HEARING IN THE DARK

Directions for Teachers

SYNOPSIS

In this activity students will explore how information is acquired and interpreted by the sense of hearing, specifically as it involves the ear and brainstem. After participating in an exercise that demonstrates the brain's ability to identify the location of a sound, students will design experiments to examine other characteristics of the sense of hearing.

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

E Exploration

- Locate sound makers, Post-it™ notes.
- Make an overhead transparency of circular locations of noisemakers, as shown in Figure 1.
- Make student data charts. See Sample Data Chart in Figure 2.

Teacher Background

Many neural signals are initiated by a stimulus to a defined set of receptors on one side of the body. These signals travel through the nervous system and are usually interpreted in the side of the brain opposite the side where the stimulus was received.

For example, if someone is pinched on the left hand, the neural signals initiated by the pinch travel to the spinal cord. These impulses enter the left side of the spinal cord and cross over to the right side of the brain.

They are now on the opposite, or contralateral, side of the nervous system from where they were initiated. These impulses will now be processed on the right, not the left, side of the brain.

The auditory pathway has bilateral input, receiving information from both ears. Much of our ability to extract information from sound is based on comparisons of the slight differences detected by each of our ears.

The auditory signal leaves the cochlea and travels down the eighth cranial nerve terminating in the cochlear nucleus in the brainstem. Axons from neurons within the cochlear nucleus carry the signal to the olivary nucleus (see Figure 3). Sound comparisons are carried out in the olivary

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STUDENT PRIOR KNOWLEDGE

Before participating in this activity students should be able to:

- Explain in very general terms how the outer, middle, and inner ear work together to receive and transmit sound.
- Draw a concept map.

INTEGRATION

Into the Biology Curriculum

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

Across the Curriculum

- Physics

OBJECTIVES

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

- Explain how the ear and/or brainstem assist in determining the location of sounds using external input.
- Design an experiment to determine characteristics of the sense of hearing.

LENGTH OF LAB

A suggested time allotment follows:

Day 1

E *20 minutes* — Conduct the initial demonstration.

C *20 minutes* — Develop explanations for the demonstration.

Day 2

A *45 minutes* — Design and conduct experiments.

MATERIALS NEEDED

E You will need the following for each group of 12 students in a class of 24:

- 1 blindfold
- 8 sound makers
- 8 Post-it notes (optional)
- 1 meter stick (optional)
- 1 location chart (Figure 1)
- 1 data chart (Figure 2)

C You will need the following materials for a class of 24:

- 1 textbook
- 1 VCR with remote control
- Overhead transparencies or chalkboard drawings of Figures 1 and 2

A You will need the following for each group of 12 students in a class of 24:

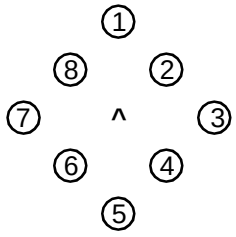
- All materials listed above for E
- 1 pair of ear covers

PREPARATION TIME REQUIRED

E *1 hour* to locate and obtain materials *
45 minutes to make overhead transparencies, photocopies, and/or chalkboard drawings of Figures 1 and 2; and to make labels for noisemakers to wear *

A *30 minutes* per class to review student proposals

* Less time will be needed if students bring in blindfolds and make labels. Refer to **Teaching Tips** on p. 23 for examples of ear covers, sound makers, and blindfolds.



Key to figures in the diagram.

^ Direction listener faces.

1 Directly in front of the listener.

3 Directly to the right of the listener.

5 Directly behind the listener.

7 Directly to the left of the listener.

2, 4, 6, 8 at 45° angles from the listener.

Figure 1. Circular locations of noisemakers in relation to the listener.

Subject	Experimental Location							
	1	2	3	4	5	6	7	8
Total Correct								
% Correct								

Figure 2. Sample data chart.

nucleus, groups of neurons located on either side of the brainstem. Cells in the olivary nuclei receive input from both ears. They also are capable of comparing the slight differences in time when a sound arrives at each ear and differences in the sound's intensity as perceived by each ear. So if the sound is closest to the right side of the body, it will arrive at the right ear before it arrives at the left ear and also be more intense on the right side. These tiny differences in time and intensity help the brain pinpoint the location of a sound.

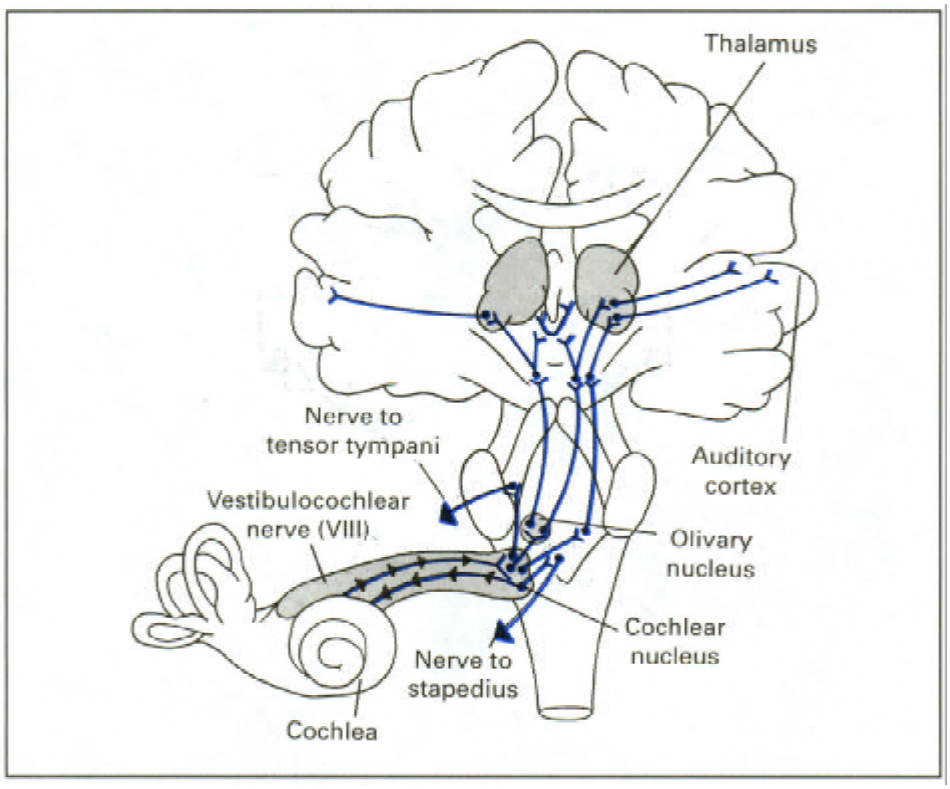


Figure 3. Anatomical drawing of cochlea, olivary nucleus, eighth cranial nerve, and brainstem.

Figure 4 will help clarify how a cell, or group of cells, compares something like the time of arrival or intensity of a signal. When a stimulus arrives in the left ear first, its auditory signal reaches the olivary nucleus before the stimulus from the right side. This means that the signal from the left ear is able to travel farther down the line of neurons than the signal from the right ear before signals from both sides converge on a single neuron. This capacity appears to be partly influenced by learning; it is experience that helps teach an individual how to recognize the direction of a sound.

Conversely, this mechanism makes it difficult to determine whether a sound originates directly in front or directly in back without using other senses, such as sight or touch. A sound coming from the front or back will arrive in both ears simultaneously, but be processed differently from sound received at the side.

Procedure

Below are three suggested ways for introducing the activity.

- Without speaking, open the class by dropping a textbook. Then, without students seeing you, push the remote button of a VCR programmed for sound only. Ask students to describe what has happened.
- Begin the class with two minutes of silence. Have students listen and list all the sounds they hear and any other information about the sounds.
- Assign students to make a list of all the noises they hear on the way to or from school, at lunch, at home, during dinner, or while they are

SAFETY NOTES

- The ear cover should not enter the ear canal. It should cover only the outside of the ear, just as an earmuff does. Do not use earplugs because they go into the ear canal and can transmit disease.
- The sound makers should not be too loud or too close to the listener's ears. The teacher should approve sound makers before they are used.
- The blindfold should be secured around the eyes of the listener with a minimum amount of pressure. Seat the listener safely in the center of the experimental circle. Remind students that they are responsible for the safety of the listener.
- Students should not share blindfolds, as they may transmit disease.
- Warn students to keep all sound makers away from the eyes.

TEACHING TIPS

- The sound made by clapping hands does not work well because the intensity varies depending on the student who is clapping.
- Examples of sound makers that work well include:
  - clickers, available from toy or nature stores for about $3.00 each
  - 1 pair of chopsticks per student, available from kitchenware stores for about $0.20 per pair
  - 2 blocks of wood, available possibly from the Music or Shop department.
- Sounds made by chopsticks or blocks of wood should be practiced by students with the listener out of hearing

— Continued

TEACHING TIPS — Continued

distance before the actual experiment. The practice period will help ensure that the sounds are of the same type and intensity.

- The data recorder's task will be easier if each person making a sound wears a label indicating the number of his/her location. Labels can be made from paper adhesive name tags, or from Post-it notes.
- Blindfolds can be made from a handkerchief, headband, or safety goggles stuffed with cotton.
- Ear covers should sufficiently cover a single ear to block sound. Students may increase the effectiveness of the ear covering by placing cotton against the ear before positioning the cover.

  Examples include:
  - having students cover the ear with the palm of the hand
  - using stereo headphones.
- An area such as the outdoors, a gymnasium, hall, or auditorium works well because groups can be separated. Other possibilities are to have groups work in different corners of the classroom, or to have groups take turns.
- To save preparation time, assign students to bring in their own blindfolds and make labels for noisemakers to wear.
- It may be difficult for some students to record data for all eight noisemakers. An alternative way to organize the class for the

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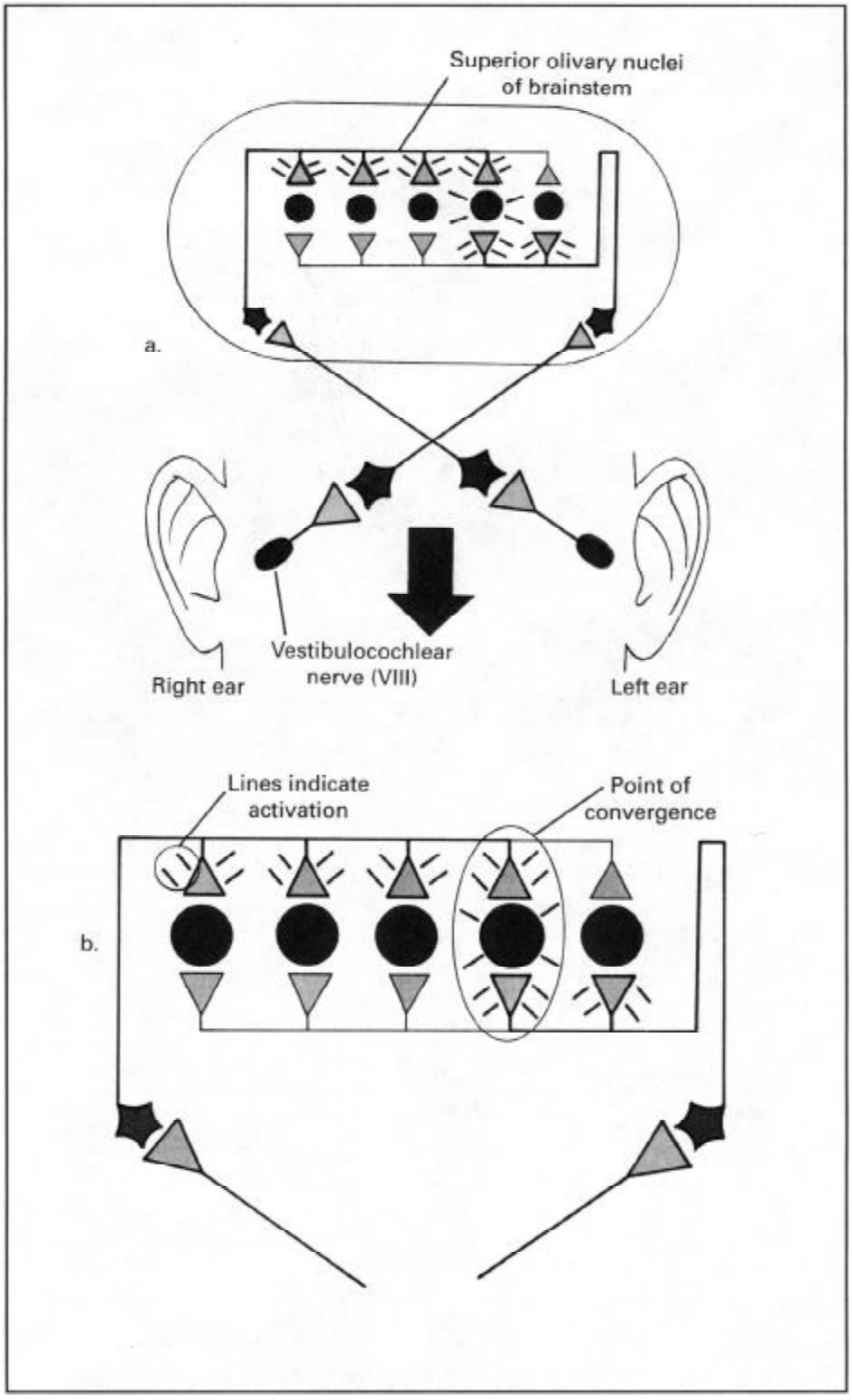

Figures 4a and 4b. Schematic of how sound is processed in relation to time of arrival or intensity of a signal.

doing their homework.

Then have students discuss the sounds they listed and what information they collected regarding these sounds. Questions you may use with this discussion might be:

- How many different sounds did you list?
- Did the number of different sounds you heard increase or decrease as you listened?
- Could you tell the direction the sounds were coming from when you did not see the sound being made?
- Did you do anything to hear the sounds better?
- Did you close your eyes to hear the sounds?

Exploration

Students may do the following activity to study one specific auditory ability, the ability to identify the location of a sound.

1. Organize a group of 12 students with the following members:
   - 8 noisemakers
   - 1 listener
   - 1 pointer
   - 1 data recorder
   - 1 group discussion coordinator.
2. Clear a 2.5 x 2.5 m area of the classroom floor. Refer to **Teaching Tips** for other ideas about where to conduct this activity.
3. Each noisemaker should take a numbered Post-it note badge and stick it on his/her shirt or blouse. The badge should be visible to the pointer and the data recorder.
4. The eight noisemakers should be seated around the listener in a circle. Their numbered badges should correlate with the positions shown in Figure 1. Each noisemaker should be at least 1 m away from the listener. All noisemakers should be equidistant from the listener.
5. The pointer should give each noisemaker a set of chopsticks and demonstrate how to strike the chopsticks together to make a consistent sound.
6. The noisemakers should practice making sounds with the chopsticks so that the same intensity of sound is made by each. If possible, the listener should be out of the room as the noisemakers practice. If this is not possible, the listener should be positioned in the room in such a way that he/she hears as little as possible of this practice session.
7. The listener should be blindfolded and seated in the center of the 2.5 x 2.5 m cleared area within the circle of noisemakers as shown in Figure 1. *At no time during the activity should the listener move his/her head.*
8. The pointer should randomly point at one of the noisemakers to make a sound with the chopsticks.
9. Without moving his/her head, the listener should point in the direction believed to be where the sound originated.

TEACHING TIPS — Continued

Exploration activity is to have eight data recorders instead of one. Each data recorder can be assigned one of the noisemakers to watch, and record data for that individual only. This organization requires a group of 19 students. Depending on the size of the class, it may be possible to form only one group and have the rest of the students act as observers.

- It is crucial that the pointer point to the noisemakers in a truly random fashion. Otherwise, the listener might anticipate where the next sound is coming from based on the pattern. Random numbers can be generated in advance.

SUGGESTED MODIFICATIONS FOR STUDENTS WHO ARE EXCEPTIONAL

Here 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

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SUGGESTED MODIFICATIONS — *Continued*

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

Blind or Visually Impaired

- Talk to the student who is blind beforehand. Make sure he/she is comfortable participating as the listener in this activity. If the student participates as a listener, make sure he/she wears a blindfold during the exercise.
- If the student who is blind or visually impaired participates as a noisemaker, have the pointer tap the student on the shoulder instead of pointing to the person when it is his/her turn to make the sound. Alternately, another student could stand behind this student and tap him/her on the shoulder as the pointer points to the noisemaker.
- Provide alternative formats for Figures 1 and 2, depending upon the degree of the visual impairment. For a student who is blind, make a raised line drawing of Figure 1 and use a data chart in braille. Alternatively, a textured drawing can be produced with glue, string, or yarn and other objects. For a student with residual sight, photoenlarge and boldface these figures.
- Have a student assistant point or guide the hand of the student who is visually impaired to his/her copy of the data chart.

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10. The data recorder should record whether the listener pointed correctly on the data chart in Figure 2. The following notation may be used:
    Y = Yes, correct N = No, incorrect
11. Repeat Steps 8–10 for three minutes.
12. At the end of three minutes, the listener may remove the blindfold. The data recorder will tally the correct and incorrect responses for each position and read these data out loud for the members of the group. Group members will record this information in their journals.

C Concept/Term Introduction

Place the following list of suggested questions on the board for group data analysis discussion or give the list to the group discussion coordinators to use while monitoring the brainstorm portion of the activity:

1. In general, what kinds of results did your group get?
2. As the following series of questions is addressed, the teacher or group discussion coordinators can point to each location as it is mentioned on a diagram of the location chart (Figure 1) that is visible to the entire class:
   - Did the listener point correctly to the sound at each of these locations: 3? 7? 1? 5? 2? 8? 4? 6?
   - Did your group have a lot of correct responses for locations 3 and 7? 1 and 5? 2, 4, 6, and 8? Did you see a similarity to these locations?
   - How might you explain the patterns of responses in each of the following locations:
     - 3 and 7 compared with 1 and 5?
     - 3 and 7 compared with 2, 4, 6, and 8?
     - 1 and 5 compared with 2, 4, 6, and 8?
3. Did you notice if the listener hesitated longer in responding to sounds coming from some locations than from others? How might you explain these differences?

It is very important that students understand the major concepts in this activity before designing experiments on their own in the ***Application*** section. If you are concerned that students do not understand, you may want to try one of the following strategies:

1. Suggest that the students return to their groups and summarize their findings. Then have the groups share their ideas with the class. By comparing notes and with teacher guidance, students will be able to see for themselves what issues they understand and where they need further assistance.
2. Form a "Group of Teacher Assistants" and have those students take questions from class members. The teacher can determine who the "assistants" are by developing a set of questions to ask the members of each group orally. Those who seem to understand the concepts based on these answers can travel to other groups and help clear up misunderstandings. If those questioned by the teacher do not understand the concepts, the teacher can give them

additional questions to work on, and the teacher can repeat the process with another group to identify assistants.

A Application

The final portion of the lab requires students to draw on the ***Exploration*** activity and information from group sessions to design experiments of their own. They may use information they gathered in developing a hypothesis earlier as they design their experiments. Begin by reminding students that location is not the only information they get from their ears. The original experiment may be modified by having the listener cover one ear, effectively blocking sound from entering the ear; allowing the listener to move his or her head; and/or having the noisemakers move either toward or away from the listener.

From the list of potential variables identified, each student should choose a specific question to try to answer. While most of these questions can have simple "yes" or "no" answers, students should design and perform experiments that will supply data enabling them to support the ear and brainstem mechanisms. Examples of questions that could be investigated include the following:

1. Can the listener tell:
   - Whether the source of a sound is moving or stationary?
   - Whether it is moving toward or away from the listener?
   - The size of the object from the sound it makes?
   - The distance of the source of the sound?
   - The speed of the source of the sound, if it is moving?
2. Does covering one ear affect the ability to detect the location of sounds?
3. If the listener is permitted to move his/her head, is the ability to detect a sound's location enhanced using one ear? Using both ears?

Your students probably will develop other questions related to the types of information coming from the sense of hearing. In the sidebar on p. 28 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"

C Concept/Term Introduction

Focus Questions

1. These animals might be able to locate the sounds from different directions more easily than humans because they have the ability to move their ears in different directions.
2. Knowing the source and location of a sound can be used as a protective mechanism. We can locate the source of danger and make adjustments for fight or flight.

SUGGESTED MODIFICATIONS ***— Continued***

- Assign all roles except pointer and data recorder to students with visual impairments.

Deaf or Hard-of-Hearing

- Make sure that the student with a hearing impairment participates as fully as possible since this exercise emphasizes hearing ability. Cue the student to watch the teacher's actions carefully.
- Use the suggestion to drop a textbook to introduce the activity if the group contains a student with no residual hearing. The student with a complete hearing loss will still be able to see what is happening and perhaps feel the vibrations made by the dropped book. For students with some residual hearing, any of the suggestions for introducing the activity may be used.
- Consider the following information when assigning roles for this activity:
  - Students with hearing impairments can play any of the assigned roles except listener.
  - Students could act as pointer or data recorder. If the student who is hearing impaired acts as the data recorder, he/she must be in a position to observe the listener's visual cue for an affirmative response such as a raised finger. With practice, the student could be a noisemaker.

— Continued

SUGGESTED MODIFICATIONS — Continued

Mobility Impaired

Assign students roles in the activity depending upon the type of impairment. Students with these impairments should be able to play one to several roles in this exercise.

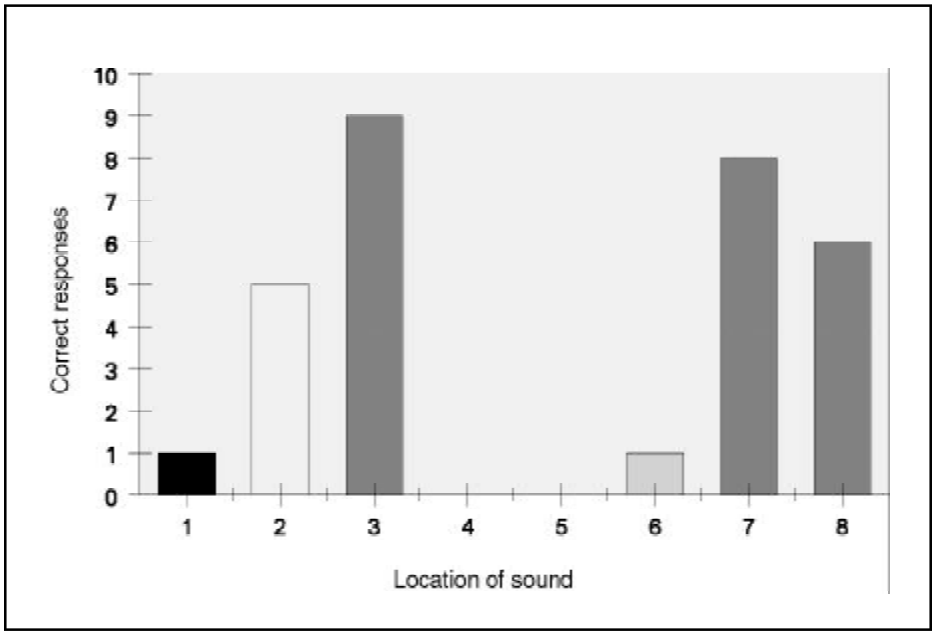
- Students with limited use of their upper extremities may need larger blocks of wood rather than chopsticks in order to act as noisemakers. They may also need alternative means for recording data or making charts.
- Students with limited use of their legs would be seated for such an exercise, but should need no other modifications.

SAMPLE HYPOTHESIS

If the listener moves his/her head as the sounds are being made, he/she will identify correctly the locations of more sounds than if the head did not move.

SAMPLE PROCEDURE

Repeat Steps 1 through 12 of the ***Exploration*** section of this activity. The only change will be that the blindfolded listener WILL be permitted to move his/her head in Step 9 as he/she identifies the locations of the sounds being made.



Graph 1. Correct responses by listener in relation to sound location.

3. You can turn your head in different directions until you can determine where the sound is the loudest.
4. The following are examples of these conditions:
   - Listening for oncoming cars as you walk or bike toward an intersection that is blocked by trees or houses.
   - Identifying the sound of a train at a railroad crossing.
   - Locating the sound of stinging insects, such as bees, wasps, and mosquitoes.

A Application

Analysis

1–2. Answers will vary depending on experiments students conduct.

3. Possible data analysis is shown in Graph 1.

4–5. Answers will vary depending on experiments students conduct.

Suggested Reading

Bloom, F.E. & Lazerson, A. (1988). *Brain, mind, and behavior*. 2nd ed. New York: W.H. Freeman & Company.

Goldberg, J. (1995). *Seeing, hearing, and smelling the world* (pp. 33–45). Chevy Chase, MD: Howard Hughes Medical Institute.

Moffett, D.F., Moffett, S.B. & Schauf, C.L. (1993). *Human physiology: Foundations & frontiers*. 2nd ed. (pp. 263–268). St. Louis, MO: Mosby.

Zimmer, C. (1993). Making senses. *Discover, 14*(6), 79–85.

HEARING IN THE DARK

Directions for Students

Introduction

Your car breaks down on a deserted stretch of road at 10:30 PM. You climb out of the car and begin to walk to a gas station you saw about two miles back. It's so dark that you can't see more than two feet in front of you. As you walk, you notice that you can hear cars on a road off to your left and a dog barking to the right. Suddenly you hear footsteps. Are they coming from the front or back? They are getting louder and faster! Suddenly....

In daily life, you rely largely on your vision to orient yourself to your surroundings. You are aware of things around you mostly because you see them. What if you couldn't see? Could you use your hearing to determine the direction of a sound? Suppose you were walking down that dark road late at night and suddenly heard footsteps. Could you tell which direction the footsteps were coming from? The size of the person making them? The speed of the person? What other information do you get from your ears?

Procedure

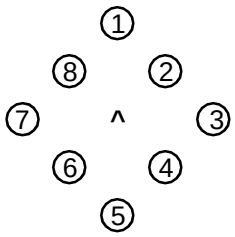
E Exploration

After your teacher introduces the activity, you will begin by performing a simple experiment that will allow you to study one specific auditory ability. Follow the directions your teacher gives you.

C Concept/Term Introduction

Work with your teacher and other students to analyze the data you just gathered. You will develop an explanation of the ear and brainstem system.

1. The group discussion coordinator will divide the group into two groups of four and one group of three.
2. Each group will analyze the data and brainstorm ideas about what occurred in the activity and why. The group discussion coordinator will monitor each group.
3. Each group will make a list of possible hypotheses to explain what the



Key to figures in the diagram.

^ Direction listener faces.

1 Directly in front of the listener.

3 Directly to the right of the listener.

5 Directly behind the listener.

7 Directly to the left of the listener.

2, 4, 6, 8 at 45° angles from the listener.

Figure 1. Circular locations of noisemakers in relation to the listener.

Materials

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

- 1 blindfold
- 8 sound makers
- 8 Post-it™ notes (optional)
- 1 meter stick (optional)
- 1 location chart
- 1 data chart

Safety Notes

- The ear cover should not enter the ear canal. It should cover only the outside of the ear, just as an earmuff does. Do not use earplugs, because they go into the ear canal and can transmit disease.
- The sound should not be too loud or too close to the listener's ears. The teacher should approve sound makers before they are used.
- Secure the blindfold safely around the eyes with a minimum amount of pressure. Seat the blindfolded student safely in the center of the experimental circle. Your research group is responsible for the safety of the blindfolded student.
- Do not share blindfolds with other students to prevent transmission of diseases.
- Keep all sound makers away from the eyes.

data showed. Then the group will select the hypothesis they feel is best to share with the rest of the class.

4. After 10 minutes of brainstorming, the groups will be called together as a class to share their hypotheses. Each group will select one hypothesis to present to the class.
5. Each student will research the group hypothesis and return to class with information for developing a procedure to test the hypothesis.
6. Your teacher may give you directions at this point for clarifying any misunderstandings you might have about the activity.

FOCUS QUESTIONS

Answer the following questions in your groups:

1. If you were able to test a dog or a cat for the direction of sound, how do you think your results might be different? Why?
2. What is the adaptive value of being able to determine the source of a sound? Explain.
3. If you can't tell whether a sound is in front or in back of you, what can you do to figure it out? Assume it is completely dark, and you must use only your sense of hearing.
4. Under what conditions would it be useful to be able to determine the size of an object making a sound, tell if an object making a sound is moving, and/or tell the distance of a sound source?

Application

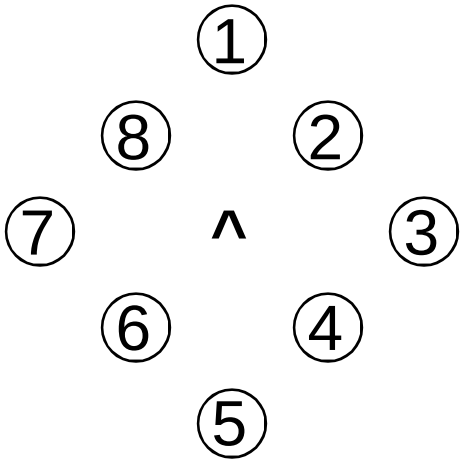
Think of questions that arose as you conducted your ***Exploration*** activity, discussed your results as a class, and answered the **Focus Questions**. You may wish to draw on information you gathered to develop your hypothesis earlier. As a group, decide what question you wish to test. Then design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

1. Writes the question as a hypothesis or in the form of an "if... then" statement.
2. Gathers quantifiable data.
3. Decides what variables must be controlled, and plans how to control these.

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?



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2, 4, 6, 8 at 45^{o} angles from the listener.

Figure 1. Circular locations of noisemakers in relation to the listener.

Subject	**Experimental Location**							
	1	2	3	4	5	6	7	8
Total Correct								
% Correct								

Figure 2. Sample data chart.

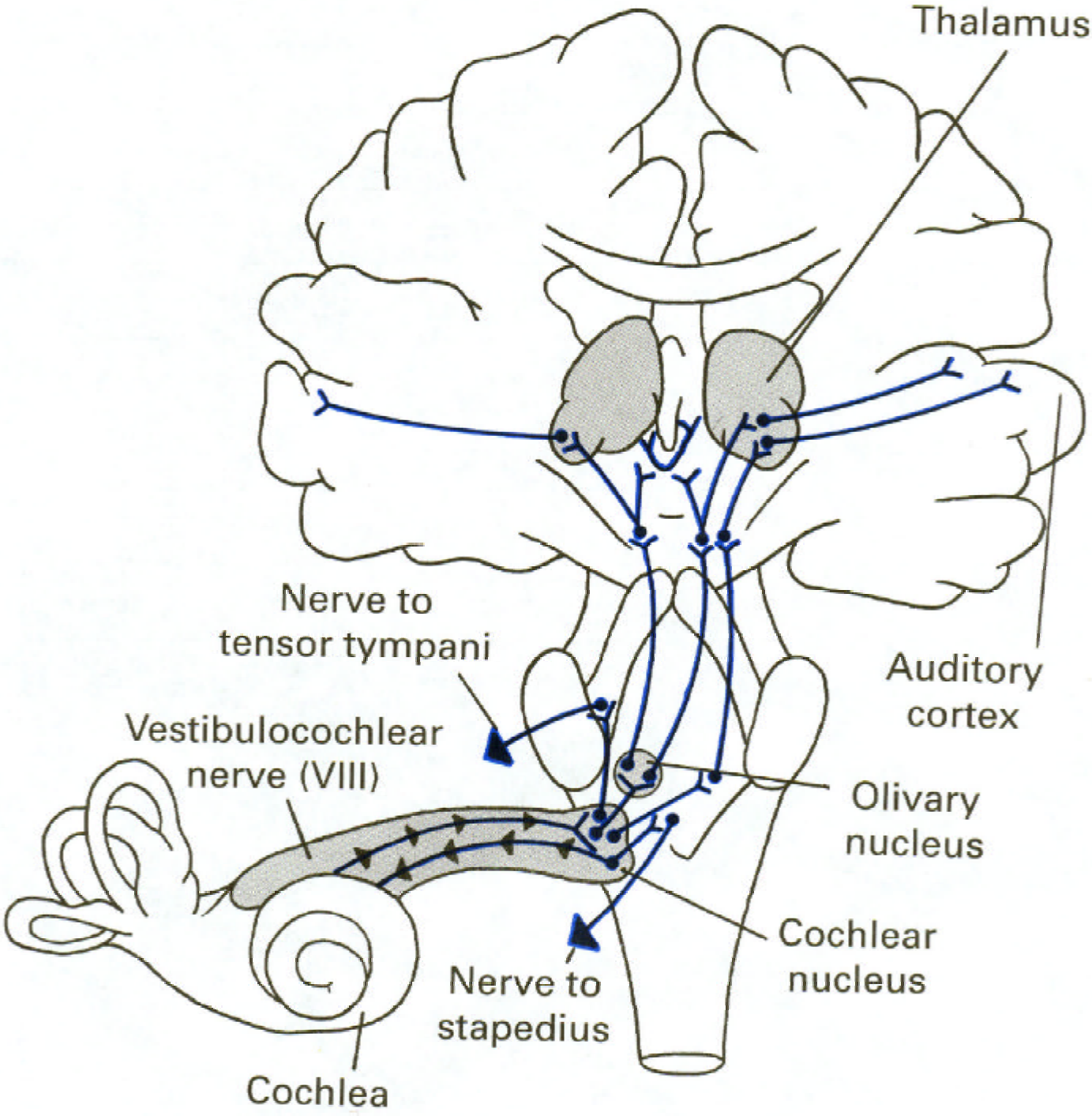
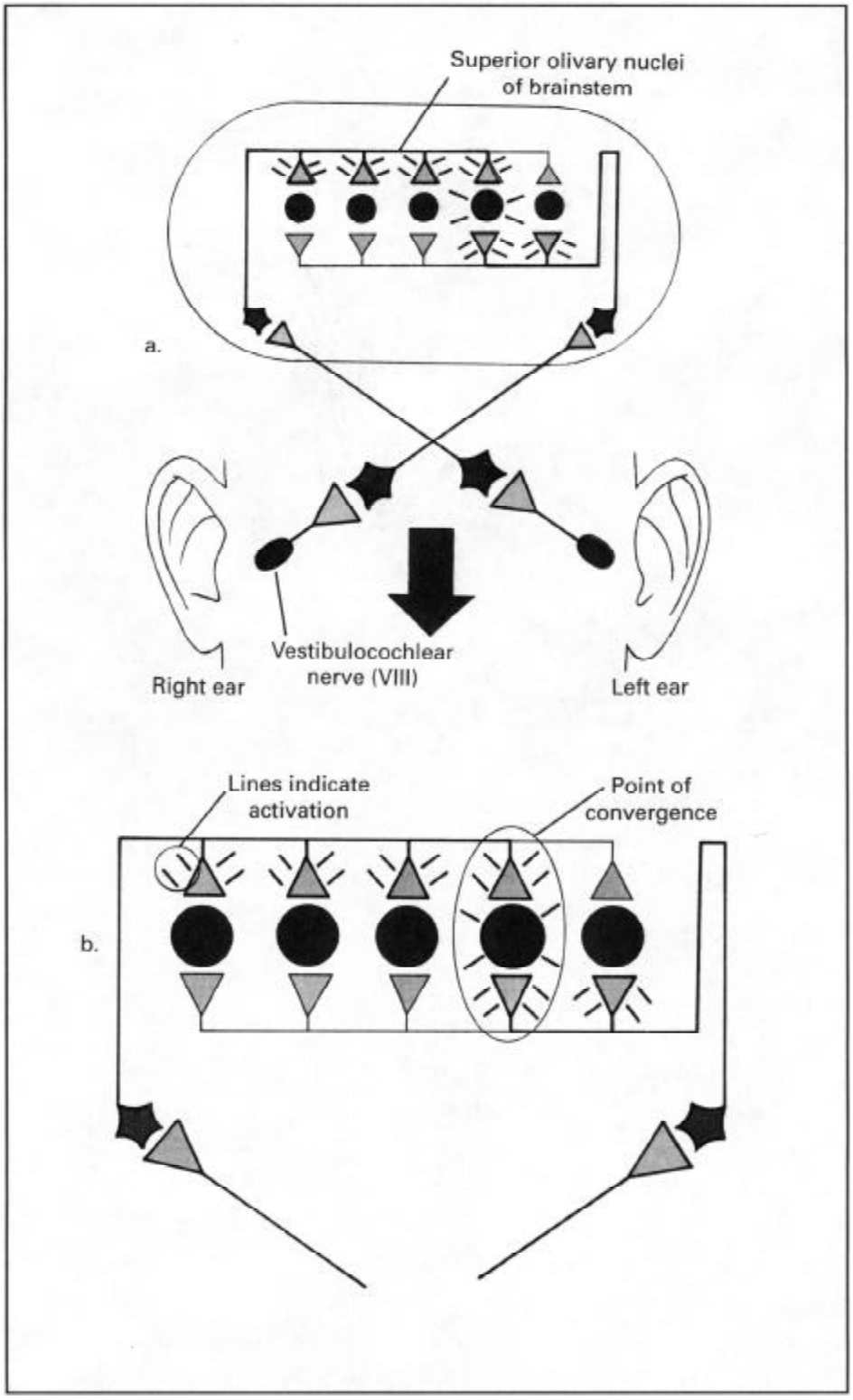


Figure 3. Anatomical drawing of cochlea, olivary nucleus, eighth cranial nerve, and brainstem.



Figures 4a and 4b. Schematic of how sound is processed in relation to time of arrival or intensity of a signal.