Compare your pain pathway with the pathways drawn by your group members. Check your pathway against the one presented by your teacher. How does it compare? What conclusions can you draw?

A Application

Application I: Modulating Pain

FOCUS QUESTIONS

1. Are there ever circumstances when you injure yourself but do not immediately sense pain? Explain.
2. If pain is necessary, why would people want to stop or reduce pain?
3. What are some of the things YOU do to stop or reduce pain? You may want to refer to your answers to questions in ***Exploration I*** before you write your answer.

FOCUS QUESTIONS
— Continued

4. Choose one of the methods for stopping or reducing pain that you listed in Question 3. Using the information you have learned about the transmission of pain and the pain pathway you drew, predict how this method stops or reduces pain. You may want to draw a diagram illustrating how your predicted mechanism works.
5. Your teacher will provide information about how some painkillers work. Using this information and your own library research, compare the prediction you made in #4 with the most up-to-date understanding neuroscientists have for how this method works to stop or reduce pain.
6. Were there differences between your prediction and the mechanism understood by neuroscientists? Do you now understand the reasons for the neuroscientists' explanation?

Application II: Pain-Related Phenomena

FOCUS QUESTIONS

1. Choose one of the questions about phenomena related to pain listed below. Using the information you have learned about the transmission of pain and the pain pathway you drew, predict the physiological mechanism of this phenomenon in the body. You may want to draw a diagram illustrating how your predicted mechanism works:
   - How does itching occur? Is it considered pain?
   - How does tickling occur? Is it considered pain?
   - How do natural endorphins reduce or block pain?
   - How does capsaicin, an ingredient in hot chili peppers, reduce pain?
   - What mechanism is responsible for hyperalgesia?
   - What causes referred pain?
   - What mechanism is responsible for the placebo effect?
   - What mechanism is responsible for phantom limb pain?
   - What mechanism is responsible for the effects of acupuncture?
   - What mechanism is responsible for migraine headaches?
2. Conduct your own library research to learn about the most up-to-date understanding neuroscientists have for how this phenomenon works. Compare the prediction you made in #1 with the explanation of the phenomenon provided by neuroscientists.
3. Were there differences between your prediction and the mechanism provided by neuroscientists? Do you now understand the reasons for the neuroscientists' explanation?

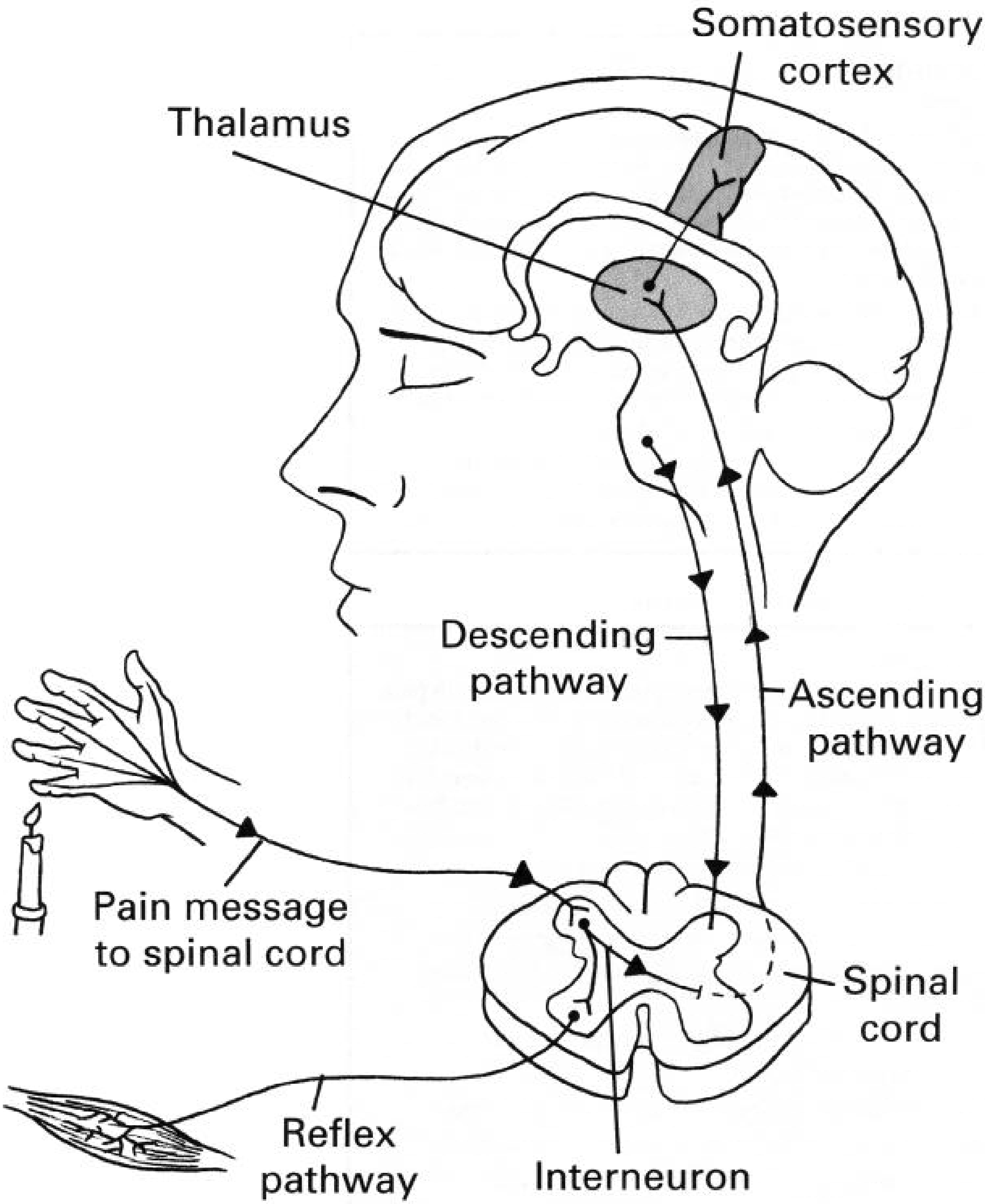

Figure 1. Transmission of pain messages to the brain.

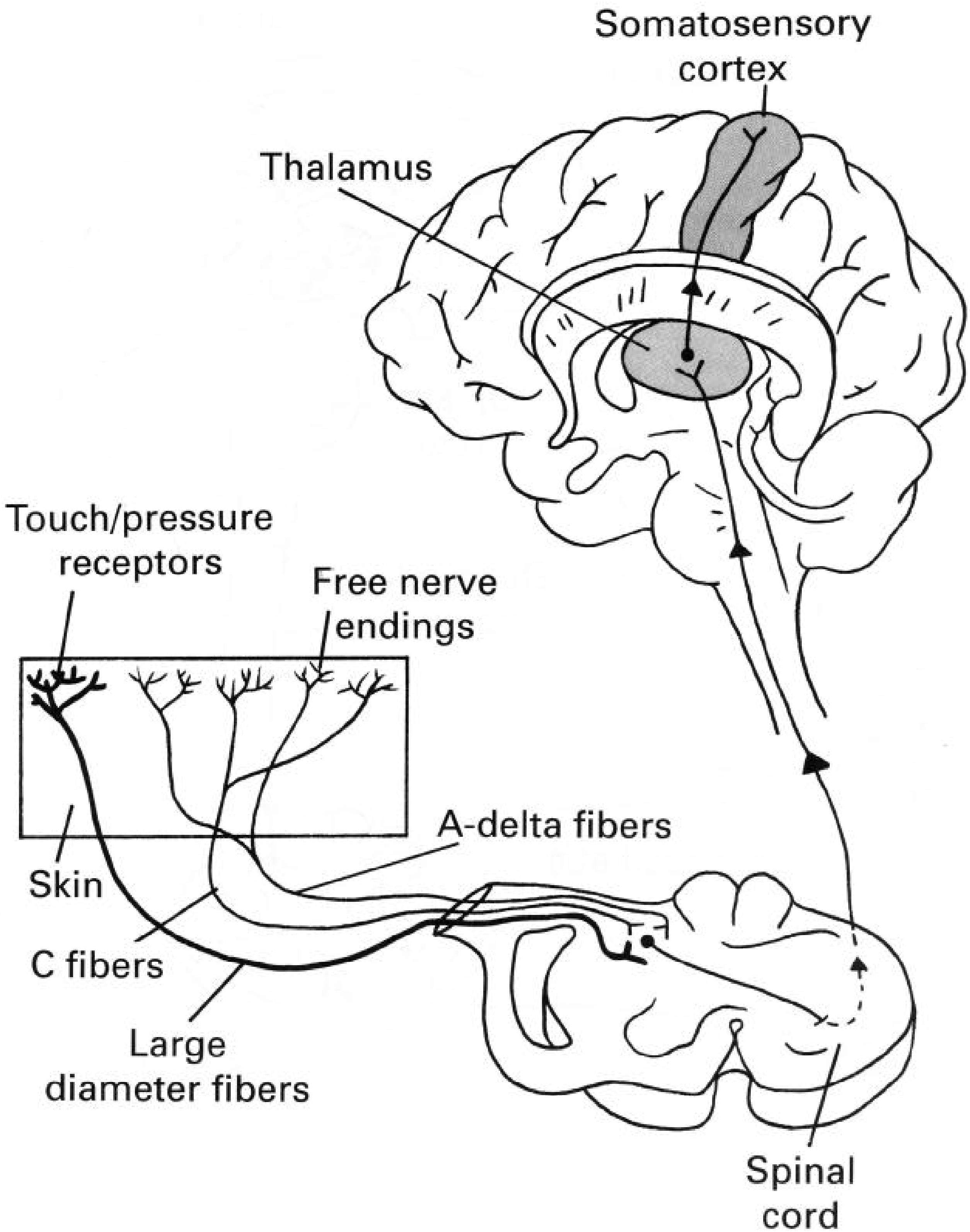

Figure 2. Different types of nerve fibers carrying pain sensations.

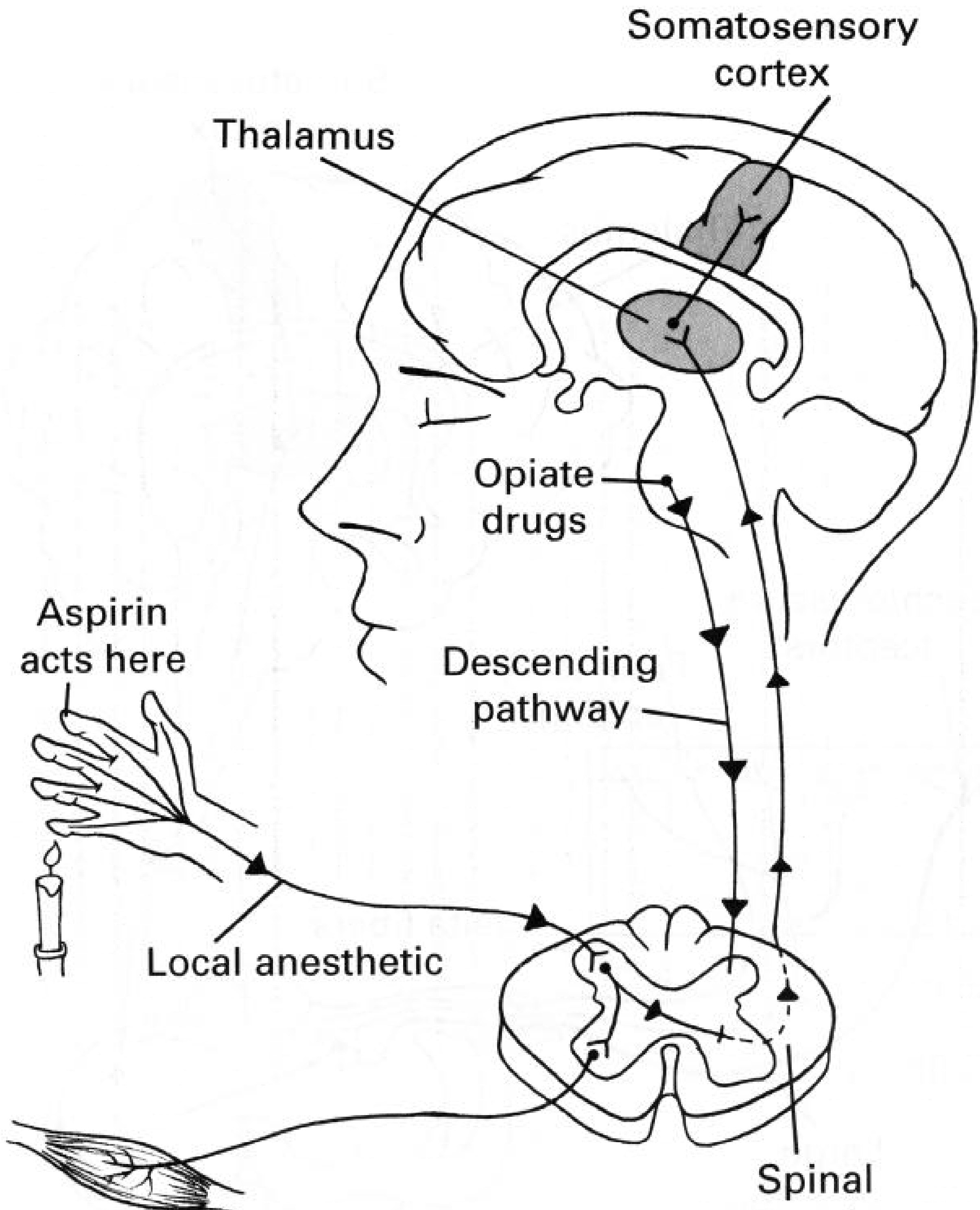

Figure 3. Sites of action of different painkillers.

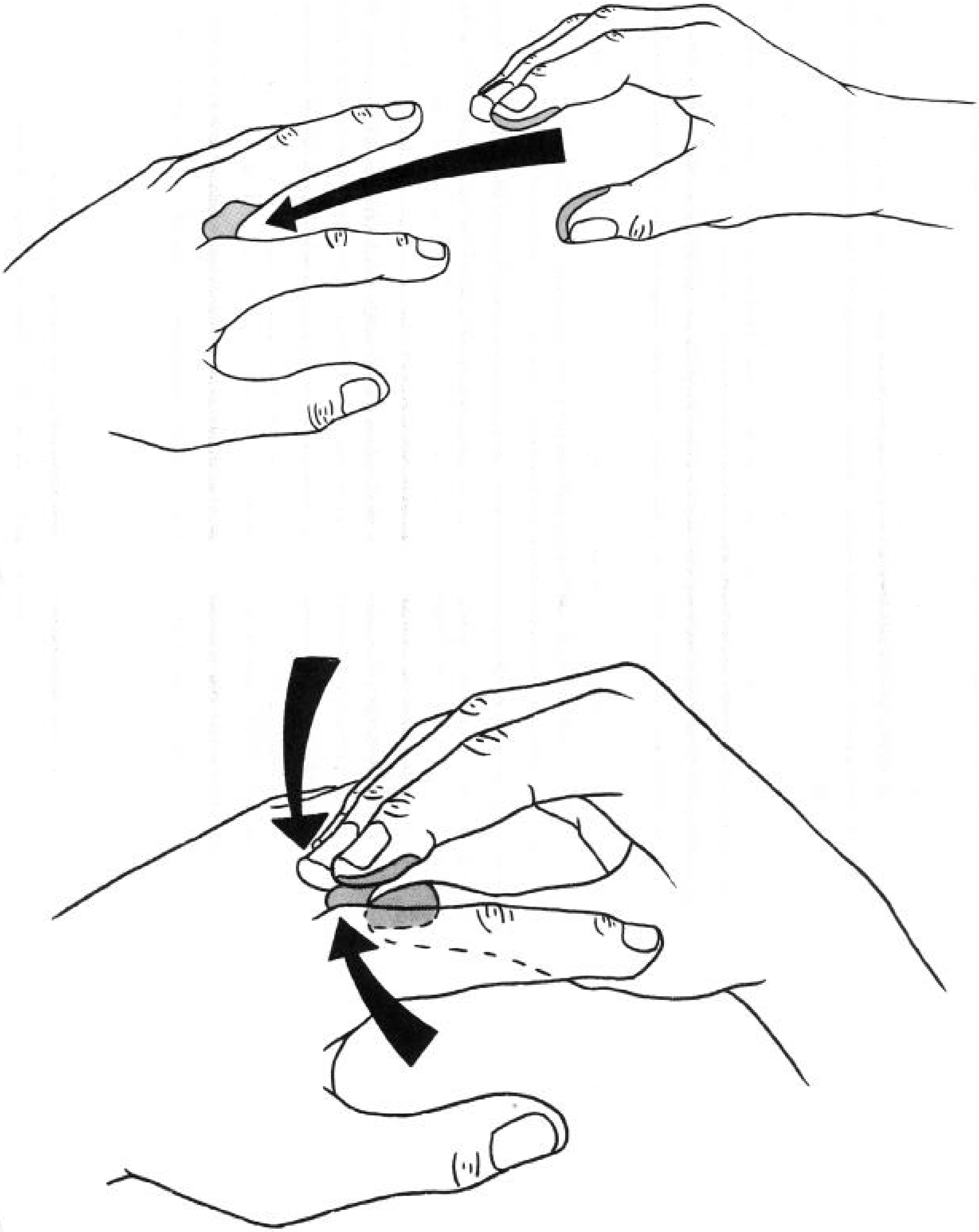

Figure 4b. Technique for pinching finger web.