NEURAL PROCESSING ACTIVITY

Directions for Teachers

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SYNOPSIS
Students will construct simple series and parallel electrical circuits to develop an understanding through analogy of how impulses in the human nervous system are transmitted. They then will identify factors that can interrupt the electrical current in the circuits and predict how injuries to the nervous system can interfere with nerve signals.

LEVEL

Exploration Phase

Concept/Term Introduction, Application Phases

STUDENT PRIOR KNOWLEDGE

Before participating in this activity students should be able to:

- Describe the parts of a neuron and their functions.
- Explain synaptic transmission.
- Describe briefly the general organization of the nervous system.

INTEGRATION

Into the Biology Curriculum

- Health
- Biology II
- Anatomy and Physiology
- AP Biology

Across the Curriculum

- Computer Science
- Physics

OBJECTIVES

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

- Compare series and parallel electrical circuits to pathways in the nervous system.
- Construct an electrical circuit that illustrates parallel processing from many sensory receptors to one brain cell.
- Discuss how the normal functioning of the nervous system can be disrupted by injury or disorders.

Getting Ready

See sidebars for additional information regarding preparation of this lab.

Directions for Setting Up the Lab

E Exploration

Circuit Board Construction

- Make photocopies and/or overhead transparencies of Figures 5a and 5b.

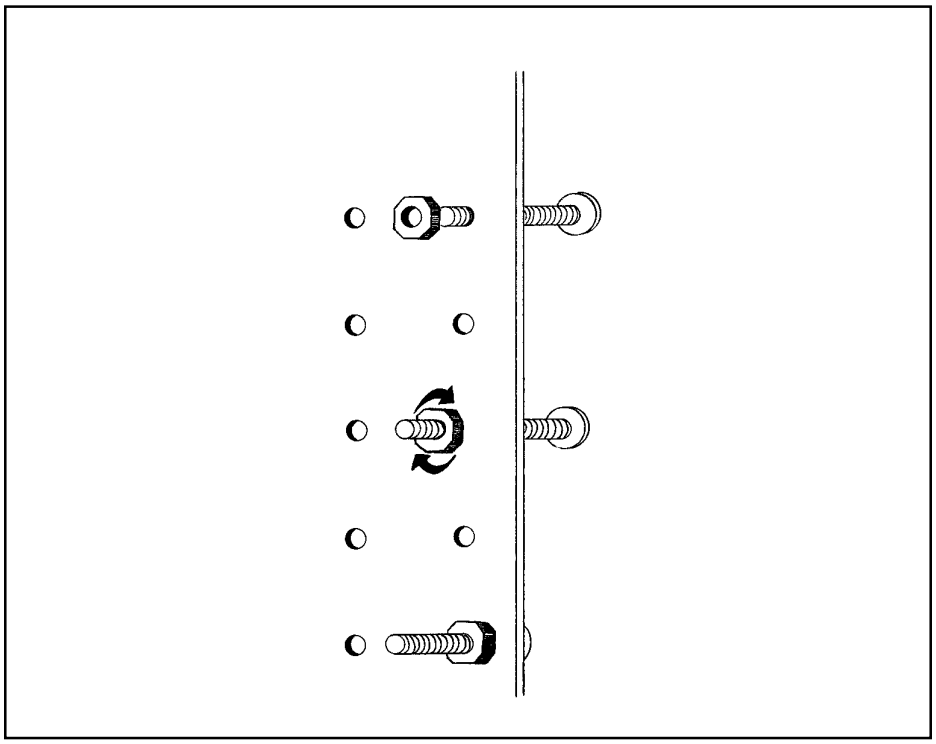

Figure 1. Pegboard with bolts secured with nuts.

LENGTH OF LAB

A suggested time allotment follows:

Day 1

E *5 minutes* — Conduct initial demonstration.
40 minutes — Conduct the initial activity.

Day 2

C *10 minutes* — Develop explanations for the activity.

A *20 minutes* — Design circuits.

MATERIALS NEEDED

You will need the following for the teacher-led introduction:

- Two strings of Christmas lights, one wired serial and one wired parallel

You will need the following for teacher preparation only:

- 1 pair electrical pliers
- 1 soldering iron

You will need the following for each group of four students in a class of 24:

E 1 pegboard section 30 x 30 cm wired with the following materials:

- 6 1-inch bolts and nuts
- 1 6-volt battery
- 3 6-volt lightbulbs
- 4 m 14-gauge insulated wire
- 45 cm 14-gauge uninsulated wire
- 16 alligator clips

C Materials listed in E

— Continued

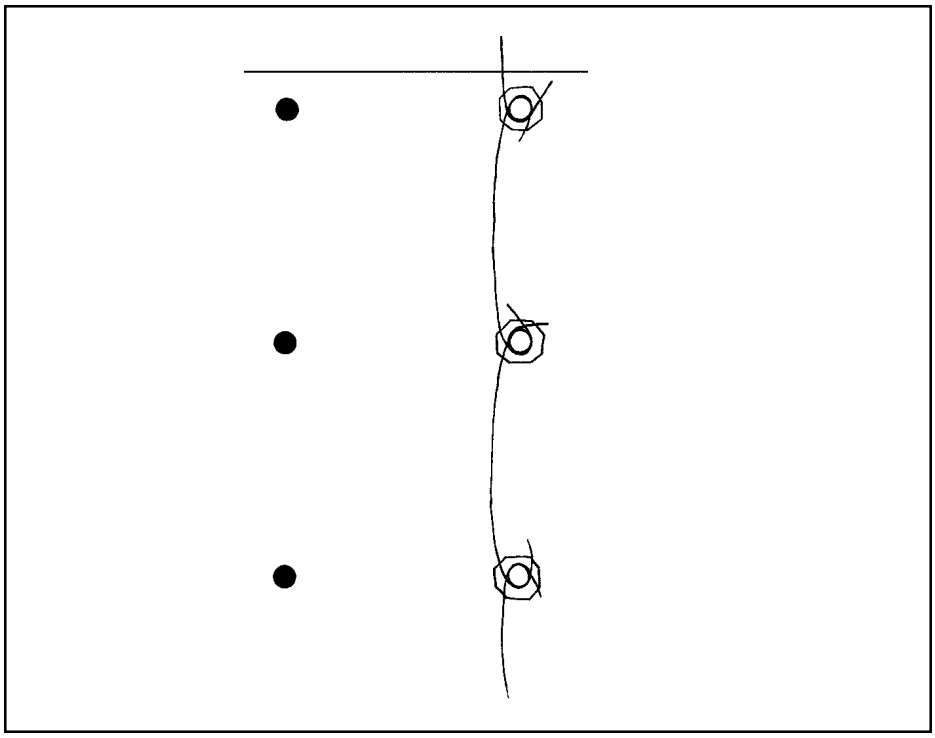

Figure 2. Row of bolts connected with uninsulated wire.

- For each student group you will need to do the following:
  1. Have the lumber or hardware store precut a 4 x 8 foot (122 x 244 cm) piece of pegboard into 30 x 30 cm squares.
  2. Push six bolts through the openings in each 30 x 30 cm square of pegboard as shown in Figure 1 and secure the bolts with six nuts. (Note: Figures 1 and 2 represent only a portion of the completed setup.)
  3. Connect a row of bolts along one end of the pegboard with 45 cm of uninsulated wire as shown in Figure 2. Be sure the wire touches each bolt to ensure that each bolt will be "live" when the wire is connected to the battery.
  4. Cut 4 m of insulated wire into 30 cm lengths.
  5. Remove approximately 1 cm of insulation from both ends of two lengths of the wire cut in Step 4.
  6. Connect an alligator clip to one stripped portion of each wire.
  7. Solder the other stripped ends of the wires on the positive and negative poles of a lightbulb, as shown in Figure 3. Make three sets.
  8. Repeat Step 5 for five additional lengths of wire. Connect an alligator clip to each of the stripped ends. Two of these wires will connect the battery to the pegboard, as shown in Figure 4.

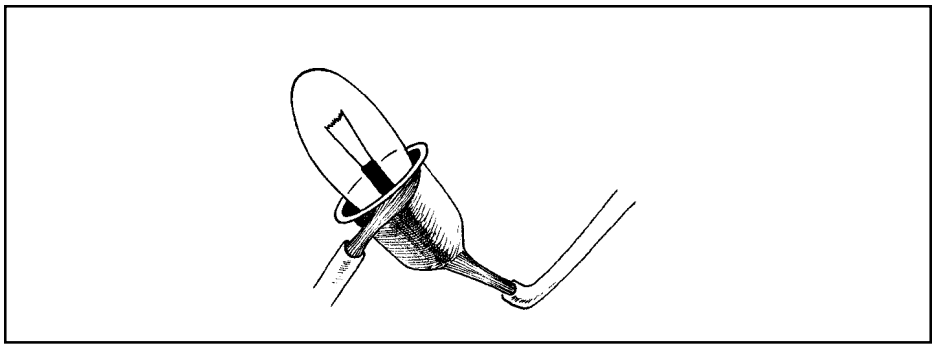

Figure 3. Solder wires to bulb.

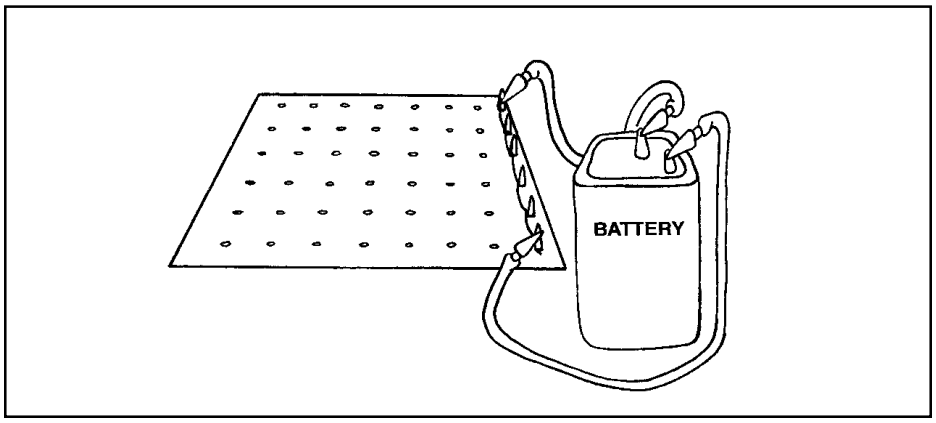

Figure 4. Circuit board showing the battery connected to the pegboard.

A Application

If the optional ***Application*** phase is done, repeat Steps 4–7 for four sets with four different colors of insulated wire. Also, obtain three additional pegboards, 40 x 40 cm, and three additional 15-cm lengths of uninsulated wire.

Teacher Background

Most students are interested in how the human nervous system transmits information, but the highly abstract concepts involved are often difficult for students to grasp. Building series and parallel electrical circuits, and exploring their functional differences, can give students a concrete representation of the patterns of neural processing. Additionally, interruption of serial as compared to parallel circuits can provide students with an understanding of varying effects of trauma in the brain such as stroke, tumors, or direct injury.

Serial processing describes nerve impulses that travel along single pathways to specific areas in the nervous system, or to effectors such as muscles. Parallel processing may be compared to neuronal inputs that are separated onto several pathways and travel simultaneously to various parts of the nervous system. Neuroscientists use the terms *serial* and *parallel processing* to describe neuronal function because they work much like the electric circuits of the same names. It should be emphasized, however, that while

MATERIALS *—Continued*

A Materials listed in E

- 60 cm each of four different colors of 14-gauge insulated wire (optional)
- 4 6-volt lightbulbs (optional)
- 8 alligator clips (optional)
- 1 pegboard 40 x 40 cm (optional)
- 3 15-cm lengths uninsulated wire

PREPARATION TIME REQUIRED

E
- *1 hour* to purchase materials
- *6 hours* to assemble the circuit boards
- *15 minutes* to prepare photocopies and/or overhead transparencies of Figures 5a and 5b.

SAFETY NOTES

- Remind students that even with the low voltage used in this activity, they should not make a closed circuit with their hands by grasping wires leading to the negative and positive poles of the battery at the same time.
- The lightbulbs get hot. Caution students not to touch them. Remind them that even unlit lightbulbs may be hot.

TEACHING TIPS

- Materials can be purchased at hardware or electronic stores or through vendor catalogs that feature physics or physical science supplies. Circuit boards can be purchased from scientific supply companies.
- Christmas lights come in two types of wiring, serial and parallel. Usually, the inexpensive lights are in serial and the more expensive ones are parallel. A good way to check is to see what happens when you remove one light. If the string of lights goes out when one bulb is removed, it is a serial wiring. If they do not all go out, you have parallel wiring.
- Circuit boards, if available, may be borrowed from the physics department.

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

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the patterns have similarities, students should not develop the idea that a nerve impulse is a flow of electrons like that in an electrical circuit. An understanding of action potentials and synaptic transmission is useful also in comprehending the different pathways that information might take in the body, and how interruptions in these pathways can affect the body's ability to function.

Serial pathways in the nervous system are composed of single neurons that synapse with the next neuron in line. The simplest neuronal circuits are the spinal reflexes composed of two or three neurons. An example is the knee-jerk reflex, produced by two neurons that synapse in the spinal cord. A tap on the patellar tendon just below the kneecap generates a burst of nerve impulses initiated in muscle stretch receptors and conducted along sensory fibers of a dorsal root ganglion cell to synapse on motor neurons in the spinal cord. In response, the motor neurons in the spinal cord are excited and contract the quadriceps muscle resulting in an upward jerk of the lower leg. (For more information on this reflex, including a diagram, refer to "What's the Connection?" on p. 59.)

Serial processing allows for rapid response. In many stretch reflexes, the processing is completed at the spinal cord, and a return message is sent back to the muscles involved. If a trauma causes damage to a serial pathway, the message is interrupted and the intended outcome, such as a knee-jerk reflex, cannot occur. There are also serial pathways, such as some of those involved in posture and locomotion, that go from sensory receptors through the spinal cord to the brain for processing.

Parallel processing allows the brain to consider all aspects of a stimulus and react to it if necessary. Inputs processed in a parallel pathway are distributed to different neurons, and the separate impulses are processed in different areas of the nervous system. Thus, the same stimulus may evoke any number of responses in the human brain. For example, smelling violets might bring to mind the color and shape of the flower, while also reminding you of your grandmother — and the fact that her birthday is near and you must shop for a gift. Visual processing is also an example of a parallel pathway. Visual stimuli are perceived when the brain interprets form, movement, color, and background, but the loss of one or more of these functions would not result in blindness. In using the complicated parallel circuits in the *Application* phase of this activity, students will notice that the bulb representing the highest order brain cell will become dimmer as they remove lower elements from the circuit. This is characteristic of a parallel circuit. As an additional analogy, suggest that as humans lose more and more aspects of sensory perception, it becomes harder to identify things in the environment.

Due to the presence of serial and parallel circuits in the central nervous system (CNS), traumatic injury to the spinal cord or brain can produce a wide range of outcomes, leading to varying prognoses. For example, spinal cord injury often leads to paralysis due to the interruption of a serial circuit to neurons that activate muscles directly. Conversely, strokes in the cerebral cortex, where there are many converging parallel pathways, may produce

complex losses of components of intellectual, behavioral, and cognitive functions.

This activity can enable students to explore the relationship of serial and parallel circuitry and damage to the CNS to the prognoses for individuals with:

- Spinal cord or head injury
- Stroke
- Tumors of the nervous system
- Physical damage related to alcohol abuse.

It is interesting to consider the effects of such trauma in children during the first 6 to 10 years of life that are considered to be the developmental period of the nervous system. Students can compare what happens to children at this age to adults. With age, there is a diminution in the ability of the brain to respond to trauma.

Procedure

Below is a suggestion for introducing the activity.

- Light two strings of Christmas lights, one wired parallel and one wired serially.
- Tell students that today they will consider ways messages flow in the nervous system.
- Then, take a bulb out of each string. As you do this, tell them that they will also consider how the nervous system responds in a similar way.
- Instruct them to use the circuit boards at their lab stations to hypothesize what occurred.

E Exploration

The ***Exploration*** activity demonstrates the concepts of serial and parallel circuits. A suggested student procedure for conducting the activity with small groups is listed below.

1. Divide the class into six groups of four students each and have each group conduct the activity.
2. With one pole of the battery connected to the uninsulated wire on the board, allow students to connect the wires in any way that will make the lights glow.
3. Ask students how they set up the board to make the lights glow.
4. Instruct students to set up their boards as diagrammed in Figures 5a and b.
5. Have them describe what is different between the two setups.

C Concept/Term Introduction

1. Introduce the terms *serial* and *parallel* and have students relate them to the two setups in the ***Exploration*** section.

SUGGESTED MODIFICATIONS — *Continued*

Assistive Listening Devices (ALDs); light probes; and talking thermometers, calculators, and clocks.

Blind or Visually Impaired

- Replace lightbulbs with buzzers in circuits for students with no vision.
- Provide all diagrams as raised line drawings using a Sewell Drawing Kit or make a tactile diagram using string, glue, and any found items that have texture for a student with no vision. Use photo-enlarged diagrams for students with limited vision.

Gifted

Advanced students can build upon the information in this activity to develop an understanding of how the nervous system integrates information for cognitive functions. They may also translate their knowledge to applications in artificial intelligence. An understanding of the power of parallel circuitry is being incorporated into all modern efforts in artificial intelligence. Explore such applications, including the benefit of such knowledge in computer science.

Mobility Impaired

Have the student with limited use of his/her arms and hands act as an advisor in assembling the circuit board. Students with other physical disabilities should have no difficulty with this exercise.

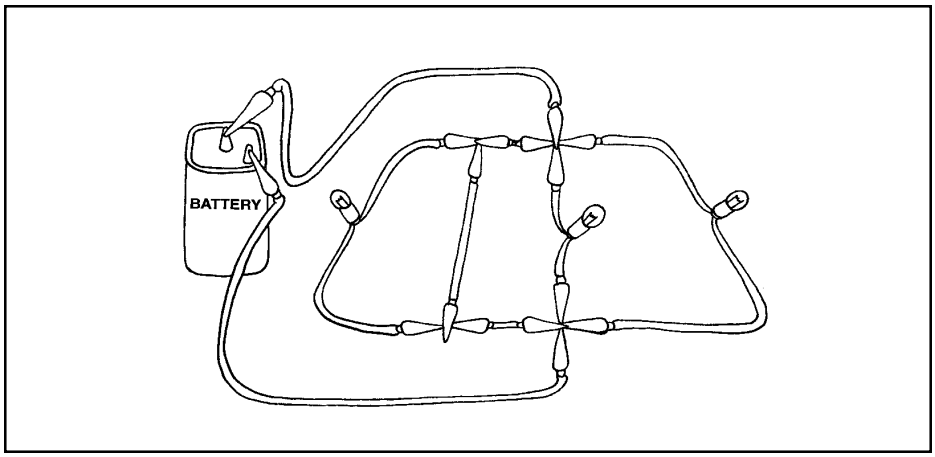

Figure 5a. Parallel pathway.

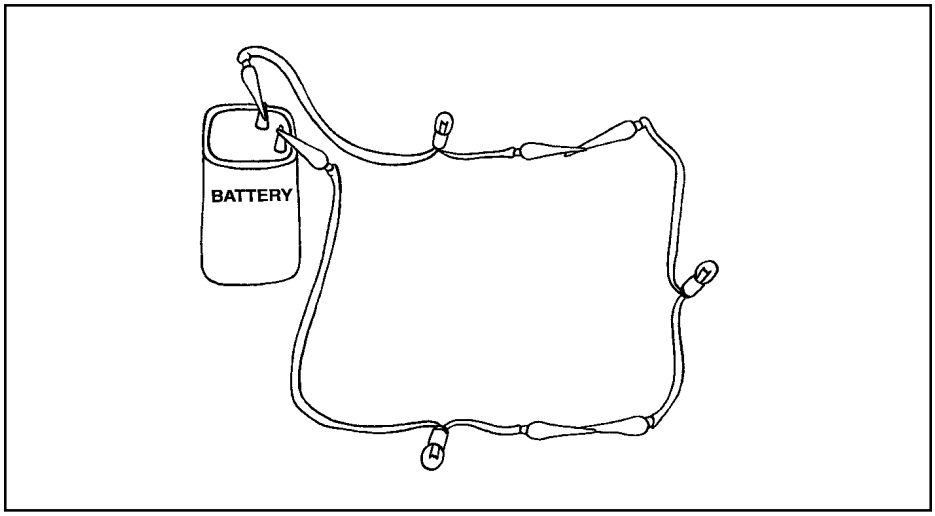

Figure 5b. Serial pathway.

2. If students have done the lab "What's the Connection?" have them follow the information in **Directions for Students** for this lab. If they have not done "What's the Connection?," review the elements of a reflex arc and then proceed with **Directions for Students**.
3. You may want to listen to the group discussions to be sure students do not have misconceptions about circuits.
4. Information regarding the **Focus Questions** may be found in the **Teacher Background** sections of this activity and "What's the Connection?"

A Application

Students now can build on their previous experiences and learn more about neural information processing using the circuit boards used in the ***Exploration*** activity. Circuit board designs can be used only to predict how injuries to the nervous system can interfere with nerve signals. Have them follow the instructions in **Directions for Students** for the ***Application*** section. A circuit board design that students may develop includes the following:

- Multiple sensory inputs to a single brain cell.
  Construct a more complex student-designed circuit with both serial and parallel components. This may be representative of multiple sensory inputs to a single brain cell. A hypothetical example would be that one brain cell recognizes the concept of a cat. The four wires leading to it represent nerve connections from four senses that can help us recognize a cat: vision, hearing, touch, and olfaction. Each sense might be represented with a different colored wire and involves different kinds of sensory input. For example, visual recognition may involve both color and shape; touch would include texture and warmth. These are represented on the lowest level of lightbulbs, as shown in
  Figure 6.

Questions such as the following may be explored:

- What happens to various lightbulbs, especially a lightbulb that might represent recognition of the object, when one of the sensory inputs is removed?
- How many sensory inputs can be removed and still allow the recognition lightbulb to remain lit?
- What happens to the parallel pathways as each lightbulb is removed? The serial pathways?

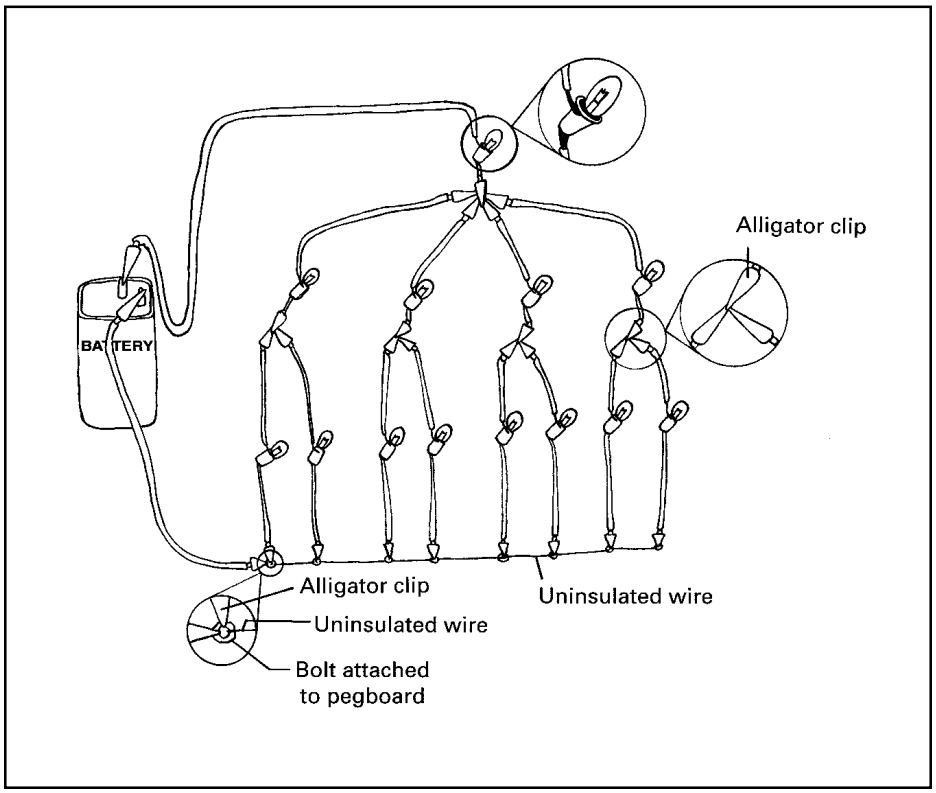

Figure 6. Schematic of student-designed circuit of multiple sensory input to a single brain cell.

- What is the importance of redundancy in the processing pathways of the brain?

  (Note: In order for students to do the setup in Figure 6, two groups will have to share some materials, or you will need to make more materials. The lights at the lowest level are attached to the bolts of the pegboard.)

Answers to Questions in "Directions for Students"

C Concept/Term Introduction

Focus Questions

1. Serial pathways are most prevalent in the spinal cord, and often related to simple reflexes. Parallel pathways provide a mechanism for the same information to be used for multiple purposes, and, at the level of the cerebral cortex, underlie complex cognitive abilities.

2a. Any injury to a component of a serial pathway will cause the entire pathway to lose its function.

2b. No.

2c. Since information is distributed across a parallel pathway, a loss of one limb of the pathway subtly changes the output but will not prevent the entire pathway from operating.

A Application

Focus Questions

3a. A parallel pathway.

3b. Often the ability to regain function in an adult is related to a diminution of the initial inflammatory response in the brain that accompanies a stroke. In a young child, whose brain is considerably more *plastic* than an adult's, recovery of the brain is due to repair of the parallel neuronal circuits.

4a. The spinal cord incorporates numerous serial circuits that, when cut or traumatized, cannot repair themselves.

4b. Diving and motor vehicle accidents are among the leading causes of spinal cord injuries, and subsequent paralysis, for teenagers.

Analysis

1–3. Answers will vary depending on experiments students conduct.

Suggested Reading

Campbell, N.A. (1987). *Biology*. 2nd ed. Redwood City, CA: The Benjamin/Cummings Publishing Company, Inc.

Kalat, J.W. (1988). *Biological psychology*. 3rd ed. Belmont, CA: Wadsworth Publishing.

Kandel, E.R. & Schwartz, J.H. (1982). Molecular biology of learning: Modulation of transmitter release. *Science, 218*, 433–443.

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

Keeton, W.T. & Gould, J.L. (1993). *Biological science*. 5th ed. New York: W.W. Norton and Company.

Marieb, E.N. (1995). *Human anatomy and physiology*. 3rd ed. Redwood City, CA: The Benjamin/Cummings Publishing Company, Inc.

NEURAL PROCESSING ACTIVITY

Directions for Students

Introduction

Imagine that you are in a discount store looking at coats on a circular rack. Your friend is standing at the next rack and you are casually discussing the coats. "Oh, isn't this nice?"

"Oh, yes, but I like this one better. What do you think?"

As you are having this conversation, a clerk comes from the back storeroom and removes the coats from the rack where you are standing. As he does, he steps on your toe and says, "Excuse me." You think nothing of it as he starts to move to the front of the store. Then, you hear "Stop! Thief!" Whoops, what is going on? You look in the direction of the yelling and see the "clerk" running wildly toward the front of the store, jumping over the turnstile and trying frantically to get out of the entrance door. Then he jumps back over the turnstile and goes out the exit. Minutes later the police arrive and ask you to describe the thief. What do you remember? You probably will remember only that you thought he was a clerk and that he was polite. You might remember his hands or his shoes. Why would you only remember bits of information? This activity will help you develop an understanding of how your brain processes information and how the stimulus is handled.

The human nervous system can react quickly to stimuli while at the same time processing a great deal of information about them. Different pathways for processing this information have evolved in the nervous system. The demonstration your teacher does and the activities below will help you develop an understanding of these concepts.

Procedure

E Exploration

After your teacher introduces the lab, you will conduct a simple activity with the materials in front of you. Follow the directions your teacher gives you.

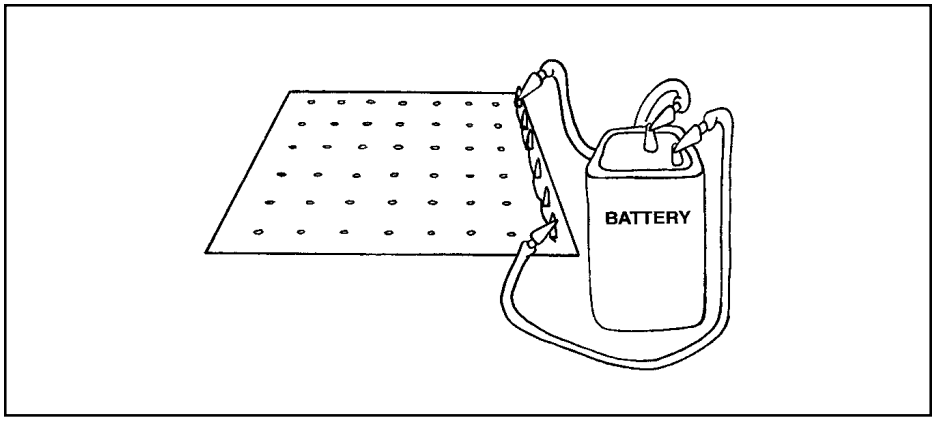

Figure 1. Circuit board showing the battery connected to the pegboard.

MATERIALS

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

- 1 pegboard setup
- 1 6-volt battery
- 3 wires with lightbulbs in the center and alligator clips on the ends
- 5 wires with alligator clips on each end

(Additional optional materials may be provided by your teacher.)

SAFETY NOTES

- Remember that you are working with electricity! Even with the low voltage used in this activity, you should never "close" a circuit with your hands by grasping wires leading to the negative and positive poles of the battery at the same time.
- Remember that lightbulbs can get HOT! Don't touch them until they have cooled.

C Concept/Term Introduction

1. Your teacher will introduce terms and have you relate them to the two setups done in the ***Exploration***.
2. Does one of the setups resemble the diagram of either response in "What's the Connection?" If so, what term would you apply to it?
3. Is all information processed this way in the nervous system? What would it be like if it were? If you are not sure, go back to the **Focus Questions** in "What's the Connection?"
4. Can you apply the other setup to processing information in the nervous system? Brainstorm ideas with your group about ways this other setup may be used in the nervous system to process information.

A Application

FOCUS QUESTIONS

Answer the following questions in your group:

1. Using the terms introduced by your teacher, what are the major differences between the two pathways in the human nervous system?

2a. How would an injury to the pathway, such as that in "What's the Connection" affect the impulse transmission in that pathway?

2b. Would the effect be the same in the other pathway discussed above?

2c. Why?

3a. Research the cause and effect of strokes in the brain. If a patient

1. What happens when a wire is removed from each setup? How does this relate to **Focus Questions** 1 and 2?
2. Make a list of the advantages and disadvantages of each type of circuit.
3. Compile a list of ways each setup might represent the processing of information by the nervous system.
4. Individually research ways the nervous system processes information and pool your research. Be prepared to present your ideas to the class.
5. In your group, design a way to change your setup to simulate an interruption of the nervous system's information processing. Predict what will happen when you make the change and explain your reasoning. Answer **Focus Questions** 3 and 4 before you make your prediction.

FOCUS QUESTIONS
— Continued

is unable to talk after a stroke, but later regains the ability to talk, which type of pathway was most likely affected?

3b. How does this recovery differ with age?

4a. Explain why injuries to the spinal cord are often permanent.

4b. What are some of the leading causes of spinal cord injuries in teenagers?

Teacher approval must be obtained before you begin this activity!

Analysis

1. Did your group obtain the results you expected?
2. How do you explain your results in terms of what you learned during group sharing?
3. Draw a concept map to explain your results.

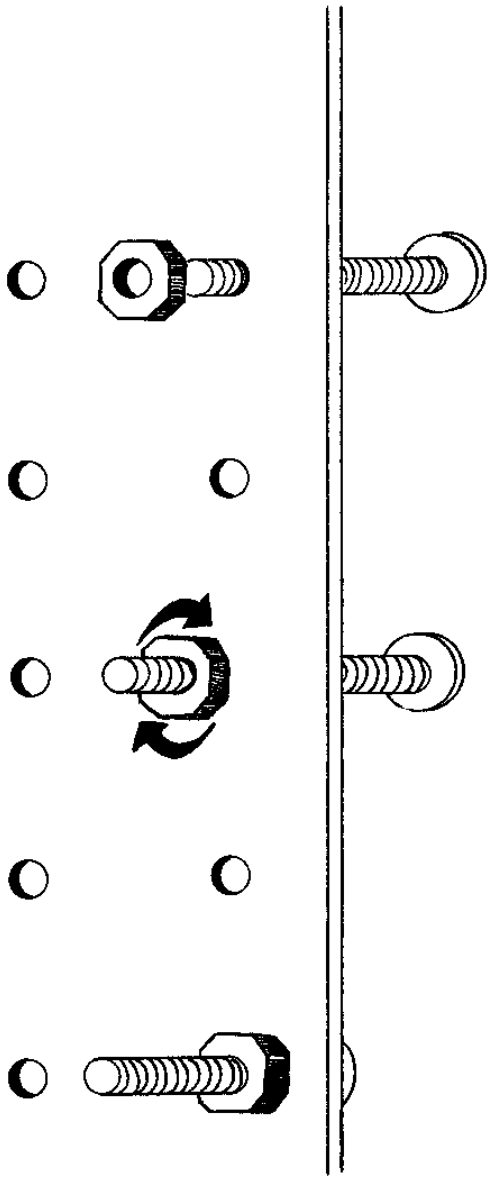

Figure 1. Pegboard with bolts secured with nuts.

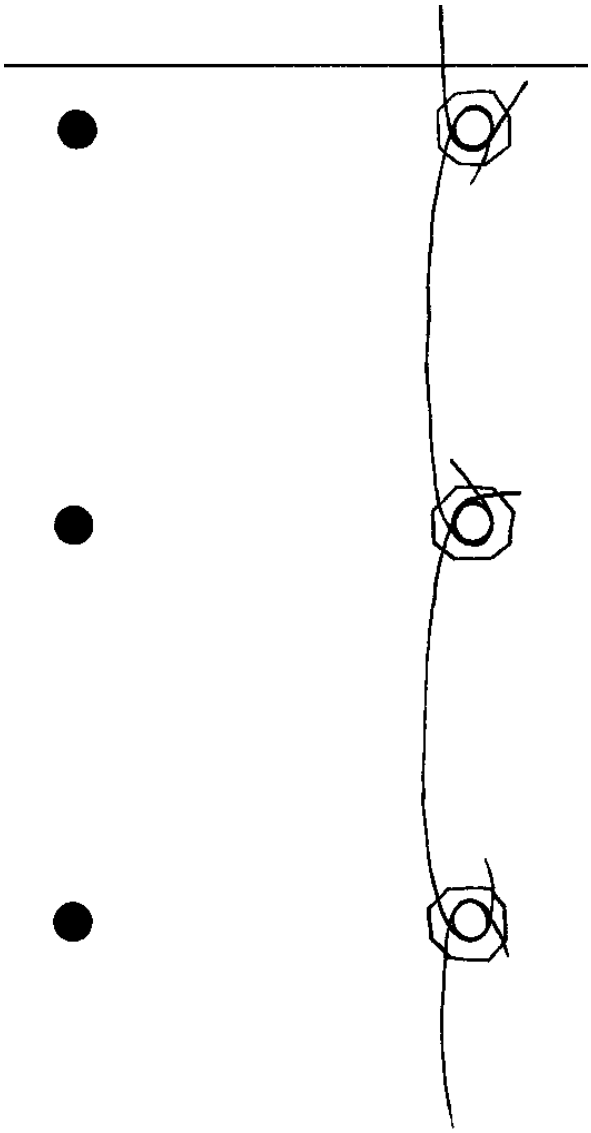

Figure 2. Row of bolts connected with uninsulated wire.

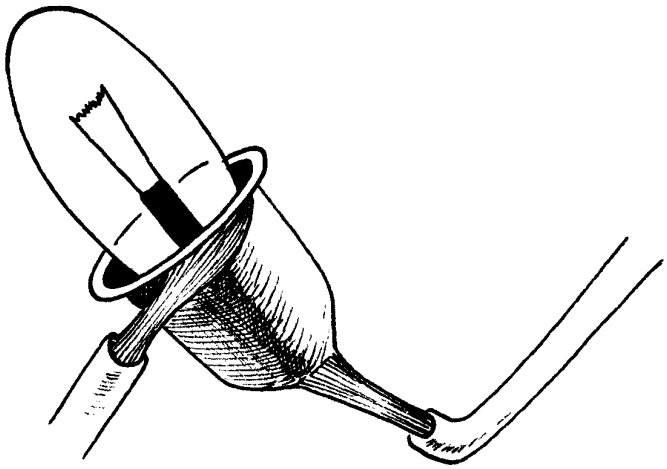

Figure 3. Solder wires to bulb.

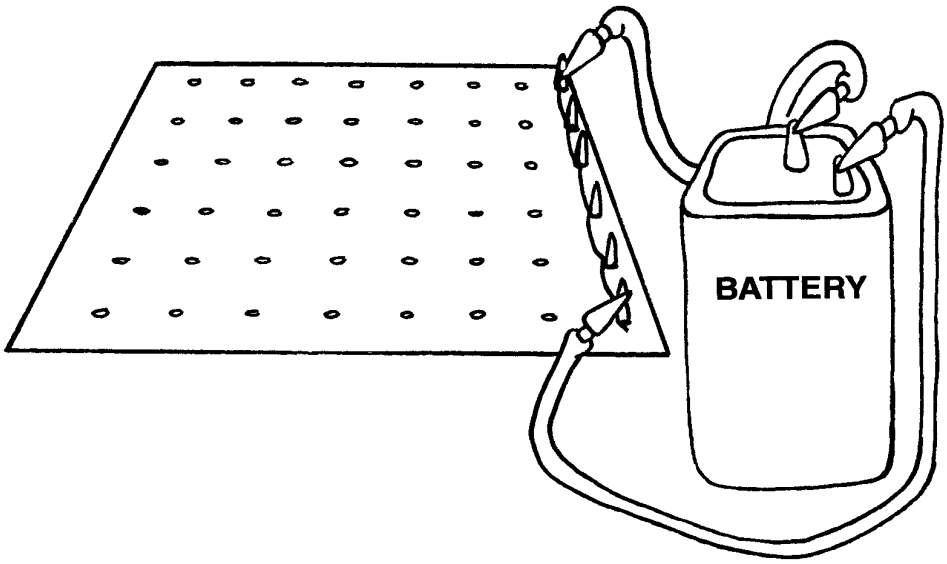

Figure 4. Circuit board showing the battery connected to the pegboard.

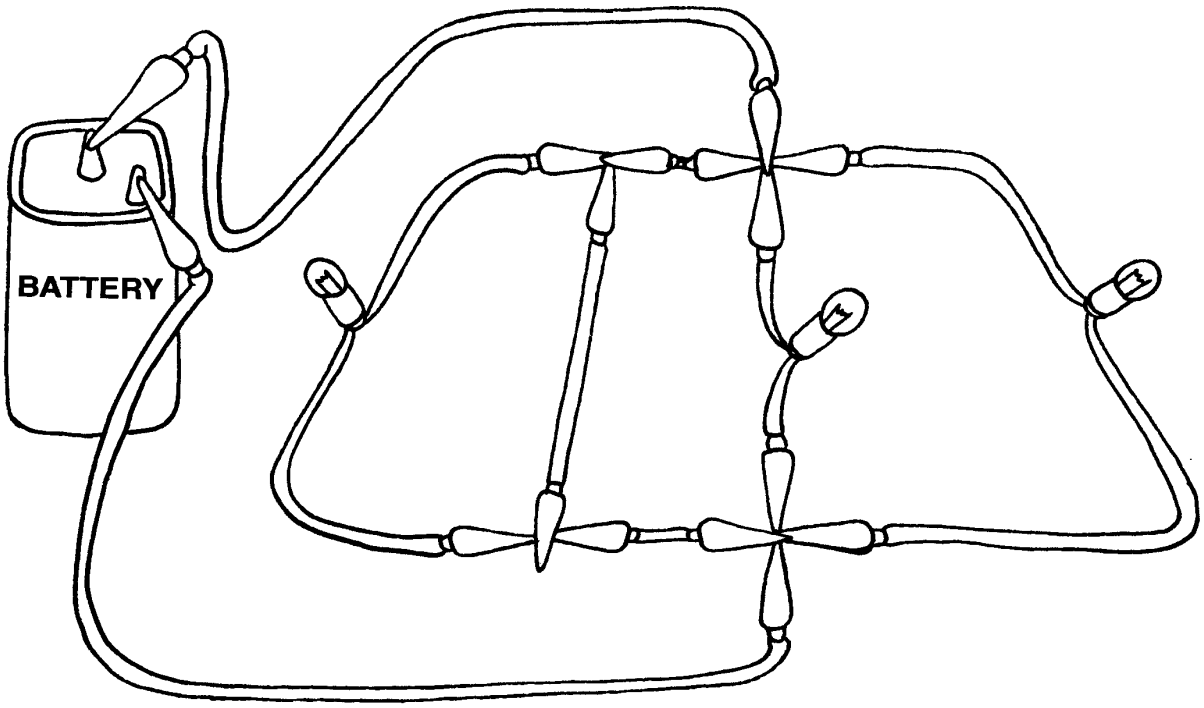

Figure 5a. Parallel pathway.

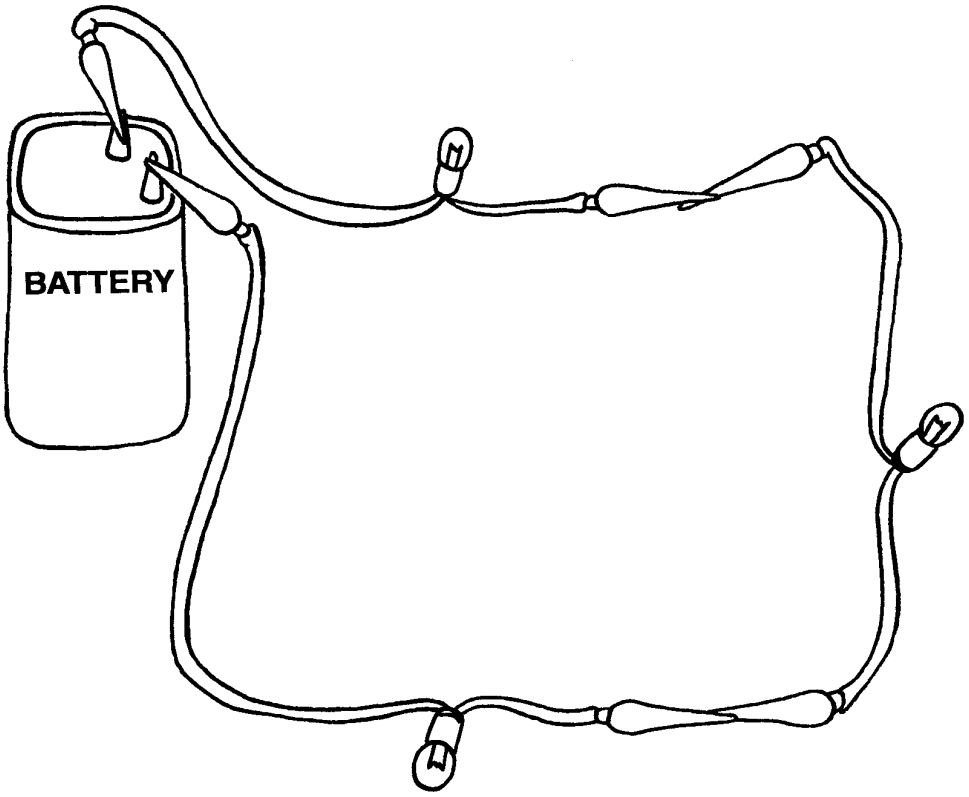

Figure 5b. Serial pathway.

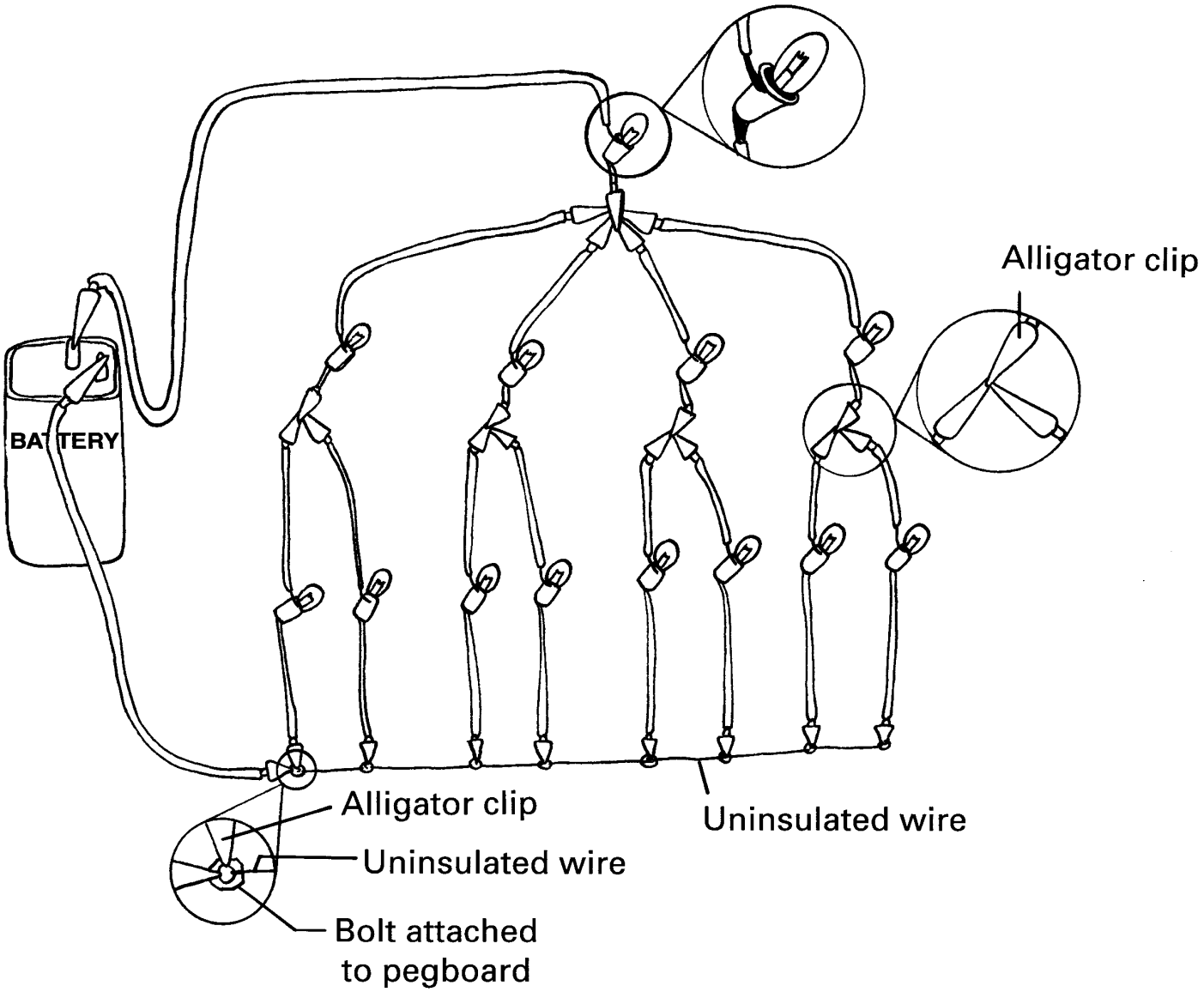

Figure 6. Schematic of student-designed circuit of multiple sensory input to a single brain cell.