Neuroscience for Kids
http://faculty.washington.edu/chudler/neurok.html

Our Sense of Hearing

Featuring a "Class Experiment" and "Try Your Own Experiment"

Teacher Guide

WHAT STUDENTS WILL DO

- PREDICT and then MEASURE peoples' ability to locate the source of a sound when blindfolded and not allowed to move their heads
- CHANGE A VARIABLE by allowing the subjects to move their heads
- CALCULATE the class averages for correct and incorrect answers for each location of the sound source
- DIAGRAM the pathway that sound signals follow from the ear to the brain
- DISCUSS advantages of using vision, hearing, or both to locate a sound source
- DESIGN AND CONDUCT experiments to study the sense of hearing further, for example:
    - TEST the ability to locate a sound source with one ear plugged
    - SIMULATE animal hearing with fabricated outer ears
    - DEVISE a test for the ability to hear different intensities of sound
    - INVESTIGATE human communication: how do we decode the meaning of words – if they are muffled, what cues do we use to decipher them?

SUGGESTED TIMES for these activities: 45 minutes for introducing and discussing the activity, 45 minutes for the "Class Experiment;" and 45 minutes for "Try Your Own Experiment."

SETTING UP THE LAB

Supplies

For the Class Experiment

Sets of identical noise makers, such as pairs of wooden pencils or chopsticks, or "clickers" (available at novelty stores) 8 are needed for each group
Post-it notes numbered 1 through 8
Blindfolds (to avoid the spread of germs, do not share blindfolds)
Diagram of locations of Listener and Noisemakers (See Procedures)
Data charts for Pointer/Data Recorder (at the end of this unit)

For "Try Your Own Experiment"

Noise makers and blindfolds from the Class Experiment
Earplugs (found in drugstores—the small foam ones that fit inside the ear canal. Have one pair for each Listener; do not share earplugs.)
Materials for making "animal ears" (construction paper, sheets or tubes of rubbery material, tape, glue, stapler, string, elastic tape or thread)
Sets of several layers of fabric for "word muffling" experiments
Tape recorder and blank tapes for sound intensity experiments (the tape recorder must have a calibrated volume control, for example, dots, lines or numbers on the dial or slider).

Optional supplies

Ear model
Wall poster of the ear
Textbooks with diagrams of auditory pathways

Other Preparations

- **Construct a chart** on the board where students can enter data for class discussion.

- **Decide the size of the student groups**: Each group will need one Listener and eight Noisemakers. The group will also need a Pointer and a Data Recorder. Divide the class into equal groups so that results can be compared quantitatively among the groups. If the numbers do not come out evenly, the Pointer and Data Recorder can be the same person, and extra people can take turns being Listeners. Try to have a minimum of three people tested as Listeners in each group to get sufficient data for calculations.

- For Try Your Own Experiment, **prepare materials** in the Supply list and display them on a table after the Class Experiment. For the "animal ears" activity, include materials for students to test how their hearing would change if they had the external ears of different animals, real or imaginary. They can make external ears that are mobile, that have extravagant ridges and folds inside, or that are permanently pointed in different directions.

- **Modify activities for exceptional students**:

  - ✓ Students who are hard of hearing can act as Data Recorders if the Listeners are told to point clearly to the source of the sound. They may also be able to act as Pointers.

  - ✓ Blind or visually impaired students can participate as Listeners if they are comfortable in this role. Make sure they wear a blindfold as other Listeners do. Someone can make a simple model of the arrangement of Noisemakers around the Listener (e.g., using blocks) for someone who is visually impaired.

INTRODUCTORY ACTIVITIES

Give students initial information

Introduce **Our Sense of Hearing** to the class according to your teaching practices; for example, with reading, lecture, and discussion before lab work (the **Teacher Resource** accompanying this unit gives background material). In addition to covering the anatomy and physiology of the auditory system, you will want to introduce the concepts of binaural hearing (hearing with two ears), frequency and intensity, and decibel levels. Other topics that may interest students include animal hearing, protecting ears from loud noises, types of deafness, how speech and hearing interact, and other topics you think might come up in the "Try Your Own Experiment" section.

Introduce auditory experiments with a demonstration

When students enter the classroom on **lab day**, you can **introduce the experiment** by having an unusual sound occur somewhere in the room while students are taking their seats. This could be a tape recorder starting to play a person's voice or animal sounds; wind chimes starting to tinkle when a small fan goes on; or a box of pencils dropped on the floor. You may need to arrange collaboration with an assistant for this: the sound should not come from something you (or another person) are seen to do.

After the sound occurs and students have reacted, ask what happened. Ask what alerted them to the event? ---(sound)--- and what did they do upon hearing it? --- (turned toward what they thought was the source). Lead the students into a discussion of how hearing is important in alerting us to happenings in our environment and how it normally works in concert with vision in helping us locate sources of noises.

Alternatively, use the **Scenario** at the beginning of the **Student Guide** to involve students in a short discussion.

Use Explore Time to engage students

After the introduction, let students **explore** a table holding the materials for the Class Experiment. Give them five to ten minutes to see what they will be working with, and when they sit down, ask what they could find out about the sense of hearing with these materials.

What's that Noise?
CLASS EXPERIMENT

The sections below match those in the Student Guide. The comments guide teachers in preparing and teaching the labs.

LAB QUESTION

After introducing the Lab, help students to write the following Lab Questions or ones that match closely:

If people in a circle around a blindfolded Listener create noises, how accurately can the Listener point to each sound source, without turning head or body? With turning head or body?

PLANS AND PREDICTIONS

Encourage students to add their own knowledge and experiences in order to make predictions after you have provided background information. When students are in their groups, have them predict whether the Listeners will be better in identifying sounds coming from some directions than others. Ask whether we use only our ears in figuring out where a sound is coming from, and how we adjust our bodies to receive sensory information.

PROCEDURE

1. **Introduce safety precautions:** Follow all standard lab safety guidelines for preparing and teaching the activity; e.g., take precautions to avoid germ spread; wash hands; use equipment properly.

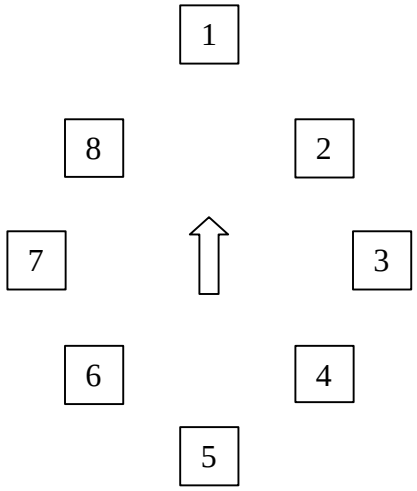
2. **Establish** the number of students in each group. The minimum number will be 1 Listener, 8 noisemakers, and 1 Pointer/Data Recorder. If this makes awkward class divisions, extra students can be additional Listeners. The Pointer and Data Recorder can be two people, or one can do both jobs. It is important to have Noisemakers at the four cardinal directions, in order for students to discover the difficulty of telling whether a noise is coming from directly in front or directly in back.

3. **Explain** the steps in the Class Experiment. These are listed in the **Student Guide,** under **Procedure**.

4. Distribute Data Recording Sheets to Pointers/Data Recorders.

5. Remind students to **clean up** the lab when they finish.

POSITIONS OF LISTENER AND NOISEMAKERS



KEY: ARROW = LISTENER, FACING IN DIRECTION OF ARROW
NUMBERS = NOISEMAKERS

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:	EQUIDISTANT BETWEEN THE ABOVE NUMBERS

DATA AND OBSERVATIONS

- Circulate among groups to see that Listeners understand that they are not to move their heads for the first part of the experiment, and that Data Recorders understand the data sheet and how to record responses.

- Each Noisemaker should make **several clicks** or sounds in succession rather than just one isolated sound. Ten clicks in about five seconds should work well. This becomes essential when students do the next part of the experiment and the Listener is allowed to move his or her head: **the blindfolded Listener can only locate the sound source by moving his or her head so one ear is pointed toward the sound.** Thus, the sound must be repeated while the Listener changes head positions.

- After the experiment, students in each group can look at the responses written by the Data Recorder and **tally** the number of correct and incorrect answers at each Noisemaker position for all their Listeners. They can then **calculate** the percent of correct vs. incorrect responses at each position. Groups may be divided to work on the data without and with head moving.

- Have Data Recorders from each group write their results of in a prepared chart on the board. Students can then get a grand class average for percent correct and incorrect for each position, without and with head moving. Get the class to discuss why

averaging may or may not be a good idea and to discuss how researchers handle data points that are very different from most others.

- Students should write down anything that they found interesting or puzzling during the experiment.

ANALYSIS: THINK ABOUT IT!

The following questions can encourage thinking about this activity; add your own questions. (*See also the specific questions in the Analysis section of the Student Guide.)*

- Were there any Noisemaker positions where Listeners missed the sound source more than others?

- What is the reason we can tell the location of a sound source? (Sound arrives at the closer ear sooner ---less than one one-thousandth of a second sooner!)

- Why is it important to be able to locate a sound source? (Locating a source of danger, such as oncoming cars; finding a lost animal; figuring out where a stinging insect is; ask for others from students.)

- How do your results compare with those of other groups?

- Can you explain any differences you see among the observations? (earplugs may not have been effective in some Listeners; perhaps some Listeners moved their heads during the first part of the experiment; we also use intensity differences to locate sounds—some clicks may have been louder than others)

- How does auditory information get from the ear to the brain? (A figure is included in the Teacher Resource—students may draw a simple diagram based on this.)

- Discuss what the results mean in terms of the concepts learned in the Background lecture and discussion on the ear.

CONCLUSIONS

Students should:

- State how the Lab Question was answered in their experiments.

- List three things (or a number you choose) they think are important about today's experiment. Focus students by asking such questions as: How is hearing important to us? What do our brains do with sensory (particularly auditory) information? Can you investigate some questions on your own? Do scientists know everything there is to know about hearing?

- List ways to improve this experiment or further things to test.

What's that noise?

TRY YOUR OWN EXPERIMENT

LAB QUESTION

After students have completed the Class Experiment, indicate the lab bench where additional materials are available for "Try Your Own Experiment" and let them **explore** the items. Then **brainstorm** with them for ideas such as continuing the sound source locating experiments, or trying other experiments such as those suggested below.

Questions can help students to formulate plans: What happens when people lose hearing in one ear? Do some animals have different hearing abilities than we do? In addition to being able to hear well, do other factors influence our ability to understand spoken language?

See that each group defines a Lab Question, as they did in the Class Experiment.

PLANS AND PREDICTIONS

SUGGESTIONS FOR EXPERIMENTS AND PROJECTS

(Add your own ideas to this list. The Student Guide also suggests some of these experiments but does not contain all details given here. Give hints and encourage students to think through the possibilities.)

EXPERIMENTS

1. **Continue** the **locating the sound source** experiments.

   - Plug one ear, allow no head movement, and repeat the Class Experiment. Then allow head movement and note that this does not help the Listener with one ear tell where the sound is coming from. Discuss the limitations of hearing with only one ear.

   - Noisemakers can move farther away or closer to the Listener.

   - Noisemakers can make a series of noises while moving. See if the Listener can tell if the noise is coming closer or going farther away.

- Change the sound source location on **vertical** axis: have some Noisemakers sit on the floor holding noise makers low, some on chairs as in the class experiment, and some stand on stepstools (safely) holding noise makers high, randomly in their 8 positions. For this experiment, the Listener should be allowed to move his or her head. See if the Listener points correctly not only horizontally but also vertically. Question: can a person tell this with one ear plugged? Theoretically, the pinna (outer ear) should help with this, even using one ear.

- Make animal outer ears to act as sound collectors. Vary the size, shape, and direction they point. How does the apparent location of the sound source change for a Subject wearing these? Construct asymmetrically placed ears such as barn owls have and see how this affects hearing. To do this, have one "ear megaphone" point up and the other down. See the Howard Hughes Medical Institute Web site for information on barn owls: http://www.hhmi.org/senses/c/c110.htm --go to "Locating a Mouse by its Sound."

2. **Ear safety:** make up an ear safety quiz of 10 or so questions. Students should predict how many questions people will answer correctly, and which ones will most often be missed. They should also think of a way to quantify their results. See http://kidshealth.org/kid/stay_healthy/body/ear_care.html for information on taking care of your ears. http://www.nih.gov/nidcd/health/pubs_hb/noise.htm is the National Institutes of Health site for noise-induced hearing problems.

3. **Decoding the sounds of speech**: Muffle a spoken sentence by speaking through layers of cloth. Begin with a large number of layers, saying the same familiar phrase over while removing one layer of cloth at a time. Use familiar phrases, such as "a, e, i, o, u," "Don't forget to brush your teeth," or "What did you say?" Have several phrases ready, because everyone will recognize them once heard, and you will need another for the next Subject. For quantification, count the number of layers cloth (hold the distance from speaker to listener constant).

4. **Sound intensity: how** loud must words be for a person to understand them? Use a tape recorder to record several sentences, then play a sentence to a Listener sitting a measured distance away. Begin very quietly, and use a recorder that has numbers or dots as calibration on the volume control knob. What factors come into play here? Understanding is not only the physical act of hearing, but cultural knowledge, cues, familiarity with the speaker's voice.

HOW TO DESIGN A GOOD EXPERIMENT

A skeleton of this section is found in the Student Guide: see if students can come up with details, or with other good ideas.

In designing experiments to answer questions like these, keep in mind what a **successful investigator** must do:

- Ask a **very specific question**: not, for example, "Can people tell what someone is saying if the speech is muffled?" but rather, "How many layers of cloth over a speaker's mouth will prevent listeners from understanding a familiar phrase?" It's

good to have the general question in mind, but ask a narrow question for each experiment. For this experiment, use a familiar phrase, such as "a,e,i,o,u," or "Don't forget to brush your teeth" or, "Have a good day." Be sure to start with numerous layers of cloth and remove them gradually, to the point where the Listener can understand the phrase. A variable to change would be to read an unfamiliar short sentence to see how that affects the ability to understand.

- Be sure you understand the **control condition**, and then **change only one thing, or variable,** in the experiment.

  - ✓ For example, if you do an "animal ear" test, you can define performance without the constructed ears as the control, and with the animal ears as the variable. To add another variable, change the type of ear.

  - ✓ Researchers try to have only one variable in an experiment. Sometimes this is difficult, but at least they must be aware of other variables they cannot eliminate, write them down, and think about what effects they might have.

- To make your activity a real **experiment**, ask a question, make a **prediction**, **test** the prediction, **analyze** the results, and draft **conclusions**.

  - ✓ For example, you could investigate how well people learn words by hearing someone read them. Make a list of ten words for people to memorize. Predict how many they will be able to repeat if **you read** them the list **aloud** once and how many if you read the list three times. This is your control experiment.

  - ✓ Next, change a variable: give them a written list of ten (different) words, and let them read the words **silently** once versus three times. For a further test with ten new words, give the written list, **and** have someone read the words aloud. Score all tests and see if you note any differences: What conclusions can you draw? (Probably, that using more senses helps one to learn faster, but because some people learn best with one sense, variations will occur with Listeners.)

  - ✓ Another variation on this experiment would be to read a list of words aloud to a Listener for the control experiment, then to read a different list of words while there is some kind of interference. This could be a rather loud radio, or two students having a conversation right next to the person trying to memorize the words. Sensory interference is a common problem (often found in classrooms!).

- If you make up a **hearing safety test**, predict the scores you think people will get. Keep it short, perhaps ten questions. Predict whether you think people will miss the same questions.

- Keep good records of everything you do.

PROJECTS

Some activities are not experiments but rather demonstrations, surveys, or library research projects. For instance, you may decide to investigate American Sign Language, or you may find out something about hearing loss. Here are some ideas for projects.

1. **American Sign Language:** learn the ASL alphabet or some common words and show them to your class; or, ask a hearing interpreter of ALS to talk to the class.

2. **Investigate** in your library or on the Internet: owl ears; bat ears. How do their hearing abilities differ from humans? What special uses do they make of what they hear?

3. **What is the meaning** of different sounds to humans? buzz, rustle, growl, chirp, laughing, words…. How do our reactions to different sounds reflect our survival, our needs, or our evolution?

4. **List the sounds** you hear in 5 min, while sitting in the cafeteria, the bus, study hall---somewhere that you go repeatedly. **Next day**, close your eyes and make a list in the same place (you need to quickly open eyes to write, then close again.) Compare the lists. Do you hear more sounds in one case or the other? What do your results mean?

PROCEDURE

- **Introduce safety precautions**:

  Follow all standard lab safety guidelines for preparing and teaching the activity; e.g., take precautions to avoid germ spread; wash hands; use equipment properly.

- If time is limited, restrict the number of materials you put out for experimenting.

- Before students begin their experiments, have each group write a simple plan that includes a **question, a prediction, a list of steps** they will take to answer the question, and **data sheets** or graphs (if needed).

- The list of steps in the experiments should include comments on the control system and on the variable being tested.

- **Approve** each group's experiment before they begin.

- Remind students to keep **good records**.

- Students should **clean up** the lab when they finish.

DATA AND OBSERVATIONS

- Make supplies available to students.

- Help students think about what data to gather and how to organize it.

ANALYSIS: THINK ABOUT IT!

The following questions can encourage thinking about the activity; add your own ideas. (*See also the specific questions in the Analysis section of the Student Guide.)*

- Have each group present its findings to the class in a quick oral presentation (two to three minutes).

- How do your data answer your Lab Question?

- What was the control experiment or condition for your experiment? What did you change or add as your variable?

- Did you make sure to change only one variable? Were there variables you could not control?

CONCLUSIONS

(See also the questions in the Student Guide.)

Ask students how certain they are of their conclusions. Would they need more evidence to make their conclusions more secure?

Each group should write a final conclusion, making sure it addresses their Lab Question.

MORE *SENSE OF HEARING* ACTIVITIES

- Do some animals have better hearing than we do? What gives them this acute hearing? How do they make use of it? Check on barn owls and bats.

- Can loud noises permanently damage your hearing? What can you do to protect your hearing?

- What are some hearing problems that people have? Try looking for some of the following terms in your library or on the World Wide Web:

  Conductive hearing loss
  Nerve deafness or sensorineural deafness
  Cochlear implant
  Noise-induced hearing loss
  Phantom hearing
  Ear infections

Here are some good web sites to visit for auditory system information. The list at the end of the student guide contains the ones most appropriate for middle school students. These sites are also listed as direct links in the Teacher Resource.

http://www.nidcd.nih.gov/health/kids/index.htm - National Institute of Deafness and Communication Disorders (NIDCD) –this is the teacher and student site; you can go to the general NIDCD site by clicking on "home" (works best with Shockwave)

http://www.nidcd.nih.gov/health/kids/owlgame/owl.html#8 - hearing quiz at the above site

http://www.nidcd.nih.gov/health/pubs_hb/presbycusis.htm - NIDCD site on age-related hearing loss

http://www.nidcd.nih.gov/health/pubs_hb/noise.htm - NIDCD site on noise-induced hearing loss

http://faculty.washington.edu/chudler/bigear.html - hearing information from Neuroscience for Kids

http://ctl.augie.edu/perry/ear/hearmech.htm - "Virtual tour of the ear." Click on one of the headings, such as "inner ear" to get started.

http://www.augie.edu/perry/ear/ar.htm - list of links to educational and health related topics about hearing. Mostly on hearing aids, self-help programs, implants.

http://www.cscd.nwu.edu/public/ears/hearloss.html - excellent discussion of types of hearing loss)conductive vs. sensorineural) from Northwestern University

http://www.sfn.org/briefings/hearing.html - Society for Neuroscience (SFN) Brain Briefings: restoring hearing with cochlear implants

http://www.sfn.org/briefings/deafness.html - SFN: deafness genes

http://www.sfn.org/briefings/hair_cell.html - SFN: hair cell regeneration

http://www.medoto.unimelb.edu.au/info/implant1.htm - What is a cochlear implant?

http://kidshealth.org/kid/body/ear_SW.html - suitable for late elementary to middle school students (need Shockwave)

http://kidshealth.org/parent/medical/ears/central_auditory.html - central auditory processing disorder--- information for teachers

http://kidshealth.org/kid/stay_healthy/body/ear_care.html - tips on taking care of your hearing

www.iurc.montp.inserm.fr/cric/audition/english - "promenade around the cochlea;" good diagrams

http://www.neurophys.wisc.edu/h%26b/textbook/chap-6.html - text explaining the auditory system—technical, for teachers

http://www.sissa.it/bp/Cochlea/twlo.htm - Fabio Mammano's page on the cochlea; see a traveling wave on the basilar membrane!

http://www.sissa.it/bp/Cochlea/utils/basilar.htm - from same site as above, a drawing of the basilar membrane

http://www.neurophys.wisc.edu/aud/training.html - Univ. Wisconsin education page—technical, for teachers

http://www.discover.com/feb_99/breakpinna.html - folds of the pinna give each person an individual auditory map

http://www.discover.com/feb_99 - scroll down to The Brain: Senses of the Blind. Blind people really do have better hearing.

http://medic.med.uth.tmc.edu/Lecture/Main/ear.htm - short tutorial on the auditory system—good diagrams

http://www.hhmi.org/senses/c/c110.htm - look under Hearing. Howard Hughes Medical Institute report on hair cells; also includes an article about how owls locate prey in the dark with their remarkable hearing (Locating a Mouse by its Sound)

http://146.139.100.40/webpages/askasci/phy99/phy99405.htm - decibel levels

SAMPLE DATA RECORDING SHEET

In each numbered *column*, make a plus + for a correct answer and a minus – for a wrong answer. Each numbered *row* is one round of noises using each Noisemaker.

LOCATION OF NOISEMAKER

LISTENER NAME	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Trials **Without** head moving								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
TOTAL CORRECT								
% CORRECT								
Trials **With** head moving								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
TOTAL CORRECT								
% CORRECT								