HOW YOUR BRAIN UNDERSTANDS WHAT YOUR EAR HEARS

NATIONAL INSTITUTES OF HEALTH,

How Y

w Your Brain Understands

our Brain Understands

What Your Ear Hears

Under a Contract from the

National Institutes of Health

National Institute on

Deafness and Other Communication Disorders

5415 Mark Dabling Boulevard

Colorado Springs, Colorado 80918

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Contents

Foreword

This curriculum supplement, from The NIH Cur-

content, and built-in assessment tools. Activities

riculum Supplement Series, brings cutting-edge

promote active and collaborative learning and

medical science and basic research discoveries

are inquiry-based to help students develop prob-

from the laboratories of the National Institutes of

lem-solving strategies and critical thinking.

Health (NIH) into classrooms. As the largest

Each curriculum supplement comes with a com-

medical research institution in the United States,

plete set of materials for both teachers and stu-

NIH plays a vital role in the health of all Ameri-

dents, including printed materials, extensive

cans and seeks to foster interest in research, sci-

background and resource information, and a

ence, and medicine-related careers for future

Web site with interactive activities. These sup-

generations. The NIH Office of Science Educa-

plements are distributed at no cost to teachers

tion (OSE) is dedicated to promoting science

across the United States. All materials may be

education and scientific literacy.

copied for classroom use, but may not be sold.

We designed this curriculum supplement to

We welcome feedback from our users. For a

complement existing life science curricula at

complete list of curriculum supplements,

both the state and local levels and to be consis-

updates, and availability and ordering informa-

tent with National Science Education Standards.1

tion, or to submit feedback, please visit our Web

It was developed and tested by a team composed

site at http://science.education.nih.gov or write to of teachers from across the country, scientists,

Curriculum Supplement Series

medical experts, other professionals with rele-

Office of Science Education

vant subject-area expertise from institutes and

National Institutes of Health

medical schools across the country, representa-

6705 Rockledge Dr., Suite 700 MSC 7984

tives from the NIH National Institute on Deaf-

Bethesda, MD 20892-7984

ness and Other Communication Disorders

We appreciate the valuable contributions of the
(NIDCD), and curriculum-design experts from
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tive. We are also grateful to the NIH scientists,
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porated real scientific data and actual case stud-
for their work and dedication. Finally, we thank
ies into classroom activities. A three-year
the teachers and students who participated in
development process included geographically
focus groups and field tests to ensure that these
dispersed field tests by teachers and students.
supplements are both engaging and effective. I
The structure of this module enables teachers to
hope you find our series a valuable addition to
effectively facilitate learning and stimulate stu-
your classroom and wish you a productive
dent interest by applying scientific concepts to
school year.
real-life scenarios. Design elements include a
Bruce A. Fuchs, Ph.D.
conceptual flow of lessons based on BSCS's 5E
Director

Instructional Model of Learning, multi-subject

Office of Science Education

integration emphasizing cutting-edge science

National Institutes of Health

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1 In 1996, the National Academy of Sciences released the National Science Education Standards, which outlines what all citizens should understand about science by the time they graduate from high school. The Standards encourages teachers to select major science concepts that empower students to use information to solve problems rather than stressing memoriza-tion of unrelated information.

About the National

out the National

Institutes of Health

Founded in 1887, the National Institutes of

designed to ensure a continuing supply of well-

Health (NIH) today is the federal focal point for

trained scientists.

medical research in the United States. Composed

• Research Facilities Program. Modernizing and

of separate institutes and centers, NIH is one of

improving intramural and extramural research

eight health agencies of the Public Health Service

facilities to ensure that the nation's scientists

within the U.S. Department of Health and Human

have adequate facilities in which to conduct

Services. The NIH mission is to uncover new

their work.

knowledge about the prevention, detection, diag-

Science education efforts by NIH and its institutes

nosis, and treatment of disease and disability, from

and centers are critical in ensuring the continued

the rarest genetic disorder to the common cold. It

supply of well-trained basic research and clinical

does this through

investigators, as well as the myriad professionals

• *Research. Enhancing research outcomes across*

in the many allied disciplines who support the

the medical research continuum by supporting

research enterprise. These efforts also help edu-

research in NIH's own intramural laboratories as

cate people about the scientific results so that they

well as the research of nonfederal scientists

can make informed decisions about their own

working in universities, medical schools, hospi-

health as well as the health of the public.

tals, and research institutions throughout the

country and abroad; communicating scientific

This curriculum supplement is one such science

results; promoting the efficient transfer of new

education effort, done through the partnership of

drugs and other technologies; and providing

the NIH National Institute on Deafness and Other *effective research leadership and administration.*

Communication Disorders, the NIH Office of Sci-

• Research Training and Career Development Pro-

ence Education, and Biological Sciences Curricu-

gram. Supporting research training and outreach

lum Study (BSCS).

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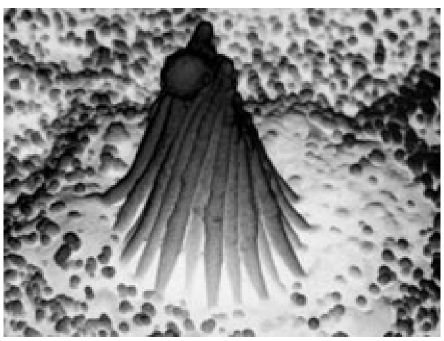


About the National Institute on Deafness

and Other Communication Disorders

lic understanding about how normal and dis-

eased processes work so that individuals can

make well-informed decisions about their health

over a lifetime. Please let us know about your

experience with the module, or let us answer any

questions you have about any aspect of the mate-

rial presented or the research of the NIDCD.

As director of the NIDCD, I am indebted to you

James F. Battey, Jr.,

for your work with these young people, and as

M.D., Ph.D.

the father of two middle schoolers, I appreciate

the challenges you will face! Thank you for your

What We Do

interest in human communication research.

Fundamental processes of hearing, balance,

Jim Battey, M.D., Ph.D., Director NIDCD

smell, taste, voice, speech, and language allow

E-mail: AskDrBattey@mail.nih.gov

humans to interact and to experience and

manipulate their environment. NIH's primary

research institute devoted to human communi-

cation research is the National Institute on Deaf-

ness and Other Communication Disorders

(NIDCD). The NIDCD supports research across

the 50 states. Some of that research may be going

on right now in your state. For more information

on the NIDCD, consult the section More About

the NIDCD and Its Research, page 145, or visit us on the Web at http://www.nidcd.nih.gov.

Your Young Scientists

The NIDCD is committed to encouraging young

people who have an interest in science to delve

into it further. It also is working to improve pub-

Electron micrograph of a healthy hair cell.

Introduction to

Introduction to How

Your Brain Understands

our Brain Understands

What Your Ear Hears

Human communication depends on taking in

What Are the Objectives of the Module?

information from the environment through the

How Your Brain Understands What Your Ear Hears

five senses and processing that information in the

has four objectives. The first is to help students

brain. The sense of hearing is critical to this

understand the interrelationship of hearing, lan-

process. Other mental abilities such as attention

guage, and human communication. It also helps

and memory are also important.

students develop healthy hearing habits so they

avoid noise-induced hearing loss.

Because human communication is a complex

process, it may be impaired in a variety of ways.

The second objective is to use hearing and com-

About one in six Americans must cope with some

munication as a way of understanding important

form of communication disorder, such as *scientific concepts. Lessons in this module help*

• not being able to hear at all or having a hearing

students sharpen their skills in observation, criti-

impairment,

cal thinking, experimental design, and data analy-

• dizziness or balance problems,

sis. They also make connections to other

• stuttering,

disciplines such as English, mathematics, and

• ringing in the ears (tinnitus),

social science.

• not being able to speak (laryngeal cancer, apha-

The third objective is to convey to students the

sia), or

purpose of scientific research. Ongoing research

• autism.

affects how we understand the world around us

Research has helped us better understand com-

and gives us a foundation for improving our

munication disorders and what causes them.

choices about personal health and the health of

Already, research has led to the development of

our community. In this module, students experi-

vaccines for diseases such as measles, mumps,

ence how science provides evidence that hearing *meningitis, and rubella—diseases that previously*

is key to language acquisition, that human com-

caused hearing loss for many people. Technolo-

munication is multisensory, and that excessive

gies to assist individuals with communication dis-

exposure to loud noise can lead to hearing loss.

orders have also been developed. Current and

The lessons in this module encourage students to

future research will help us better detect, diag-

think about the relationships among knowledge,

nose, intervene, rehabilitate, or treat newborns

choice, behavior, and human health in this way:

with hearing loss; understand the genetic contri-

Knowledge (what is known and not known) +

butions to hearing and communication; and apply

Choice = Power

appropriate technologies to assist those who have

communication disorders.

Power + Behavior = Enhanced Human Health

1

How Your Brain Understands What Your Ear Hears

The final objective of this module is to encourage

• *It is an* ***integrated*** *module, drawing most heav-*

students to think in terms of these relationships

ily from the subjects of science, social science, *now and as they grow older.*

mathematics, and health.

• *The module has a Web-based* ***technology com-***

Why Teach the Module?

ponent *on which there are sound clips, video,*

Middle school life science classes offer an ideal

and interactive animations.

setting for integrating many areas of student inter-

• *The module includes built-in* ***assessment tools****,*

est. In this module, students participate in activi-

which are noted in each of the lessons with an

ties that integrate inquiry science, human health,

assessment icon.

mathematics, and the interweaving of science,

In addition, the module provides a means for ***pro-***

technology, and society. The real-life context of

fessional development*. Teachers can engage in*

the module's classroom lessons is engaging, and

new and different teaching practices such as those

the knowledge gained can be applied immediately

described in this module without completely

to students' lives.

overhauling their entire program. In Designing

Professional Development for Teachers of Science

"Nice reflection on self-issues of hearing. Many

and Mathematics, the authors write that supple-

students are amazed at how many times they might

ments such as this one "offer a window through

be causing damage." – Field-Test Teacher

which teachers get a glimpse of what new teach-

ing strategies look like in action."6 By experienc-

"I learned a lot about how hearing works and

ing a short-term unit, teachers can "change how

what you can do to keep it working well."

they think about teaching and embrace new

– Field-Test Student

approaches that stimulate students to problem-

solve, reason, investigate, and construct their own

What's in It for the Teacher?

meaning for the content." The use of a supple-

How Your Brain Understands What Your Ear Hears

mental unit such as this module can encourage

meets many of the criteria by which teachers and

reflection and discussion, and stimulate teachers

their programs are assessed.

to improve their practices by focusing on student

• The module is ***standards based*** *and meets sci-*

learning through inquiry.

ence content, teaching, and assessment stan-

dards as expressed in the National Science

The following table correlates topics often included

Education Standards. It pays particular attention in a biology curriculum with the major concepts

to the standards that describe what students

presented in this module. This information is pre-

should know and be able to do with respect to

sented to help teachers make decisions about incor-

***scientific inquiry**.*

porating this material into the curriculum.

2

Correlation of How Your Brain Understands What Your Ear Hears to Middle School Life Science Topics Topic

Lesson 1

Lesson 2

Lesson 3

Lesson 4

Lesson 5

Organisms sense and respond to

✔

✔

✔

✔

✔

environmental stimuli.

Sound is a form of energy.

✔

✔

✔

✔

Energy can change from one form

✔

to another.

Human health and medicine

✔

✔

✔

Risk assessment and management

✔

Relationship of science, technology,

and society

✔

3

Introduction

Implementing

the Module

The five lessons in this module are designed to

tists. They are introduced to the concepts of loud-

be taught in sequence for one to two weeks (as a

ness and pitch, and they learn how these concepts

supplement to the standard curriculum) or as

relate to hearing and hearing loss in humans (Do

individual lessons that support or enhance your

You Hear What I Hear?). Students are then intro-

treatment of specific concepts in middle school

duced to the hearing pathway and the concept of

science. The following pages offer general sug-

transduction in A Black Box Problem: How Do I

gestions about using these materials in the class-

Hear? In the final lesson, students evaluate the risk room. You will find specific suggestions in the

of noise-induced hearing loss for fictitious individ-

procedures provided for each lesson.

uals. They also consider whether their own lifestyle

places them at risk (Too Loud, Too Close, Too Long).

What Are the Goals of the Module?

The table on pages 8 and 9 illustrates the scientific *content and conceptual flow of the five lessons.*

is designed to help students achieve the following

major goals associated with scientific literacy:

How Does the Module Correlate with the

• *to understand a set of basic scientific principles*

National Science Education Standards?

related to hearing and communication and

How Your Brain Understands What Your

their relationship to human health;

Ear Hears supports teachers in their

• *to experience the process of scientific inquiry*

efforts to reform science education in

and develop an enhanced understanding of the

the spirit of the National Research

nature and methods of science; and

Council's 1996 National Science Educa-

• *to recognize the role of science in society and*

tion Standards (NSES). The content is explicitly the relationship between basic science and

standards based. Each time a standard is addressed

human health.

in a lesson, an icon appears in the margin and the

applicable standard is identified. The Content Stan-

What Are the Science Concepts

dards chart on pages 6 and 7 lists the specific con-

and How Are They Connected?

tent standards that this module addresses.

The lessons are organized into a conceptual frame-

work that allows students to move from what they

Teaching Standards

already know about hearing, some of which may

The suggested teaching strategies in all of the les-

be incorrect, to gaining a scientific perspective on

sons support teachers as they work to meet the

the nature of hearing and communication. Stu-

teaching standards outlined in the National Sci-

dents learn about hearing and human communica-

ence Education Standards. This module helps

tion by investigating the diversity of languages and

teachers of science plan an inquiry-based science

their acquisition (Getting the Message). Students program by providing short-term objectives for

then explore the multisensory nature of communi-

students. It also includes planning tools such as

cation and classify the types of sounds in their

the Science Content and Conceptual Flow of the

environment (Sound Communication). Students

Lessons table and the Suggested Timeline for

proceed to learn how sound is studied by scien-

teaching the module. Teachers can use this mod-

Content Standards: Grades 5–8

Standard A: As a result of their activities in grades 5–8, Correlation to How Your

all students should develop

Brain Understands What

Your Ear Hears

Abilities necessary to do scientific inquiry

• Identify questions that can be answered through scientific investigations.

Lesson 4

• Use appropriate tools and techniques to gather, analyze, and interpret Lesson 3

data.

• Develop descriptions, explanations, predictions, and models using Lessons 3, 4

evidence.

• Think critically and logically to make the relationships between Lessons 3, 4, 5

evidence and explanations.

• Recognize and analyze alternative explanations and predictions.

Lessons 1, 2, 3, 4

• Communicate scientific procedures and explanations.

Lessons 2, 4, 5

• Use mathematics in all aspects of scientific inquiry.

Lessons 3, 5

Understandings about scientific inquiry

• Different kinds of questions suggest different kinds of scientific investi-All Lessons

gations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects; and some involve making models.

• Mathematics is important in all aspects of scientific inquiry.

Lessons 3, 5

Standard B: As a result of their activities in grades 5–8, all students should develop an understanding of

Transfer of energy

• Energy is a property of many substances and is associated with heat, Lesson 4

light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

Standard C: As a result of their activities in grades 5–8, all students should develop an understanding of

Structure and function in living systems

• Living systems at all levels of organization demonstrate the comple-Lesson 4

mentary nature of structure and function. Important levels of organization for structure and function include cells, organs, tissues, organ systems, whole organisms, and ecosystems.

• Specialized cells perform specialized functions in multicellular organisms.

Lesson 4

Groups of specialized cells cooperate to form a tissue, such as muscle.

Different tissues are in turn grouped together to form larger functional units, called organs. Each type of cell, tissue, and organ has a distinct structure and set of functions that serve the organism as a whole.

6

• Disease is a breakdown in structures or functions of an organism.

Lessons 3, 4, 5

Some diseases are the result of intrinsic failures of the system. Others are the result of damage by infection by other organisms.

Regulation and behavior

• Behavior is one kind of response an organism can make to an internal Lessons 1, 2, 5

or environmental stimulus.

Standard E: As a result of their activities in grades 5–8, all students should develop

Understandings about science and technology

• Science and technology are reciprocal. Science helps drive technology.

Lessons 3, 4, 5

Technology is essential to science, because it provides instruments and techniques that enable observations of objects and phenomena that are otherwise unobservable.

• Technological solutions have intended benefits and unintended conse-Lesson 5

quences.

Standard F: As a result of their activities in grades 5–8, all students should develop an understanding of

Personal health

• The potential for accidents and the existence of hazards imposes the Lesson 5

need for injury prevention. Safe living involves the development and use of safety precautions and the recognition of risk in personal decisions.

Risks and benefits

• Risk analysis considers the type of hazard and estimates the number of Lesson 5

people who might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.

• Important personal and social decisions are made based on percep-Lesson 5

tions of benefits and risks.

Science and technology in society

• Technology influences society through its products and processes. Tech-Lessons 4, 5

nology influences the quality of life and the ways people act and interact.

Standard G: As a result of their activities in grades 5–8, all students should develop an understanding of

Science as a human endeavor

• Science requires different abilities, depending on such factors as the All Lessons

field of study and type of inquiry. Science is very much a human endeavor, and the work of science relies on basic human qualities, such as reasoning, insight, energy, skills, and creativity.

Nature of science

• Scientists formulate and test their explanations of nature using obser-Lessons 3, 4

vation, experiments, and theoretical and mathematical models.

Science Content and Conceptual Flow of the Lessons

Lesson and Learning Focus*

Topics Covered and Major Concepts

1: Getting the Message

Distinguishing between hearing and communication.

• Hearing involves sound, while understanding involves the brain.

Engage: *Students become en-*

gaged in the study of hearing, com-

Relating the concept of critical period to language acquisition.

munication, and understanding.

• There is a critical period during which language acquisition takes place.

2: Sound Communication

Communication is multisensory.

• The most effective communication is multisensory.

Explore: *Students watch and listen*

• Sound is a powerful and important means of communication.

to human speech. They explore the

multisensory nature of human

Sounds can be environmental, voiced, and musical.

communication. The Explore phase

• There are three types of sound: environmental, voiced, and gives students a common set of

musical.

experiences upon which to begin

building their understanding.

3: Do You Hear What I Hear?

Characteristics of loudness and pitch.

• Loudness and pitch are distinct properties of sound.

Explore/Explain: *Students gener-*

• Loudness is related to the amplitude of the sound wave; ate a hearing-response curve.

pitch is related to its frequency.

They also listen to recordings that

simulate hearing loss. Students

The human hearing response and hearing loss.

express their understanding of the

• Humans do not hear all pitches equally well.

relationships among loudness,

• The loudness of very-low- and very-high-pitched sounds

pitch, and hearing.

must be increased for them to be detected.

• A healthy sense of hearing is characterized by the recognition of a wide spectrum of pitches.

• Hearing loss may involve failure to detect specific pitches.

4: A Black Box Problem: How

The components of the hearing pathway and their functions.

Do I Hear?

• The hearing pathway processes sound in a series of steps that involve different structures within the ear.

Elaborate: *Students deepen*

• Hearing requires the passage of vibrational energy from one their understanding of hearing

medium to another, as well as its conversion to electrical by investigating the parts of the

energy (in the form of nerve impulses).

hearing pathway and their

• Damage to specific parts of the hearing pathway results in functions.

predictable changes in hearing.

The process of transduction.

• Transduction is the conversion of vibrational energy into electrical energy that occurs in the cochlea.

8

5: Too Loud, Too Close, Too

Understanding occurs in the brain.

Long

• Understanding what one hears occurs in the brain.

• Damage to specific parts of the hearing pathway results in

Elaborate/Evaluate: *Students*

predictable changes in hearing.

reflect on what they learned in the

module in the context of noise-

Characteristics, causes, and prevention of noise-induced

induced hearing loss (NIHL). They

hearing loss.

evaluate risks for NIHL for several

• Noise-induced hearing loss leads to an inability to hear and fictitious individuals as well as for

understand speech and other sounds at normal loudness

themselves and recommend ways

levels.

to reduce these risks.

- *Noise-induced hearing loss can be temporary or permanent.*

- *Noise-induced hearing loss can result from a one-time exposure to extremely loud sound, repeated or long-term expo-*

sure to loud sound, or extended exposure to moderate

sound.

- *Noise-induced hearing loss can happen to people of all ages.*

- *The best way to protect one's hearing is to avoid loud noise whenever possible.*

**See How Does the 5E Instructional Model Promote Active, Collaborative, Inquiry-Based Learning? on pages 9 to 11.*

ule to update their curriculum in response to their

variety of assessment components embedded

students' interest in this topic. The focus on

within the module's structure. The assessment

active, collaborative, and inquiry-based learning

tasks are authentic; they are similar to tasks that

in the lessons helps teachers support the develop-

students will engage in outside the classroom or

ment of student understanding and nurture a

to practices in which scientists participate. Anno-

community of science learners.

tations guide teachers to these opportunities for

assessment and provide answers to questions that

The structure of the lessons in this module enables

can help teachers analyze student feedback.

teachers to guide and facilitate learning. All of the

activities encourage and support student inquiry,

How Does the 5E Instructional

promote discourse among students, and challenge

Model Promote Active, Collaborative,

students to accept and share responsibility for their

Inquiry-Based Learning?

learning. The use of the 5E Instructional Model,

Because learning does not occur by way of passive

combined with active, collaborative learning,

absorption, the lessons in this module promote

allows teachers to respond effectively to the diver-

active learning. Students are involved in more

sity of student backgrounds and learning styles.

than listening and reading. They are developing

The module is fully annotated, with suggestions

skills, analyzing and evaluating evidence, experi-

for how teachers can encourage and model the

encing and discussing, and talking to their peers

skills of scientific inquiry, as well as foster curios-

about their own understanding. Students work

ity, openness to new ideas and data, and skepti-

collaboratively with others to solve problems and *cism, which characterize the study of science.*

plan investigations. Many students find that they

learn better when they work with others in a col-

Assessment Standards

laborative environment than when they work

Teachers can engage in ongoing assessment of

alone in a competitive environment. When active,

their teaching and of student learning using the

collaborative learning is directed toward scientific

inquiry, students succeed in making their own

• determine students' current understanding

discoveries. They ask questions, observe, analyze,

about hearing and communication;

explain, draw conclusions, and ask new ques-

• invite students to raise their own questions

tions. These inquiry-based experiences include

about hearing and its relationship to human

both those that involve students in direct experi-

communication;

mentation and those in which students develop

• encourage students to compare their ideas with

explanations through critical and logical thinking.

those of others; and

• enable teachers to assess what students do or do

The viewpoint that students are active thinkers

not understand about the stated outcomes of the

who construct their own understanding from

lesson.

interactions with phenomena, the environment,

and other individuals is based on the theory of

Explore

constructivism. *A constructivist view of learning*

In the Explore phase of the module, Lesson 2:

recognizes that students need time to

Sound Communication, and Lesson 3: Do You Hear

• express their current thinking;

What I Hear? , students investigate the multisen-

• interact with objects, organisms, substances,

sory nature of human communication and com-

and equipment to develop a range of experi-

municating by way of sounds in their

ences on which to base their thinking;

environment. Students also investigate the charac-

• reflect on their thinking by writing and express-

teristics of sound, such as loudness and pitch.

ing themselves and comparing what they think

These lessons provide a common set of experi-

with what others think; and

ences within which students can begin to con-

• make connections between their learning expe-

struct their understanding. Students

riences and the real world.

• interact with materials and ideas through class-

This module provides a built-in structure for creat-

room demonstrations and simulations;

ing a constructivist classroom: the 5E Instructional

• consider different ways to solve a problem or

Model. The 5E model sequences the learning expe-

answer a question;

riences so that students have the opportunity to

• acquire a common set of experiences with their

construct their understanding of a concept over

classmates so they can compare results and

time. The model leads students through five phases

ideas;

of learning that are easily described using words

• observe, describe, record, compare, and share

that begin with the letter E: Engage, Explore,

their ideas and experiences; and

Explain, Elaborate, and Evaluate. The following

• express their developing understanding of

paragraphs illustrate how the five Es are imple-

sound, hearing, and communication.

mented across the lessons in this module.

Explain

Engage

The Explain lesson provides opportunities for stu-

Students come to learning situations with prior

dents to connect their previous experiences and to

knowledge. This knowledge may or may not be

begin to make conceptual sense of the main ideas

congruent with the concepts presented in this

of the module. This stage also allows for the

module. The Engage lesson provides the opportu-

introduction of formal language, scientific terms,

nity for teachers to find out what students already

and content information that might make stu-

know or think they know about the topic and

dents' previous experiences easier to describe. The

concepts to be covered.

Explain lesson for this module, Lesson 3: Do You

The Engage lesson in this module, Lesson 1: Get-

Hear What I Hear? , encourages students to

ting the Message, is designed to

- *explain concepts and ideas (in their own words)*
- *pique students' curiosity and generate interest;*

about sound in terms of loudness and pitch;

• listen to and compare the explanations of others

The Evaluate lesson in this module, Lesson 5: Too

with their own;

Loud, Too Close, Too Long, provides an opportunity

• become involved in student-to-student dis-

for students to

course in which they explain their thinking to

• demonstrate what they understand about the

others and debate their ideas;

ear and hearing and how well they can apply

• revise their ideas;

their knowledge to solve a problem, namely

• record their ideas and current understanding;

reducing risk for noise-induced hearing loss;

• use labels, terminology, and formal language;

• share their current thinking with others;

and

• assess their own progress by comparing their

• compare their current thinking with what they

current understanding with their prior knowl-

previously thought.

edge; and

• ask questions that take them deeper into a

Elaborate

concept.

In Elaborate lessons, students apply or extend

previously introduced concepts in new situations

To review the relationship of the 5E Instructional

and relate their previous experiences to new ones.

Model to the concepts presented in the module,

In the Elaborate lesson in this module, Lesson 4:

see the table titled Science Content and Concep-

A Black Box Problem: How Do I Hear?, students

tual Flow of the Lessons, on pages 8 and 9.

• make conceptual connections between new and

former experiences, connecting the structure of

When a teacher uses the 5E Instructional Model,

the ear with their concepts of sound and com-

he or she engages in practices that are very differ-

munication;

ent from those of a traditional teacher. In

• connect ideas, solve problems, and apply their

response, students also learn in ways that are dif-

understanding to a new situation;

ferent from those experienced in a traditional

• use scientific terms and descriptions;

classroom. The following charts, What the

• draw reasonable conclusions from evidence and

Teacher Does and What the Students Do, outline *data;*

these differences.

• *add depth to their understanding of concepts*

and processes; and

How Does the Module Support

• *communicate their understanding to others.*

Ongoing Assessment?

Because teachers will use this module in a variety

Evaluate

of ways and at a variety of points in the curricu-

The Evaluate lesson is the final stage of the

lum, the most appropriate mechanism for assess-

instructional model, but it only provides a "snap-

ing student learning is one that occurs informally

shot" of what the students understand and how

at various points within the lessons, rather than

far they have come from where they began. In

just once at the end of the module. Accordingly,

reality, the evaluation of students' conceptual

integrated within the lessons in the module are

understanding and ability to use skills begins with

specific assessment components. These "embed-

the Engage lesson and continues throughout each

ded" assessment opportunities include one or

stage of the instructional model, as described in *more of the following strategies:*

the following section. Combined with the stu-

• performance-based activities, such as develop-

dents' written work and performance of tasks

ing graphs or participating in a discussion about

throughout the module, however, the Evaluate

risk assessment;

lesson can serve as a summative assessment of

• oral presentations to the class, such as reporting

what students know and can do.

experimental results; and

What the Teacher Does

Stage

That is consistent with

That is inconsistent with

the 5E Instructional Model

the 5E Instructional Model

Engage

• Piques students' curiosity and generates

• Introduces vocabulary

interest

• Explains concepts

• Determines students' current understand-

• Provides definitions and answers

ing (prior knowledge) of a concept or idea

• Provides closure

• Invites students to express what they think

• Discourages students' ideas and questions

• Invites students to raise their own questions

Explore

• Encourages student-to-student interaction

• Provides answers

• Observes and listens to the students as

• Proceeds too rapidly for students to

they interact

make sense of their experiences

• Asks probing questions to help students

• Provides closure

make sense of their experiences

• Tells students that they are wrong

• Provides time for students to puzzle

• Gives information and facts that solve the

through problems

problem

• Leads students step-by-step to a solution

Explain

• Encourages students to use their common

• Neglects to solicit students' explanations

experiences and data from the Engage and

• Ignores data and information students

Explore lessons to develop explanations

gathered from previous lessons

• Asks questions that help students express

• Dismisses students' ideas

understanding and explanations

• Accepts explanations that are not sup-

• Requests justification (evidence) for

ported by evidence

students' explanations

• Introduces unrelated concepts or skills

• Provides time for students to compare

their ideas with those of others and

perhaps to revise their thinking

• Introduces terminology and alternative ex-

planations after students express their ideas

Elaborate

• Focuses students' attention on conceptual

• Neglects to help students connect new

connections between new and former

and former experiences

experiences

• Provides definitive answers

• Encourages students to use what they have

• Tells students that they are wrong

learned to explain a new event or idea

• Leads students step-by-step to a solution

• Reinforces students' use of scientific terms

and descriptions previously introduced

• Asks questions that help students draw

reasonable conclusions from evidence

and data

Evaluate

• Observes and records as students demon-

• Tests vocabulary words, terms, and iso-

strate their understanding of concept(s)

lated facts

and performance of skills

• Introduces new ideas or concepts

• Provides time for students to compare

• Creates ambiguity

their ideas with those of others and per-

• Promotes open-ended discussion unre-

haps to revise their thinking

lated to the concept or skill

• Interviews students as a means of assess-

ing their developing understanding

• Encourages students to assess their own

progress

12

What the Students Do

Stage

That is consistent with

That is inconsistent with

the 5E Instructional Model

the 5E Instructional Model

Engage

• Become interested in and curious about

• Ask for the "right" answer

the concept/topic

• Offer the "right" answer

• Express current understanding of a concept

• Insist on answers or explanations

or idea

• Seek closure

• Raise questions such as, What do I already

know about this? What do I want to know

about this? How could I find out?

Explore

• "Mess around" with materials and ideas

• Let others do the thinking and exploring

• Conduct investigations in which they

(passive involvement)

observe, describe, and record data

• Work quietly with little or no interaction

• Try different ways to solve a problem or

with others (only appropriate when

answer a question

exploring ideas or feelings)

• Acquire a common set of experiences so

• Stop with one solution

they can compare results and ideas

• Demand or seek closure

• Compare their ideas with those of others

Explain

• Explain concepts and ideas in their own

• Propose explanations from "thin air" with

words

no relationship to previous experiences

• Base their explanations on evidence

• Bring up irrelevant experiences and

acquired during previous investigations

examples

• Record their ideas and current understand-

• Accept explanations without justification

ing

• Ignore or dismiss other plausible expla-

• Reflect on and perhaps revise their ideas

nations

• Express their ideas using appropriate scien-

• Propose explanations without evidence

tific language

to support their ideas

• Compare their ideas with what scientists

know and understand

Elaborate

• Make conceptual connections between

• Ignore previous information or evidence

new and former experiences

• Draw conclusions from "thin air"

• Use what they have learned to explain a

• Use terminology inappropriately and

new object, event, organism, or idea

without understanding

• Use scientific terms and descriptions

• Draw reasonable conclusions from evi-

dence and data

• Communicate their understanding to others

• Demonstrate what they understand about

the concept(s) and how well they can

implement a skill

Evaluate

• Compare their current thinking with that of

• Disregard evidence or previously accepted

others and perhaps revise their ideas

explanations in drawing conclusions

• Assess their own progress by comparing

• Offer only yes-or-no answers or memo-

their current understanding with their prior

rized definitions or explanations as

knowledge

answers

• Ask new questions that take them deeper

• Fail to express satisfactory explanations

into a concept or topic area

in their own words

• Introduce new, irrelevant topics

How Your Brain Understands What Your Ear Hears

• written assignments, such as answering ques-

• Do not overlook any violation of a safety prac-

tions or writing about demonstrations.

tice, no matter how minor. If a rule is broken,

take steps to assure that the infraction will not

These strategies allow the teacher to assess a variety

occur a second time.

of aspects of the learning process, such as students'

• Set a good example by observing all safety prac-

prior knowledge and current understanding, prob-

tices. This includes wearing eye protection dur-

lem-solving and critical-thinking skills, level of

ing all investigations when eye protection is

understanding of new information, communica-

required for the students.

tion skills, and ability to synthesize ideas and apply

• Know and follow waste-disposal regulations.

understanding to a new situation.

• Be aware of students who have allergies or other

An assessment icon and an annotation

medical conditions that might limit their ability

that describes the aspect of learning

to participate in activities. Consult with the

that teachers can assess appear in the

school nurse or school administrator.

margin beside each step in which

• Anticipate potential problems. When planning

embedded assessment occurs.

teacher demonstrations or student investiga-

tions, identify potential hazards and safety con-

How Can Teachers Promote Safety

cerns. Be aware of what might go wrong and

in the Science Classroom?

what can be done to prevent the worst-case sce-

Even simple science demonstrations and investi-

nario. Before each activity, verbally alert the stu-

gations can be hazardous unless teachers and stu-

dents to the potential hazards and distribute

dents know and follow safety precautions.

specific safety instructions as well.

Teachers are responsible for providing students

• Supervise students at all times during a hands-

with active instruction concerning their conduct

on activity.

and safety in the classroom. Posting rules in a

• Provide sufficient time for students to set up the

classroom is not enough; teachers also need to

equipment, perform the investigation, and prop-

provide adequate supervision and advance warn-

erly clean up and store the materials after use.

ing if there are dangers involved in the science

• Never assume that students know or remember

investigation. By maintaining equipment in

safety rules or practices from their previous sci-

proper working order, teachers ensure a safe envi-

ence classes.

ronment for students.

How Can Controversial Topics Be

The following are important ways to implement

Handled in the Classroom?

and maintain a safety program:

• Provide eye protection for students, teachers,

Teachers sometimes feel that the discussion of

and visitors. Require that everyone participating

values is inappropriate in the science classroom

wear regulation goggles in any situation where

or that it detracts from the learning of "real" sci-

there might be splashes, spills, or spattering.

ence. The lessons in this module, however, are

Teachers should always wear goggles in such sit-

based upon the conviction that there is much to

uations.

be gained by involving students in analyzing

• Know and follow the state and district safety

issues of science, technology, and society. Society

rules and policies. Be sure to fully explain to the

expects all citizens to participate in the demo-

students the safety rules they should use in the

cratic process, and our educational system must

classroom.

provide opportunities for students to learn to

• At the beginning of the school year, establish

deal with contentious issues with civility, objec-

consequences for students who behave in an

tivity, and fairness. Likewise, students need to

unsafe manner. Make these consequences clear

learn that science intersects with life in many

to students.

ways.

14

In this module, students are given a variety of

• Use unbiased questioning to help the students

opportunities to discuss, interpret, and evaluate

critically examine all views presented.

basic science and health issues, some in light of

• Allow for the discussion of all feelings and

their values and ethics. As students encounter

opinions.

issues about which they feel strongly, some dis-

• Avoid seeking consensus on all issues. The mul-

cussions might become controversial. The degree

tifaceted issues that the students discuss result

of controversy will depend on many factors, such

in the presentation of divergent views, and stu-

as how similar the students are with respect to

dents should learn that this is acceptable.

socioeconomic status, perspectives, value sys-

• Acknowledge all contributions in the same

evenhanded manner. If a student seems to be

tems, and religious preferences. In addition, the

saying something for its shock value, see

language and attitude of the teacher factor into the

whether other students recognize the inappro-

flow of ideas and the quality of exchange among

priate comment and invite them to respond.

the students.

• Create a sense of freedom in the classroom.

The following guidelines may help teachers facili-

Remind students, however, that freedom implies

tate discussions that balance factual information

the responsibility to exercise that freedom in

with feelings.

ways that generate positive results for all.

• Remain neutral. Neutrality may be the single

• Insist upon a nonhostile environment in the

most important characteristic of a successful

classroom. Remind students to respond to ideas

discussion facilitator.

instead of to the individuals presenting those

• Encourage students to discover as much infor-

ideas.

mation about the issue as possible.

• Respect silence. Reflective discussions often

• Keep the discussion relevant and moving for-

are slow. If a teacher breaks the silence, stu-

ward by questioning or posing appropriate

dents may allow the teacher to dominate the

problems or hypothetical situations. Encourage

discussion.

everyone to contribute, but do not force reluc-

• At the end of the discussion, ask the students to

tant students to enter the discussion.

summarize the points that they and their class-

• Emphasize that everyone must be open to hear-

mates have made. Respect students regardless of

ing and considering diverse views.

their opinion about any controversial issue.

NSES

Using the

Using the

Student Lessons

The heart of this module is the set of five class-

*• **Web-Based Activities** tells the teacher which of*

room lessons. These lessons are the vehicles that

the lesson's activities use the How Your Brain *will carry important concepts related to hearing*

Understands What Your Ear Hears Web site as

and communication to your students. To review

the basis for instruction.

the concepts in detail, refer to the chart Science

• ***Photocopies*** *lists the paper copies and trans-*

Content and Conceptual Flow of the Lessons, on

parencies that need to be made from masters,

pages 8 and 9.

which follow the student lesson.

• ***Materials*** *lists all the materials other than pho-Format of the Lessons*

tocopies needed for each of the activities in the

As you scan the lessons, you will find that each

lesson.

contains several major features.

• ***Preparation*** *outlines tasks the teacher needs to*

perform prior to the lesson.

At a Glance *gives the teacher a convenient sum-*

mary of the lesson.

Procedure *outlines the steps in each activity of the*

• *The* ***Overview*** *provides a short summary of stu-*

lesson. It provides implementation hints and

dent activities.

answers to discussion questions.

• *The* ***Major Concepts*** *section states the central*

Within the procedure, annotations provide addi-

idea(s) the lesson is designed to convey.

tional commentary.

• ***Objectives*** *lists specific understandings or abilities students should have after completing the*

• ***Assessment*** *provides strategies for assessing*

lesson.

student progress throughout the module, and is

• ***Teacher Background*** *specifies which portions*

identified by an assessment icon (see page 18).

of the background section titled Information

• ***Icons*** *identify specific annotations:*

about Hearing, Communication, and Understand-

identifies teaching strategies that

ing relate directly to the student lesson. This

address specific science content stan-

reading material provides the teacher with the

dards as defined by the National Sci-

science content that underlies the key concepts

ence Education Standards.

covered in the lesson. The information pro-

vided is not intended to form the basis of lec-

identifies when to use the Web site as

tures to students. Instead, it enhances the

part of the teaching strategy. Instruc-

teacher's understanding of the content so that tions tell the teacher how to access the

he or she can more accurately facilitate class

Web site and the relevant activity.

discussions, answer student questions, and pro-

Information about using the Web site can be found

vide additional examples.

in Using the Web Site (see pages 21–24) . A print-based alternative to Web activities is provided in

In Advance provides instructions for collecting

the event that computers with Internet access are

and preparing the materials required to complete

not available.

the activities in the lesson.

How Your Brain Understands What Your Ear Hears

identifies a print-based alternative to a

The Lesson Organizer provides a brief summary of

Web-based activity to be used when

the lesson. It outlines procedural steps for each

computers are not available.

activity and includes icons that denote where in

each activity masters, transparencies, and the Web

identifies when assessment is embed-

site are used. The lesson organizer is intended to be

ded in the module's structure. An

a memory aid for you to use only after you become

annotation suggests strategies for

familiar with the detailed procedures for the activi-

assessment.

ties. It can be a handy resource during lesson prepa-

ration as well as during classroom instruction.

Suggested Timeline

Timeline

Activity

Reserve computers

3 weeks ahead

Verify ability to access Internet and to download required plug-ins Copy masters

1 week ahead

Make transparencies

Gather materials

Lesson 1

Day 1

Activity 1: What Did You Say?

Monday

Activity 2: When the Time Is Right

Lesson 2

Day 2

Activity 1: How Do We Understand?

Tuesday

Activity 2: Sound Safari

Day 3

Lesson 3

Wednesday

Activity 1: Measuring Intensity

Day 4

Activity 2: Pitch Me a Curve

Thursday

Day 5

Lesson 4

Friday

Activity 1: The Mysterious Black Box

Day 6

Activity 2: Understanding Form and Function

Monday

Lesson 5

Day 7

Activity 1: It's Too Loud!

Tuesday

Activity 2: Assessing Risk for Hearing Loss

Day 8

Activity 3: Sound Advice

Wednesday

*The **Masters** required to teach the activities are*

ule. This schedule assumes that you will teach the *located at the end of each lesson.*

activities on consecutive days. If your class

requires more time for completing the procedures,

Timeline for the Module

for discussion of issues raised in this module, or

The timeline (on page 18) outlines the optimal

for completing activities on the Web site, adjust

plan for completing the five lessons in this mod-

your timeline accordingly.

Using the

Using the

Web Site

The How Your Brain Understands What Your Ear

QuickTime Player plug-ins are provided on the

Hears Web site is a tool, like an overhead projec-Web site main page. The minimum hardware and

tor or a textbook, that can help you organize your

software requirements for using the Web site are

use of the module, engage student interest in

listed in the following table.

learning, and orchestrate and individualize

To access the Web site, type the following URL

instruction. The Web site features sound clips,

into your browser: http://science.education.nih.gov/

video clips, and animations that complement

supplements/hearing/teacher.

three of the module lessons.

Getting the Most out of the Web Site

Hardware/Software Requirements

Before you use the Web site, or any other piece of

The Web site can be accessed from Apple Macin-

instructional software in your classroom, it may

tosh and IBM-compatible personal computers.

be valuable to identify some of the benefits you

Links to download the Macromedia Flash and

Minimum Hardware/Software Requirements for Using the Web Site *CPU/Processor (PC Intel, Mac)*

Pentium 333 MHz, Power PC or faster

Operating system (DOS/Windows, Mac OS)

Windows 95/98/2000 or Mac OS 7

System memory (RAM)

64 MB or more

Screen display

800 x 600, 16 bit (65K colors)

Browser

Microsoft Internet Explorer 5.5 or

Netscape Communicator 4.75 and higher

Browser settings

JavaScript enabled

Free hard drive space

10 MB

Connection speed

56 kbps

Plug-ins

Macromedia Flash Player (version 6 and higher)

and QuickTime Player (version 5 and higher)

Audio

Sound card with speakers

expect the software to provide. Well-designed

than this will have difficulty organizing the stu-

instructional multimedia software can

dent-computer interactions equitably, which can

• motivate students by helping them enjoy learn-

lead to one or two students' assuming the primary

ing and want to learn more because it enlivens

responsibility for the computer-based work.

content that students otherwise might find

Although this type of arrangement can be effi-

uninteresting;

cient, it means that some students will not have

• offer unique instructional capabilities that allow

the opportunity to experience the in-depth dis-

students to explore topics in greater depth and *covery and analysis that the Web site was*

in ways that are closer to actual real-life experi-

designed to stimulate.

ence than print-based resources can offer;

We recommend that you keep your students in

• provide teachers with support for experiment-

the same collaborative teams for all of the activi-

ing with new instructional approaches that

ties in the lessons. This will allow each team to

allow students to work independently or in

develop a shared experience with the Web site and

small teams and that give teachers increased

with the ideas and issues that the activities pre-

credibility among today's technology-literate

sent. A shared experience also will enhance your

students; and

students' perceptions of the lessons as a concep-

• increase teacher productivity by helping teach-

tual whole.

ers with assessment, record keeping, and class-

room planning and management.

If your student-to-computer ratio is greater than *four students to one computer, then you will need*

The ideal use of the Web site requires one com-

to change the way you teach the module from the

puter for each student team. However, if you have

instructions in the lessons. For example, if you

only one computer available in the classroom, you

have only one computer available, you may want

can still use the Web site (for example, by using a

students to complete the Web-based work over an

suitable device for projecting the screen image, or

extended time period. You can do this in several

by rotating student teams through the computer

ways. The most practical way is to use your com-

station). If you do not have the facilities for using

puter as a center along with several other centers

the Web site with your students, the print-based

at which students complete other activities. In this

alternatives are provided for those lessons.

approach, students rotate through the computer

center, eventually completing the Web-based

Collaborative Groups

work that you have assigned.

Many of the activities in the lessons are designed

to be completed by teams of students working

A second way to structure the lessons if you have *together. Although individual students working*

only one computer available is to use a projection

alone can complete these activities, this strategy

system to display the desktop screen for the whole

will not stimulate the types of student-student

class to view. Giving selected students in the class

interactions that are part of active, collaborative,

the opportunity to manipulate the Web activities

inquiry-based learning. Therefore, we recommend

in response to suggestions from the class can give

that you organize collaborative teams of two to

students some of the same autonomy in their

four students each, depending on the number of

learning they would have gained from working in

computers available. Students in groups larger

small teams.

Web Activities for Students

If you use assistive technology (such as a Braille

with Disabilities

reader or a screen reader) and the format of any

The Office of Science Education (OSE) is com-

material on our Web sites interferes with your

mitted to providing access to the Curriculum

ability to access the information, please let us

Supplement Series for individuals with disabili-

know. To enable us to respond in a manner most

ties, including members of the public and federal

helpful to you, please indicate the nature of your

employees. To meet this commitment, we will

accessibility problem, the format in which you

comply with the requirements of Section 508 of

would prefer to receive the material, the Web

the Rehabilitation Act. Section 508 requires that

address of the requested material, and your con-

individuals with disabilities who are members of

tact information.

the public seeking these materials will have

Contact us at

access to and use of information and data that

Office of Science Education

are comparable to those provided to members of

National Institutes of Health

the public who are not individuals with disabili-

6705 Rockledge Drive, Suite 700 MSC 7984

ties. The online versions of this series have been

Bethesda, MD 20892-7984

prepared to comply with Section 508.

ose@science.education.nih.gov

How Your Brain Understands What Your Ear Hears 508-Compliant Web Activities Lesson,

For students with hearing impairment

For students with sight impairment

activity

Lesson 1, Activity 1:

Students may click on the closed-cap-

There is a text description within the

What Did You Say?

tioning icon to view the captioning for

activity that is read by screen readers.

Tracks 1–6.

It describes the format of the activity

and indicates what software is

required for optimal performance.

The closed-captioning icon is located

Tracks 1–6 are accessible via the

in the top left corner of the activity,

keyboard. When using a screen

within the rounded gray rectangle.

reader, Track 4 includes a descriptive

The text appears below the track list-

narration.

ing and animation.

Lesson 3, Activity 2:

Students may click on the closed-cap-

There is a text description within the

Pitch Me a Curve

tioning icon to view the captioning

activity that is read by screen readers.

for the Introduction and Filtered

It describes the format of the activity

Sound sections.

and indicates what software is

required for optimal performance.

The Introduction screen includes a

text description of the oscilloscope

The closed-captioning icon is

tracings.

located in the top left corner of the

activity, within the rounded gray

When using a screen reader, the

rectangle. The text appears below

hearing-response graph begins with

the animation.

an audio description and instructions

for the activity. Students may navigate

between pitches with the Tab key

Using the Web Site

How Your Brain Understands What Your Ear Hears

Throughout the activity, an oscillo-

and increase/decrease the loudness

scope provides a visual representa-

with the +/– keys.

tion of the sounds that occur.

When using a screen reader, the Fil-

tered Sound section begins with an

audio description and instructions for

the activity. The audio describes the

differences between each track. Stu-

dents may navigate to the three track

buttons using the Tab key.

Supervision is recommended.

Lesson 4, Activity 1:

Introduction, Animation, Sequencing

There is a text description within the

The Mysterious

Activity

activity that is read by screen readers. It

Black Box

describes the different sections of the

Students may click on the closed-cap-

activity and indicates what software is

tioning icon to view the captioning

required for optimal performance.

for the Introduction and Animation

sections. The final animation at the

When using a screen reader, the Intro-

end of the Sequencing Activity also

duction includes a descriptive narra-

has captioning available.

tion that explains the animation. A

second descriptive narration explains

the Black Box Animation.

When using a screen reader, students

The icon is located in the top left cor-

will encounter an accessible version

ner of the activity, within the rounded

of the Sequencing Activity. This

gray rectangle. The text appears

includes text instructions and audio

below the animations.

feedback during the game. Students

are instructed to complete the

sequence by putting the components

of the hearing pathway in their correct

order. Once they have placed the

components in order, they can review

and test the sequence.

Once the Sequencing Activity has

been completed successfully, students

move on to the final animation. A

descriptive narration explains the ani-

mation of the hearing pathway.

Supervision is recommended.

Lesson 5, Activity 1:

No special considerations are

An equivalent description of the

How Small Is a

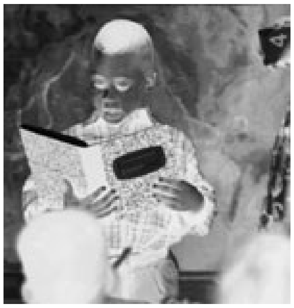
required.

video has been provided. It is

Hair Cell?

located directly beneath the video

and is accessible via a screen reader.



Information about

Hearing, Communication,

and Understanding

Figure 1. *Sounds may be classified as environmental, voiced, or musical.*

1 Introduction

• A recent study showed that men who hunt ex-

Sound offers us a powerful means of communica-

perience an increased risk of high-pitched hear-

tion. Our sense of hearing enables us to experience

ing loss of 7 percent for every five years that

the world around us through sound. Because our

they hunt? Nearly all (95 percent) of these same

sense of hearing allows us to gather, process, and

hunters report that they do not use hearing pro-

interpret sounds continuously and without con-

tection while hunting.11

scious effort, we may take this special sense of

Contemporary hearing research is guided by les-

communication for granted. But, did you know

sons learned from sensory research, namely that

that

specialized nerve cells respond to different forms

• Human communication is multisensory, involv-

of energy—mechanical, chemical, or electromag-

ing visual, tactile, and sound cues?

netic—and convert this energy into electrochemi-

• The range of human hearing, from just audible

cal impulses that can be processed by the brain.

to painful, is over 100-trillion-fold?

• Tiny specialized cells in the inner ear, known as

The brain then works as the central processor of

hair cells, are responsible for converting the

sensory impulses. It perceives and interprets them

vibrational waves of sound into electrical signals

using a "computational" approach that involves

that can be interpreted by the brain?

several regions of the brain interacting all at once.

• Tinnitus, commonly known as "ringing in the

This notion is different from the long-held view

ears," is actually a problem that originates in the

that the brain processes information one step at a

brain?

time in a single brain region. Over the past decade,

scientists have begun to understand the intricate

Misconception 1: Our senses provide a complete

mechanisms that enable the ear to convert the

and accurate picture of the world.

mechanical vibrations of sound to electrical

Younger students are often unaware of the limita-

energy, thereby allowing the brain to process and

tions of their senses. They may believe that what

interpret these signals.

they perceive is all that there is. Most students

would be quite surprised to learn that their ears

Scientific understanding of the role of genes in

produce measurable sounds of their own that are

hearing is also increasing at an impressive rate.

normally inaudible to the brain. Also, they might

The first gene associated with hearing was isolated

not be aware that some animals use sound fre-

in 1993. By the end of 2000, more than 60 genes

quencies that are out of our hearing range. For

related to hearing were identified.15 In addition,

example, whales communicate using low-fre-

scientists have pinpointed over 100 chromosomal *quency sounds that are inaudible to humans and*

regions believed to harbor genes affecting the

can carry across vast expanses of ocean. This

hearing pathway. Many genes were first isolated in

module will make students aware that our senses

the mouse, and from this, the human genes were

react to only a limited range of the energy inputs

identified. Completion of the Mouse and Human

available. Much sensory information exists

Genome Projects is helping scientists isolate these

beyond our ability to experience it. Our level of

genes.

awareness is influenced by our individual abilities,

our genes, our environment, and our previous

The rapid growth in our understanding is of more

experiences, as well as the interactions among

than academic interest. In a practical sense, shar-

them. Learning about the limitations of our senses

ing this information with young people can

can help students interpret their environment

enable them to adopt a lifestyle that promotes the

more accurately.

long-term health of their sense of hearing. With

this in mind, this supplement will address several

key issues, including

Your ears produce sounds of their own

• What is the nature of sound?

that are normally inaudible to the brain.

• What mechanism allows us to process sounds

with great precision—from the softest whisper

Misconception 2: Our senses function

to the roar of a jet engine, from a high-pitched

independently of one another.

whistle to a low rumble?

Students may believe that because each sense is

• What are the roles of hearing, processing, and

specialized for a particular type of sensation,

speaking in human communication?

senses function by themselves and do not interact

• What happens when the hearing mechanism is

with one another or with the rest of the body.

altered or damaged? How does sound process-

Research, however, reveals many interactions

ing change?

between the senses.7 During this module, students

• What can be done to prevent or accommodate

will learn about the sensory integration that takes

damage to our sense of hearing?

place in the brain.

2 Misconceptions Related to Sensory

Misconception 3: As we age, our brain networks

Perception and Hearing

***become fixed and cannot be changed*.**

In presenting the material contained within this

Scientific research has shown that the brain never

supplement, you may have to deal with students'

stops changing and adjusting to its environment.1

incomplete understanding about hearing. Some of

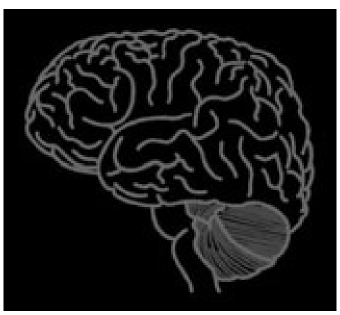
This ability is important for acquiring new knowl-

the likely misconceptions about hearing that stu-

edge and for compensating for deficiencies that

dents have follow:

result from age or injury. The ability of the brain



they will learn about simple, effective ways to minimize harmful stimuli.

3 Major Concepts Related to Hearing and Communication

Research into hearing and communication is providing a scientific foundation for understanding the anatomy, physiology, and genetics of the hearing pathway, as well as the social and cultural aspects of human communication. The following discussion is designed to introduce you to some major concepts about hearing and communication.

Figure 2. *Regardless of the senses used, under-*

3.1 Communication is multisensory

standing occurs in the brain.

Although some people might define communication as an interaction between two or more living

to "reprogram" itself is called plasticity. Special *creatures, it involves much more than this. For*

brain exercises, or training techniques, exploit

example, we are constantly receiving information

brain plasticity to help people cope with specific

from, and changing our relationship with, our

language and reading problems.

environment. This communication is received

Misconception 4: Our senses do not really

through our senses of smell, taste, touch, vision,

require any preventive maintenance.

and hearing. Communication with others makes

Students may believe that because our senses

use of vision (making eye contact or assessing

function without any conscious input, always

body language) and sound (using speech or

being "on," their function and health are not

other sounds, such as laughing and crying).

influenced by what we do. The module will make

When a group of people shares a need or desire

students aware that the overall health of their

to communicate, language is born. The most

senses, like all other bodily systems, is affected by

common human language is the language of

the lifelong demands placed on them. Students

words. Words may be communicated in various will learn about biological mechanisms in which

ways. Although they are usually spoken, they

potentially harmful input can lead to both short-

also may be written, fingerspelled, or expressed

term and long-term hearing impairments, and

through sign language.

Figure 3. *Words may be communicated by writing, speaking, and signing.*

How Your Brain Understands What Your Ear Hears

white-crowned sparrow usually begins singing its

Communication with others

full song between 100 and 200 days of age. Proper

makes use of sound and vision.

song acquisition is needed for mating and for

marking territory. However, to learn his song, the

young bird must be exposed to an adult bird's

3.2 Language acquisition: imprinting

song consistently and frequently between one

and critical periods

week and two months after hatching (its critical

Since the time of Plato, there has been debate over

period for song acquisition). If the male sparrow

the nature of language. Some believe that lan-

hears the song only before or after its critical

guage is inborn and purposeful, while others

period, then he will not be able to learn the song

believe it to be artificial and arbitrary. Some con-

correctly.

sider language to be an evolutionary product,

while others do not. It appears that words are not

"built into" the brain, because language is a rela-

tively recent evolutionary development and also

because languages differ substantially from one

another. Language and communication are made

possible by specialized structures. We have

evolved a sophisticated apparatus for both speech

and hearing. Our brains have specific regions

devoted to speech, hearing, and language func-

tions. Still, the mechanisms by which children

acquire language are only partially understood.

Our brains have specific regions

devoted to speech, hearing,

and language functions.

Figure 4. *Konrad Lorenz with young goslings that imprinted to him.*

There are two concepts important to the acquisi-

tion of language. One is imprinting, which refers

These examples demonstrate the brain's flexibil-

to the ability of some animals to learn rapidly at a

ity—its ability to be changed or to adapt to its

very early age and during a well-defined period in

environment. They demonstrate that an animal

their development. Imprinting generally refers to

may alter its behavior or acquire a behavior that

the ability of offspring to acquire the behaviors

helps improve its chances for survival. Do animals

characteristic of their parents. This process, once

have anything to teach us about our own acquisi-

it occurs, is not reversible. A famous example of

tion of language? The answer seems to be yes.

imprinting was described by Nobel laureate Kon-

Consider the following: Scientists have reported

rad Lorenz in the 1930s.5 Lorenz observed that

that seal pups learn to recognize their mothers'

newly hatched goslings would follow him, rather

voices within a few days of being born.2 This is

than the mother goose, if they saw him first. The

important because the mother seals must leave

period of imprintability may be very short, just

their pups after roughly a week to go hunting.

hours for some species.

Upon returning, mother seals vocalize and wait

A second concept, related to imprinting, is ***critical***

for their pups to respond. By playing recordings of

periods*. A nonhuman example of a critical period*

various females, the investigators determined that

is the limited time frame within which a male bird

for the first few hours after birth, seal pups will

must acquire his song.8 For instance, a male

respond to the voice of any adult female. How-

28

ever, after two to five days, the pups learn to

module focuses on the key issues of how sound is

respond only to their mother's voice.

processed so that communication is achieved.

Very soon after birth, human infants learn to dis-

3.3 Sound has a physical basis

tinguish speech sounds from other types of

Sound represents vibrational energy. It is created

sound. Within the next month or two, the infant

when a medium such as air, wood, metal, or a per-

learns to distinguish between different speech

son's vocal cords vibrate. Sounds carried as energy

sounds.4, 14 An 18-month-old toddler can recog-

are transferred from one molecule to the next in *nize and use the sounds (called* ***phonemes****) of his*

the vibrating medium. To understand sound, con-

or her language and can construct two-word

sider the analogy in which a stone is dropped into

phrases. A 31/2-year-old child can construct nearly

a body of water. This action produces ripples that

all of the possible sentence types. From this point

will spread out in all directions from the point

on, vocabulary and language continue to expand

where the stone contacted the water. The ripples

and be refined.12

become weaker (decrease in intensity) as they get

farther away from the origin. So it is with sound.

Communication is truly a multisensory

The vibration through a medium proceeds in

experience. For most individuals, the

waves. However, unlike ripples on water, sound

pathway from creating sound (speaking)

waves move away from their point of origin in

to receiving, processing, and interpreting

three dimensions, not just two.

sound (hearing) is critical.

Sound waves possess specific characteristics. ***Fre-***

quency *represents the number of complete wave*

The parameters of language development and *cycles per unit of time, usually one second (see*

developmental phases are under rigorous study.

Figure 5). Frequency is expressed in ***hertz (Hz)****,*

For ethical reasons, investigators cannot explore

which means cycles per second. Low-frequency

such questions through human experimentation

sounds are those that vibrate only a few times per

that would deprive infants of language intention-

second, while high-frequency sounds vibrate

ally. Occasionally, however, unusual circum-

many more times per second. The term used to

stances provide us with a glimpse of how humans

distinguish your perception of higher-frequency

acquire or do not acquire spoken language. There

sounds from lower-frequency sounds is ***pitch****.*

are examples of individuals who were not exposed

to spoken language from birth but who had nor-

mal hearing. These individuals never developed

normal language or speech. Although such exam-

ples have been put forth as justification for the

critical-period hypothesis for language develop-

ment, there are confounding issues. The possibil-

ity exists that these individuals had some type of

brain abnormality that was responsible for their

not acquiring spoken language. Nonetheless, the *importance of sound as a stimulus for the hearing*

Figure 5. *Representation of frequency. The arrow apparatus and its need to be processed by the*

indicates one cycle of the sound wave.

brain for understanding is unquestioned.

Communication is truly a multisensory experi-

The speed of sound is constant for all frequencies,

ence. For most individuals, the pathway from cre-

although it does vary with the medium through

ating sound (speaking) to receiving, processing,

which it travels. In air, sound travels at a speed of

and interpreting sound (hearing) is critical. This

roughly 340 meters per second. Sound travels

fastest through metals because the molecules of

the sound wave (see Figure 7). The greater the

that medium are packed very closely together.

amplitude of the sound wave, the greater the

Similarly, sound travels about four times faster in

intensity, or pressure, of the sound. ***Intensity***

water than in air. It follows that sound travels

refers to the overall amplitude of a sound. This

faster in humid air than dry air; in addition,

distinction in terms is necessary, since nearly all

humid air absorbs more high frequencies than low *sounds to which we are exposed are complex*

frequencies, leading to differences in the percep-

sounds made up of a combination of sound waves.

tion of sound heard through the two media.

***Loudness** is our perception of the intensity, fre-*

Finally, temperature can affect the speed of sound

quency, and duration of a sound.

in any medium. For instance, the speed of sound

in air increases by about 0.6 meters per second for

each degree Celsius increase in temperature.

The human ear responds to frequencies in the

range of 20 Hz to 20,000 Hz (20 kHz),18 although

most speech frequencies lie between 100 and

4,000 Hz. Frequencies above 20,000 Hz are

*referred to as **ultrasonic**. Though ultrasonic fre-*

quencies are outside the range of human percep-

tion, many animals can hear these sounds. For

instance, dogs can hear sounds at frequencies as

high as 50,000 Hz, and bats can hear sounds as

high as 100,000 Hz. Other sounds, such as some

***Figure 7.** Representation of amplitudes of a wave.*

produced by earthquakes and volcanoes, have fre-

The dashed line has a lower amplitude than the

quencies of less than 20 Hz. These sounds,

solid line.

*referred to as **infrasonic** or **subsonic**, are also outside the range of human hearing.*

Sound intensity is measured in relation to an

We all know that sounds can be louder or softer,

accepted reference point. One such reference is

but what does this mean? Sound is energy, and

the threshold at which a sound can be heard.

this energy, when traveling through air, displaces,

How the intensity of any given sound compares

or vibrates, air molecules. For example, the softest

with this standard reference level is given in

sound humans can hear is a sound that displaces

*units known as decibels (dB). The **decibel** is*

particles of air by one-billionth of a centimeter.13

one-tenth of a bel, a unit named after the inven-

The extent to which air particles move from their

tor Alexander Graham Bell. The decibel scale is

*original resting point determines the **amplitude** of not a linear one, but rather represents the ratio of*

***Figure 6.** The sound spectrum.*

the sound to the reference standard. To understand

Table 1. The Decibel System

why ratios are necessary, consider the tremendous

range of sound intensities we are capable of hear-

Intensity Ratio

Intensity

ing. Scientists estimate that the human ear is sensi-

Difference (dB)

tive to about 100,000,000,000,000 (1014) units of

1:1

0

intensity. Also consider that a shout is about

1,000,000 (106) times more powerful than a

2:1

3

whisper. Because dealing with such large num-

4:1

6

bers is cumbersome, the decibel scale is used to

8:1

9

simplify comparisons (see Table 1). Every 10-dB

increase in sound intensity represents a 10-fold

10:1

10

increase in sound intensity and a perceived dou-

16:1

12

bling in loudness. Therefore, a sound at 60 dB is

20:1

13

100 times as intense as a sound at 40 dB but is

only perceived as four times as loud. In this way,

100:1

20

the predominant range of human hearing is rep-

400:1

26

resented on a scale from 0 to 140 dB. The aver-

800:1

29

age intensities of some everyday sounds are

1,000:1

30

presented in Table 2.

2,000:1

33

Every 10-dB increase in sound

8,000:1

39

intensity represents a 10-fold increase

10,000:1

40

in sound intensity and a perceived

100,000:1

50

doubling in loudness.

1,000,000:1

60

10,000,000:1

70

Individuals are often unaware of the damage

loud noise does to their hearing. Even common

100,000,000:1

80

noises, such as highly amplified music and gas-

1,000,000,000:1

90

engine mowers or leaf blowers, can damage

10,000,000,000:1

100

human hearing with prolonged exposure. Sport-

ing events can also expose individuals to haz-

100,000,000,000:1

110

ardous decibel levels as defined by the

1,000,000,000,000:1

120

Occupational Health and Safety Administration

10,000,000,000,000:1

130

(OSHA). Under OSHA guidelines, the limit of

100,000,000,000,000:1

140

continuous noise exposure for an eight-hour day

in an industrial setting is 90 dB. OSHA also pro-

hibits workplace ***impact noise*** *(short bursts of*

sound) greater than 140 dB. By increasing our

Even common noises, such as highly

awareness of decibel levels of common environ-

amplified music and gas-engine mowers

mental noises, we can better limit our exposure

or leaf blowers, can damage human

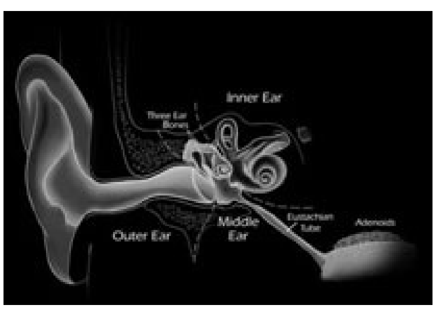
to hazardous noise levels or take measures to

hearing with prolonged exposure.

protect our ears.

31

Information about Hearing, Communication, and Understanding



How Your Brain Understands What Your Ear Hears

Table 2. Average Intensities of Everyday Sounds

Sound

dB Level

hearing threshold

0

breathing

10

rustling leaves

20

whispering

25

library

30

refrigerator

45

average home

50

normal conversation

60

clothes dryer

60

Figure 8. *Anatomy of the human ear.*

washing machine

65

car

70

3.4 Perception of sound has a biological basis

vacuum cleaner

70

When sound, as vibrational energy, arrives at the

busy traffic

75

ear, it is processed in a complex but distinct series

noisy restaurant

80

of steps. These steps reflect the anatomical divi-

outboard motor

80

sion of the ear into the outer ear, middle ear, and

inside car in city traffic

85

inner ear (see Figure 8).

electric shaver

85

The pathway from the outer ear to the inner ear is

screaming child

90

remarkable in its ability to precisely process

passing motorcycle

90

sounds from the very softest to the very loudest

convertible ride on freeway

95

and to distinguish very small changes in the fre-

table saw

95

quency of sound (pitch). Humans can discern a

hand drill

100

difference in frequency of just 0.1 percent. This

tractor

100

means that humans can tell the difference

diesel truck

100

between sounds at frequencies of 1,000 Hz and

circular saw

100

1,001 Hz.

jackhammer

100

The outer ear. *The outer ear is composed of two gas engine mower*

105

parts. The ***pinna*** *is the outside portion of the ear helicopter*

105

and is composed of skin and cartilage. The second

chain saw

110

*part is called the **ear canal** (also called the exter-amplified rock concert*

90–130

nal auditory canal). The pinna, with its twists and

shout into ear at 20 cm

120

folds, serves to enhance high-frequency sounds

car horn

120

and to focus sound waves into the middle and

inner portions of the ear. The pinna also helps us

siren

120

determine the direction from which a sound orig-

threshold of pain

120–140

inates. However, the greatest asset in judging the

gunshot

140

location of a sound is having two ears. Because

jet engine

140

one ear is closer to the source of a sound than the

12-gauge shotgun

165

other, the brain detects slight differences in the *rocket launching*

180

times and intensities of the arriving signals. This

loudest audible tone

194

allows the brain to approximate the sound's loca-

32

tion. Interestingly, the position and orientation of

the pinna, at the side of the head, help reduce

The elegance of the middle ear

sounds that originate behind us. This helps us

system lies in its ability to greatly

hear sounds that originate in the direction we are

amplify sound vibrations before they

looking and reduces distracting background

enter the inner ear.

noises.

Some students (and adults) may believe that the

***The middle ear.** The tympanic membrane size of the ear is an indication of the organism's*

(eardrum) separates the outer ear from the middle

hearing ability—that is, the larger the ear, the bet-

ear. It is a continuously growing structure, which

ter the ability to hear. This misperception doesn't

means that damage to the membrane can gener-

take into account the internal structures of the *ally be repaired. The membrane is circular in*

ear that process sound vibrations. A large pinna

shape. The elastic properties of the tympanic

may serve a function that is unrelated to hearing.

membrane allow it to vibrate in response to sound

For example, the external ear of the African ele-

waves. Vibrations from the tympanic membrane

phant is filled with small blood vessels that help

tend to focus near the center of the structure .

the animal dissipate excess heat. The external ear

From there, the vibrations are transferred to the

may be specialized in other ways, as well. Cat

***malleus**, the first of the three bones of the middle owners, for example, have undoubtedly observed*

ear. The three bones of the middle ear are collec-

the rather dramatic movement of their pet's pin-

*tively called the **ossicles**. The second bone of the nae as the animal attempts to locate the source of*

*middle ear is the **incus**, which is connected to the a sound.*

malleus and vibrates in concert with it. A third

*bone, the **stapes**, is connected to the incus, and*

The ear canal is about 2.5 cm (1 inch) long and

also vibrates. The stapes sits in an opening in the

*leads to the **tympanic membrane** (eardrum) of*

*bony wall, called the **oval window**, that separates*

the middle ear. The outer two-thirds of the canal

the middle ear from the inner ear. The elegance of *contains glands that secrete a wax-like substance.*

the middle ear system lies in its ability to greatly

This earwax, along with hairs that are present,

amplify sound vibrations before they enter the

serves to keep dust, insects, and other foreign

inner ear. Amplification occurs in part because the

material from going deeper into the ear. It also

tympanic membrane is 15–30 times larger than

helps maintain a constant humidity and tempera-

the oval window. This size difference allows the

ture for the middle ear. Individuals should not

force from the initial movement of the tympanic

attempt to remove earwax, since this secretion

membrane to be concentrated as this energy trans-

will work itself out of the canal naturally in most

fers to the inner ear. The ossicles are the smallest

cases. To avoid damage, it should be removed by a

bones in the body. The three bones are smaller

medical professional. Hearing researchers strongly

than an orange seed. The malleus reaches an aver-

concur with the truth of the adage: Put nothing

age length of about 8 mm, the incus 9 mm, and

smaller than your elbow into your ear. In addition to the stapes, only 3 mm. These bones also are

its protective function, the ear canal acts as an

referred to informally as the hammer, anvil, and *amplifier for sound frequencies between 3,000*

stirrup, respectively.

and 4,000 Hz.

The middle ear is an air-filled space. It is con-

nected to the back of the throat by a small tube

The ear canal acts as an amplifier

*called the **eustachian tube**, which allows the air in for sound frequencies between*

the middle ear space to be refreshed periodically.

3,000 and 4,000 Hz.

The eustachian tube can become blocked by infec-

tion, and fluid may fill the middle ear space.

Changes in air pressure can also affect the tym-

of a sound source, transduction is a critical

panic membrane, resulting in the ear-popping

process, providing information to the brain in a

phenomenon experienced by people who fly in

form that it can process.

airplanes or drive over mountain roads. The mem-

The cochlea is divided into an upper chamber,

brane may bend in response to altered air pressure

*called the **scala vestibuli** or **vestibular canal**, and and then "pop" back to its original position when*

*a lower chamber, called the **scala tympani** or **tym-the eustachian tube opens and internal and exter-***

panic canal. These are seen most easily if the

nal air pressures are equalized.

cochlea is represented as uncoiled, as in Figure 9.

Both the upper and lower chambers are filled with

The process of converting the

a fluid, called perilymph, which is nearly identical vibrational energy of sound into nerve

to spinal fluid. The stapes vibrates against the oval

impulses is called transduction.

window, creating fluid vibrations that are trans-

mitted as pressure waves all the way through the

The inner ear. Two interconnected parts that form cochlea. As represented by the arrows in Figure

a system of small cavities and passageways make

10, these waves move from the upper chamber to

up the inner ear. One part is the vestibular sys-

the lower chamber, to the round window. The

tem, which is responsible for helping maintain

round window allows the release of the hydraulic

balance. The second part is the cochlea, a coiled

pressure caused by vibration of the stapes in the

cavity about 35 mm long. The human cochlea

oval window. Additionally, the diameter of the

makes about two turns. It is shaped like a spiral

chambers decreases from base (closest to the win-

seashell or snail shell and is the hearing portion of

dows) to apex.

the inner ear. It is responsible for converting the *vibrational energy produced by the middle ear*

The upper and lower chambers are separated from

into nerve impulses (electrical energy) that will

one another by the cochlear duct. The cochlear

travel to the brain. The process of converting

duct is separated from the lower chamber by the

energy from one form into another is called trans-

basilar membrane and is filled with endolymph, duction. Because the brain is incapable of intera
fluid similar to that found within cells. Sitting on

preting the information in the vibrational energy

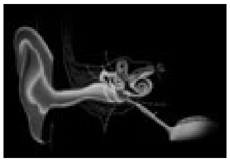
the basilar membrane is the highly sensitive organ

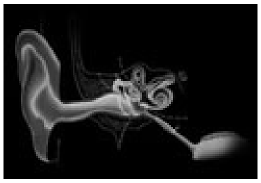
Figure 9. An uncoiled

cochlea, to the right of the

oval and round windows.

34





of hearing called the organ of Corti, named after

cells are arranged in a single row along the full

Alfonso Corti, the Italian anatomist who discov-

length of the organ of Corti. There are about

ered it in the late 1800s. The relationships

3,500 of them in total. The outer hair cells run *between the basilar membrane and the organ of*

the full length of the organ of Corti but are

Corti are depicted in Figure 11.

arranged in three parallel rows. There are nearly

four times more outer hair cells than inner hair

Hair cells of the organ of Corti are the specialized cells (about 12,000 per ear). The inner hair cells

receptor cells of hearing. Under a microscope,

contact nearly all of the nerve fibers of the audi-

these cells appear as elongated ovals with hairlike

tory nerve that transmits information to the

extensions, the stereocilia , waving at one end.

brain. The outer hair cells primarily contact

Like microphones, hair cells ultimately translate,

nerve fibers that carry information from the

or transduce, mechanical vibrations occurring in

brain. Hair cells are quite sensitive to stimulation

the outer, middle, and inner ear into electrical

by slight sounds and also are extremely rapid in

impulses. These nerve impulses are then relayed

their responses and communication with audi-

to the brain via the auditory nerve. There are

tory neurons. Hair cells, for example, respond

actually two types of hair cells. The inner hair

1,000 times faster to stimulation than do visual

receptor cells. The key to their sensitivity lies in *part with their structure. The membrane-bound*

hairlike structures that give hair cells their name,

stereocilia, extend from the cell tops and are

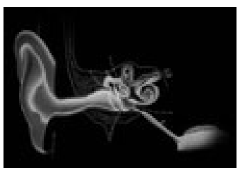
embedded in an overhanging sheet of cells called

Figure 10. Diagrammatic representation of the

movement of vibrational energy through the

Figure 11. Details inside a coil of the cochlea cochlea.

showing the organ of Corti.



How Your Brain Understands What Your Ear Hears

the tectorial membrane (see Figure 12). Each

Sound is mapped to different parts of the cochlea

hair cell may have about 100 stereocilia. In a rest-

according to frequency. Figure 13 shows where

ing state, the stereocilia lean on one another and

tones of different frequencies cause vibrations of

have the overall appearance of a conical bundle.

maximum amplitude along the length of the

cochlea. The base, close to the stapes, is stiff and

narrow and responds more to high-frequency

Hair cells ultimately translate,

(high-pitched) sounds. The apex, far from the

or transduce, mechanical phenomena

stapes, is broad and responds more to low-fre-

occurring in the outer, middle, and

quency sounds.

inner ear into electrical impulses.

To understand how hair cells function to trans-

duce the mechanical vibrations of sound, consider

Figures 10 and 12.

Figure 13. Specific frequencies cause vibrations of maximum amplitude at different points along the

Figure 12. Details of the organ of Corti showing cochlea. The numbers in the diagram represent

hair cells and the relationship of the stereocilia

frequency in hertz.

(hair bundles) to the adjacent membrane.

Transmission to the brain. Extending from the The bodies of hair cells sit on top of the basilar

organ of Corti are 30,000–40,000 nerve fibers that

membrane (see Figure 12). The stereocilia of hair

form the auditory nerve. The number of fibers

cells connect the body of the cell with the tector-

required to carry a sound signal may give the

ial membrane. Pressure waves in the cochlea (see

brain a measure of the sound's intensity. The fibers

Figure 10) move the basilar membrane and cause

of the auditory nerve proceed a short distance to

the stereocilia to move. This movement initiates

the brainstem. From there, fibers extend to the *biochemical events in the cells that result in the*

midbrain and then to the auditory cortex, which generation of electrical signals.

is located in the temporal lobe of the brain (see

36

Figure 14). Through mechanisms that remain

because children with the disorder may not recog-

unknown, the brain interprets the electrochemical

nize the subtle differences between sounds in

information it receives, thus allowing us to per-

words. For example, children with APD may hear

ceive sounds as having varying loudness and

the sentence "Tell me how a couch and a chair are

pitch.

alike" as "Tell me how a cow and a hair are alike."

What causes this apparent deficiency or slowing

in the brain's ability to process auditory informa-

tion? Researchers do not know. Auditory process-

ing is a learned function, and if something

interferes with the brain's training, the result may

be a deficit in the capacity to process sound.

Sound direction is localized by virtue of

our having two ears and our ability to

use different parts of the auditory system

to process distinct aspects of incoming

directional information.

Sound direction is localized by virtue of our hav-

ing two ears and our ability to use different parts

of the auditory system to process distinct aspects

Figure 14. The location of the auditory cortex in of incoming directional information. Certain cells

the human brain.

in the brainstem compare the intensities of sound

coming into each ear and then relay a computed

The brain recognizes and interprets sound in our

signal to the auditory cortex to estimate the

environment through a sequence of events called

sound's direction. Another group of brainstem

auditory processing. A disorder, known as audi-

cells contributes to the interpretation of sound

tory processing disorder (APD), came to promi-

direction by specifically comparing the time lag

nence in the 1970s.[3, 9] In APD, something

between the sound reaching them from the right

interferes with the brain's ability to process or

ear versus the left ear.

interpret information about sound, although hear-

Nerve fibers coming from the brain may carry

ing seems to be normal. Children with APD typi-

information back to the ear. This is the brain’s way

cally have normal hearing and intelligence.

of filtering out signals that are unimportant, and

Symptoms of APD are having difficulty paying

concentrating only on important signals. Other

attention and remembering information presented

nerve fibers proceed from the brain to the middle

orally; poor listening skills; difficulty carrying out

ear, where they control muscles that help protect

multistep directions; poor spelling, vocabulary,

against the effects of dangerously loud sounds.

and reading comprehension skills; difficulty pro-

cessing information; low academic performance;

Not only does the inner ear process the sound

behavioral problems; language difficulty (tendency

vibrations it receives, it also creates its own sound

to confuse syllable sequences); and difficulty

vibrations. When hair cells respond to vibration,

developing vocabulary and understanding lan-

their movement in the fluid environment of the

guage. APD is sometimes called “word-deafness”

cochlear duct produces friction, and this results in

a loss of energy. However, a group of hair cells

your eardrum. A common cause of conductive

replaces the lost sound energy by creating their

hearing loss in children is ear infections. Other

own. Some of this sound energy leaks back out of

causes of conductive hearing loss are a punctured

the ear and can be detected using a computer-

eardrum or otosclerosis (a buildup of spongy tis-

based sound analyzer and a probe inserted into

sue around the middle ear). These can be treated

the outer third of the ear canal. This ability of hair

through surgery.

cells to respond to sound by producing their own

Sensorineural hearing loss is generally associated

sound is the basis of one type of hearing test per-

with damage to the hair cells in the inner ear. Such

formed on infants and young children.

damage is the most common cause of hearing loss

and can result from a number of factors working

alone or in combination.

The auditory pathway is capable of providing a *lifetime of useful service. It is, however, fragile*

4.1 Noise exposure

and subject to damage from a variety of sources.

When hair cells are damaged, their ability to par-

Hearing loss and deafness can result from sound

ticipate in sound transduction is compromised. If

your hair cells are completely destroyed, you will

exposure, heredity, ototoxic drugs (chemicals that

be unable to hear any sounds, no matter how loud

damage auditory tissues), accidents, and disease

they are. If the hair cells are damaged, you may

or infection. Conductive hearing loss results from still hear sounds, but the sounds will be distorted.

damage to the outer or middle ear, and sen-

Recall that different hair cells respond to different

sorineural hearing loss results from damage to

pitches. The pattern of hair-cell damage deter-

the inner ear.

mines which pitches are preferentially lost. Typi-

cally, hair cells that respond to higher pitches are

Hearing loss and deafness can

lost first. One reason is that the basilar membrane

result from sound exposure, heredity,

vibrates more vigorously in response to higher

ototoxic drugs, accidents, and

pitches. These vibrations can cause the delicate *disease or infection.*

stereocilia of the hair cells to be sheared off (see

Figure 15). One consequence of this damage is

that it becomes more difficult to understand the

Damage associated with conductive hearing loss

higher-pitched voices of women and children. It

interferes with the efficient transfer of sound to

also becomes more difficult to distinguish a per-

the inner ear. Conductive hearing loss is charac-

son's speaking voice from background noise. The

terized by a loss in sound intensity. Voices may

effects of noise-induced hearing loss may be tem-

sound muffled, while at the same time the indi-

porary or permanent, depending on the intensity

vidual's own voice may seem quite loud. It can be

and duration of the exposure. Although a person's

caused by anything that interferes with the vibra-

hearing may recover from temporary, slight dam-

tion of the eardrum or with the movement of the

age to the hair cells, the complete loss of hair cells

bones of the middle ear. Even a buildup of earwax

is irreversible in humans. Reptiles and birds are

can lead to conductive hearing loss.

able to regenerate hair cells, however, so scientists

A number of treatment options exist for conduc-

are currently exploring ways to encourage regen-

tive hearing loss. The appropriate response

eration of hair cells in humans.

depends upon the cause of the problem. For

example, an ear doctor can simply remove a

The effects of noise-induced hearing

buildup of earwax. It should be pointed out, how-

loss may be temporary or permanent,

ever, that you should never try to remove wax

depending on the intensity and

from your own ears. You can too easily push the

duration of the exposure.

wax further into the ear canal and even damage

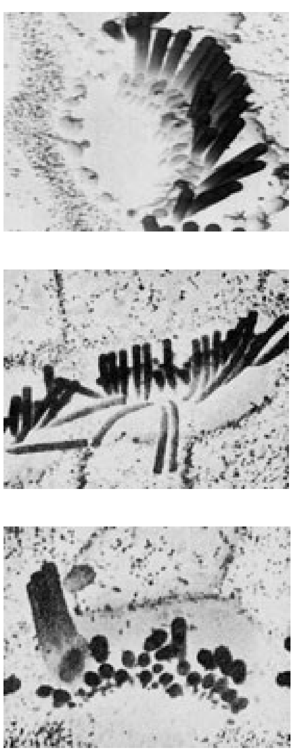


Figure 15. The left panel shows normal stereocilia (or hair bundles) associated with inner hair cells in the cochlea. The middle and right panels show noise-induced damage to hair cells. Note the bent-over stereocilia in the middle panel. The right panel shows missing and fused stereocilia.

The phrase “too loud, too long, too close” (see the

4.3 Ototoxic drugs

WISE EARS! Web site, http://www.nidcd.nih.gov/

Medications and chemicals that are poisonous to

health/wise/index.asp) summarizes the causes of

auditory structures are called ototoxic. Certain

noise-induced hearing loss. The intensity, dura-

antibiotics can selectively destroy hair cells,

tion, and proximity of sound to the listener deter-

enabling scientists to better understand hair-cell

mine whether or not damage occurs and if that

function in normal and abnormal hearing. Other

damage is reversible or permanent. Hearing loss

types of drugs can be used to selectively destroy

can result from a single loud noise, such as an

other tissues of the auditory pathway. A few com-

explosion, but more commonly results from

mon medications can produce the unwanted side

repeated exposure to less intense sounds that are

effect of tinnitus, or ringing in the ears. One such close by.

drug is aspirin. Arthritis sufferers, who may con-

sume large amounts of aspirin, sometimes experi-

ence tinnitus and hearing loss as a side effect of

The phrase “too loud, too long, too

their aspirin use. Fortunately, the effect is tempo-

close” summarizes the causes of noise-

rary and the tinnitus tends to disappear when

induced hearing loss.

aspirin use is discontinued.

4.4 Disease and infections

4.2 Aging

A variety of diseases and infections can lead to

Damage to hair cells is associated with aging,

hearing loss. Children are especially prone to the

though it is not inevitable. Such damage can result

ear infection called otitis media from viruses or

from a combination of factors, such as noise expo-

bacteria. Children are more susceptible to infection

sure, injury, heredity, illness, and circulation prob-

lems. Some of these factors, such as noise

than adults are, partly because the location of their

exposure, can take many years before their damag-

eustachian tube in relation to the middle ear allows

ing effects are noticeable. Hearing loss often begins

easier access to bacteria from the nasal passages.

when a person is in his or her 20s, though it may

These infections cause pain and may result in a

not be noticed until the person is in his or her 50s.

buildup of fluid, which can lead to hearing loss.

Not surprisingly, the greater the noise exposure

Usually, the bacterial infections can be controlled

over a lifetime, the greater the hearing loss.

by antibiotics. Antibiotics are ineffective against

Because the hair cells at the base of the cochlea

viruses, however. The over-prescription of antibi-

“wear out” before those at the apex, the higher

otics to treat viral forms of otitis media has led to a

pitches are lost first, followed by the lower ones.

rise in bacteria that are resistant to antibiotics. If

allowed to progress untreated, ear infections can

cation of hearing-related genes has moved at an

lead to a much more serious condition called

incredibly fast pace in the past decade. The first

meningitis. Young children who experience ear

genetic mutation affecting hearing was isolated in

infections accompanied by hearing loss for pro-

1993; by the end of 2000, the number of identified

longed periods also may exhibit delayed speech

auditory genes was over 60. Scientists have also

development. The reason for this is that the first

pinpointed over 100 chromosomal regions

three years of life are a critical period for acquiring

believed to harbor genes affecting the hearing *language, which depends upon a child's ability to*

pathway.

hear spoken words.

An important technology for investigating the

roles that genes play in hearing is the production

Young children who experience ear

of transgenic and "knockout" mice, which result

infections accompanied by hearing loss

when scientists insert a foreign gene into (trans-

for prolonged periods also may exhibit

genic) or delete a targeted gene from (knockout)

delayed speech development.

the mouse genome. The hearing responses of

transgenic or knockout mice are compared with

Otosclerosis refers to a condition in which the

their unaltered counterparts. If differences are

bones of the middle ear are damaged by the

detected, they are presumed to be caused by the

buildup of spongy or bone-like tissue. The

specific gene that was inserted or deleted. Eventu-

impaired function of the ossicles (the malleus,

ally, scientists hope to use their understanding of

incus, and stapes) can reduce the sound reaching

the genetic basis of hearing to develop treatments

the ear by as much as 30 to 60 dB. This condition *for hereditary hearing loss and deafness.*

may be treated by surgically replacing all or part of

the ossicular chain with an artificial one.

The Mouse and Human Genome Projects

Ménière's disease affects the inner ear and

are setting the stage for identifying the

vestibular system, the system that helps us main-

genetic contributions to hearing.

tain our balance. In this disorder, the organ of

Corti becomes swollen, leading to a loss of hear-

4.6 Cochlear implants

ing that comes and goes. Other symptoms include

A cochlear implant (see Figure 16) is a hearing

tinnitus, episodes of vertigo (dizziness), and

device designed to bypass absent or damaged hair

imbalance. The disease can exist in mild or severe

cells. The cochlear implant is a small, complex,

forms. Unfortunately, the cause of the disease is

electronic device that can help provide an inter-

not well understood and effective treatments are

pretable stimulus to a person who is profoundly

lacking.

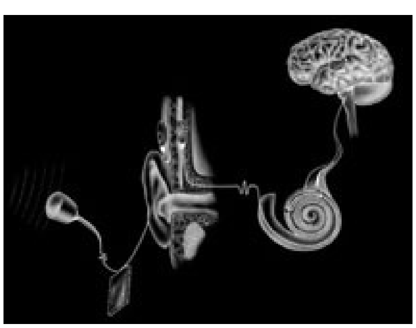
deaf or severely hard-of-hearing. The implant is

4.5 Heredity

surgically placed under the skin behind the ear, *The Mouse and Human Genome Projects are setting the stage for identifying the genetic contributions to hearing. Though deciphering the genetics underlying any developmental pathway is complex, identifying genes involved in the hearing pathway can greatly aid our understanding of the hearing process. Genes associated with a number of hereditary conditions that cause deafness, such as Usher syndrome[16] and Waardenburg syndrome,[17] already have been isolated. The identifi-*

and consists of four basic parts:

- *a microphone that picks up sound from the environment;*
- *a speech processor, which selects and arranges sounds picked up by the microphone;*
- *a transmitter and receiver/stimulator that receives signals from the speech processor and converts them into electric impulses; and*
- *electrodes that collect the impulses from the stimulator and send them to the brain.*



policy is that when a patient receives a cochlear implant, whatever hearing they have is destroyed. Eventually, it was discovered that patients with some residual hearing could benefit more from the procedure than those with profound hearing loss. For appropriate individuals, cochlear implants can be extremely beneficial. Each case must be examined individually to determine whether the cochlear implant is the best treatment available.

The use of cochlear implants can be controversial, especially among some deaf people. Just as spoken language helps define the culture of the hearing world, sign language helps define the culture

Figure 16. Diagram of a typical cochlear-implant of the deaf community. The issues surrounding system.

the use of speech or American Sign Language by the deaf community illustrate the profound effects

A cochlear implant does not restore or create

of language, hearing, and communication on one's

normal hearing. Instead, under the appropriate

sense of self.

conditions, it can give a deaf or severely hard-of-hearing person a useful auditory understanding of

5 Prevention of Noise-Induced

the environment, including sirens and alarms. A

Hearing Loss

cochlear implant is very different from a hearing

Noise-induced hearing loss (NIHL) is a serious

aid. Whereas hearing aids amplify sound and

health problem. It occurs on the job as well as in

change the acoustical signal to match the degree

nonoccupational settings. An estimated 10 mil-

of hearing loss, cochlear implants compensate for

lion Americans have suffered irreversible hearing

damaged or nonworking parts of the inner ear by

damage due to noise exposure. Another 30 mil-

bypassing them altogether. When hearing is func-

lion Americans are exposed to dangerous levels of

tioning normally, complex processes in the inner

noise every day.10 This is especially tragic because

ear convert sound waves in the air into electrical

NIHL is completely preventable. Although the

impulses. These impulses are then sent to the

consequences may vary for people who are

brain, where a hearing person recognizes them as

exposed to identical levels of noise, some general

sound. A cochlear implant works in a similar man-

conclusions can be stated. For example, studies

ner: it electronically transforms sounds and then *have shown that sound levels of less than 75 dB*

sends them to the brain. Hearing through an

are unlikely to cause permanent hearing loss, even

implant sounds different from normal hearing, but

after prolonged exposure. However, sound levels

it allows many people with severe hearing prob-

equal to or greater than 85 dB—about the same

lems to participate fully in oral communication.

level as loud speech—for eight hours per day will

produce permanent hearing loss after many years.

Outcomes for patients with cochlear implants

At this time, it is not possible to predict a given

vary. For many, the implant provides sound cues

individual's degree of sensitivity to dangerous

that help them better understand speech. Many

noise. Some people may be more sensitive to noise

are helped to such an extent that they can carry on

exposures than others.

a telephone conversation. Originally, only patients

with profound hearing loss were deemed suitable

In the work environment, employers are obligated

for the procedure. One reason for this restrictive

to protect their workers from hazardous noise.

How Your Brain Understands What Your Ear Hears

Hearing-conservation programs, when imple-

become active. People experiencing tinnitus show

mented effectively, are associated with increased

brain activation in only one side of the brain,

worker productivity and decreased absenteeism.

however. This difference in neural activity caused

They also lead to fewer workplace injuries and

by external sounds (bilateral activation) versus

workman's compensation claims. Whenever haz-

tinnitus (unilateral activation) indicates that the

ardous levels of sound are encountered, either on

disorder is likely to be a result of changes in the

the job or at home, you can protect yourself by

brain itself. Tinnitus may be produced by distur-

using ear protection such as earplugs or special

bances in auditory processing by the brain.

earmuffs. Do not simply put your fingers in your

Over 50 million Americans experience tinnitus at

ears or stuff cotton in them. Additionally, anyone

some point in their lives. The disorder is perceived

exposed to significant levels of noise for long

by some as an annoying background noise while

durations should receive regular hearing tests to

others are incapacitated by loud noise that dis-

detect changes in hearing.

turbs them day and night. Although the exact

causes of tinnitus are not known, scientists agree

An estimated 10 million Americans

that it is associated with damage to the ear. Possi-

have suffered irreversible hearing

ble triggers of tinnitus include NIHL, too much

damage due to noise exposure.

alcohol or caffeine, stress, inadequate circulation,

allergies, medications, and disease. Of these fac-

Tinnitus is the medical term for the perception of

tors, exposure to loud noise is by far the most

sound when no external sound is present. The

probable cause of tinnitus. Perhaps not surpris-

disorder is characterized by ringing, roaring, or

ingly, there is no single effective treatment.

repeated soft clicks in the ears. It is known that

Depending on the suspected cause, individuals

the ear continuously sends electrical impulses to

may be given drugs to increase blood flow, or pro-

the brain, even in the absence of sound. Some sci-

vided guidance on ways to reduce their stress or to

entists speculate that when hair cells are damaged,

change their diets. The best advice for those con-

the impulses are disrupted and the brain responds

cerned about NIHL is to limit exposure to haz-

by generating its own sound signals. Normally,

ardous noise (both proximity to and duration of),

when an ear is stimulated by sound, auditory

wear ear protection when exposed, and have hear-

regions on both the left and right side of the brain

ing tests performed regularly.

Figure 17. Ear protec-

tion, such as earplugs or

special earmuffs, helps

prevent noise-induced

hearing loss.

Glossary

amplitude: The displacement of a wave. In the

cochlear implant: A medical, electronic device that case of a sound wave, the greater the amplitude of

bypasses the damaged structures in the inner ear

the wave, the greater the intensity, or pressure, of

and directly stimulates the auditory nerve. An

the sound. The extent to which air particles are *implant does not restore or create normal hearing.*

displaced in response to the energy of a sound.

Instead, under the appropriate conditions, it can

give a deaf person a useful auditory understanding

APD: See auditory processing disorder.

of the environment and help him or her under-

auditory cortex: The area of the brain (in the tem-stand speech. The implant is surgically placed

poral cortex) that connects fibers of the auditory

under the skin behind the ear. An implant has four

nerve and interprets nerve impulses in a form that

basic parts: a microphone, which picks up sound

is perceived as sound.

from the environment; a speech processor, which

selects and arranges sounds picked up by the

auditory nerve: The eighth cranial nerve, which

microphone; a transmitter and receiver/stimulator,

connects the inner ear to the brainstem and is

which receives signals from the speech processor

responsible for hearing and balance.

and converts them into electric impulses; and elec-

auditory processing disorder (APD): Reduced or

trodes, which collect the impulses from the stimu-

impaired ability to discriminate, recognize, or

lator and send them to the brain.

comprehend complex sounds, such as those used *conductive hearing loss: A type of hearing loss*

in words, even though the hearing is normal

that results from dysfunction of the outer or mid-

(such as coat/boat or sh/ch).

dle ear (such as a punctured eardrum or buildup

basilar membrane: Found in the organ of Corti, it

of ear wax) that interferes with the efficient trans-

is the cellular membrane in which the hair cells

fer of sound to the inner ear; characterized by a

are embedded. The basilar membrane moves in

loss in sound intensity.

response to pressure waves in the cochlea, initiat-

critical period: A period of time during an organ-

ing a chain of events that results in a nerve

ism's development in which the brain is optimally

impulse traveling to the brain.

capable of acquiring a specific ability, provided

brainstem: A region of the brain that connects the that appropriate environmental stimuli are pres-
spinal cord to higher levels of the brain, such as

ent. Humans as well as some animals are known

the cortex.

to have a critical period during which language is

acquired.

cochlea: Snail-shaped structure in the inner ear

that contains the organ of hearing. The cochlea is

decibel (dB): A unit that measures the intensity of a coiled, fluid-filled cavity responsible for con-

sound.

verting vibrational energy from the middle ear

ear canal: A component of the outer ear that leads into nerve impulses that travel to the brain.

to the tympanic membrane (eardrum) of the mid-

cochlear duct: See scala media.

dle ear. The ear canal is lined with wax and hairs

that prevent small foreign material from traveling

infrasonic: Sounds with frequencies below 20 Hz

deeper into the ear.

and, therefore, beyond the range of human hear-

ing.

endolymph: A fluid that is located in the

labyrinth, the organ of balance in the inner ear.

intensity: The amplitude of a sound wave. Sound

intensity, which is expressed in decibels, is meas-

eustachian tube: A small tube that connects the

ured in relation to an accepted reference, such as

middle ear with the back of the throat. It allows

the threshold at which an average person can hear

the air in the middle ear to be refreshed periodi-

a sound.

cally.

inner ear: The most interior portion of the ear, made up of two interconnected parts: the vestibular system, a balance organ, and the cochlea, a hearing organ.

frequency: The number of times a sound vibrates per unit of time. Frequency is expressed in hertz (Hz), a unit of measurement equal to one cycle per second.

gene: The functional and physical unit of heredity. Genes are segments of DNA found along a chromosome. They typically encode information used to produce a specific protein. Human DNA is organized into 46 chromosomes—23 from the father and 23 from the mother. The study of mice with hereditary hearing loss has enabled researchers to begin understanding the role that DNA and genetics play in human hearing disorders.

loudness: Our perceived impression of the intensity, frequency, and duration of a sound.

malleus: The first bone in the series of three small bones, or ossicles, of the middle ear. Sometimes called the hammer.

Ménière’s disease: Inner ear disorder that can affect both hearing and balance. Ménière’s disease can cause episodes of vertigo, hearing loss, tinnitus, and the sensation of fullness in the ear.

midbrain: A region of the brain that relays sound

hair cells: Found in the organ of Corti in the

input to the auditory cortex.

cochlea of the inner ear, these are the specialized

receptors of hearing. The name refers to stere-

middle ear: The part of the ear that includes the

ocilia, bundles of hairlike projections jutting

eardrum and ossicles and ends at the round win-

upward from the cells. When the stereocilia are

dow that leads to the inner ear. An air-filled space

moved by sound vibrations, the hair cells translate

connected to the back of the throat by the

this mechanical stimulation into an electrical

eustachian tube.

nerve impulse that is carried to the brain by the

NIHL: See noise-induced hearing loss.

auditory nerve.

noise-induced hearing loss (NIHL): Irreversible

hertz (Hz): A unit of frequency equal to one cycle hearing loss caused by exposure to very loud

per second.

impulse sounds, such as an explosion, or to less-

impact noise: A short burst of sound.

intense sounds for an extended period of time.

Loud noise levels damage hair cells of the inner

imprinting: The process by which young individ-

ear.

uals of a species acquire irreversible behavior pat-

terns of that species. With respect to hearing,

organ of Corti: The sensitive organ of hearing

imprinting involves the ability of the brain to dis-

within the cochlear duct. The organ of Corti con-

tinguish and process the sounds and rhythms of

tains specialized cells called hair cells that trans-

the first language or languages the young hear.

duce sound vibrations into electrical impulses.

incus: The center bone of the series of three small ossicles: The three smallest bones in the human

bones, or ossicles, of the middle ear. Sometimes

body. The ossicles consist of the malleus, incus,

called the anvil.

and stapes (known also as the hammer, anvil, and

pitch: The perception of a sound based on its fre-

stirrup, respectively), found in the middle ear.

quency.

They are part of the system that amplifies sound

round window: An opening in the cochlea that

vibrations that enter the middle ear.

allows pressure from sound waves to be released.

ossicular chain: The three bones that make up the

scala media: Also called the cochlear duct, this *ossicles of the middle ear (the malleus, incus, and*

region between the upper and lower chambers of

stapes).

the cochlea contains the organ of Corti.

otitis media: An inflammation of the middle ear,

scala tympani: The lower chamber of the cochlea.

usually associated with a buildup of fluid related

to a viral or bacterial infection. The obstruction

scala vestibuli: The upper chamber of the

can cause hearing problems, which may arise

cochlea.

when the fluid interferes with the ability of the

sensorineural hearing loss: Hearing loss caused

ossicles to conduct sound vibrations to the inner

by damage to the hair cells or nerve fibers of the

ear.

inner ear.

otosclerosis: An abnormal growth of bone in the

sensory integration: The involuntary process by

middle ear, which prevents structures within the

which the brain assembles a picture of our envi-

ear from working properly, causing hearing loss.

ronment at each moment in time using informa-

ototoxic: Any substance that damages auditory

tion from all of our senses. Children with learning

tissues, including a special class of antibiotics,

disabilities or autism have difficulties with sen-

called aminoglycoside antibiotics, that can dam-

sory integration. (See the Web site of Sensory

age hearing and balance organs for individuals

Integration International, The Ayres Clinic,

who are sensitive.

http://www.sensoryint.com/faq.html.)

outer ear: The part of the ear composed of the

sound: Vibrational energy. A pressure disturbance

pinna and the ear canal.

propagated through a medium and displacing

molecules from a state of equilibrium. The audi-

oval window: An opening in the bony wall that

tory perception of this disturbance. Something

separates the middle ear from the inner ear.

heard by the ears.

perilymph: A fluid, nearly identical to spinal

sound intensity: The magnitude of a sound,

fluid, that fills the cochlea.

measured against a standard reference in units

perilymph fistula: The leakage of inner ear fluid

known as decibels (dB). Intensity refers to the

into the middle ear. It is associated with head

amplitude of a sound.

trauma, physical exertion, or exposure to severe

sound waves: The longitudinal progressive vibra-

pressure, but it can also occur without apparent

tions in an elastic medium by which sounds are

cause.

transmitted.

phonemes: The basic sound elements of a spoken

stapes: The final bone in the series of three small language.

bones, or ossicles, of the middle ear. Sometimes

pinna: The outer ear, which is composed of skin

called the stirrup.

and cartilage. The pinna focuses sound waves into

stereocilia: Hairlike extensions jutting from one

the middle and inner ears. Having two pinnae

end of the inner ear's hair cells into the cochlear

helps animals determine the location of a sound.

fluid.

In some animals, the pinna serves additional func-

tions, such as heat dissipation.

subsonic: See infrasonic.

tectorial membrane: Found in the organ of Corti

vibrations are transferred to the small bones in the *of the cochlea, this sheet of cells lies above the*

middle ear.

stereocilia of the hair cells. Movement of the basi-

ultrasonic: Sounds with frequencies above 20,000

lar membrane (to which the hair cells are

Hz and, therefore, beyond the range of human

attached) causes the stereocilia to move against

hearing.

the tectorial membrane, initiating a nerve impulse

that travels from the hair cell to the brain.

vertigo: The illusion of movement. A sensation

that the external world is revolving around an

temporal lobe: A region of the brain that contains individual (objective vertigo) or the individual is

the auditory cortex, which is necessary for inter-

revolving in space (subjective vertigo). May be

preting sounds.

caused by an inner ear dysfunction.

tinnitus: The term for the perception of sound

vestibular canal: See scala vestibuli.

when no external sound is present. The sensation

vestibular system: The system responsible for

of ringing, roaring, buzzing, or clicking in the ears

maintaining balance, posture, and the body's orien-

or head. An ailment that is associated with many

tation in space. This system also regulates locomo-

forms of hearing impairment and noise exposure.

tion and other movements and keeps objects in

transduction: A process by which energy is con-

visual focus as the body moves. Located next to the

verted from one form to another.

cochlea, the vestibular system consists of three

semicircular canals oriented in different planes.

tympanic canal: See scala tympani.

Movement of fluid within the canals responds to

tympanic membrane: The eardrum. A structure

movements of the head and visual information,

that separates the outer ear from the middle ear

allowing the brain to process an animal's current

and vibrates in response to sound waves. These

state of balance.

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Note from the NIDCD for the

Teacher Who Has a Student Who

Is Deaf or Hard-of-Hearing or Has

Another Communication Disorder

Instruction about disorders of human communi-

increasingly likely that you will have a child in

cation can be sensitive, especially if you have a

your class who has a cochlear implant. For more

student in your classroom who is deaf or hard-of-

information about cochlear implants, visit http://

hearing, who has specific language impairments,

www.nidcd.nih.gov/health/hearing/coch.asp.

such as stuttering, or who has experienced other

Use the term challenge or disability—not handicap.

communication challenges. It may be helpful to

The Council of Representatives, a group whose

point out to the class that one out of six people

membership includes the full range of deafness or

has some form of communication disorder and

hard-of-hearing organizations and the educational

that a communication disorder or challenge may

and health professionals who relate to them, has

not be readily apparent. Many students may have

indicated that the right descriptors to use are

relatives or friends with deafness, hearing loss,

people who are deaf or hard-of-hearing or people aphasia, balance disorders, or other disabilities.

who are deaf or have a hearing loss. Be attuned to (Aphasia is the partial or total loss of the ability to

the way the student or his or her family uses terms

use or understand language or produce speech; it's

such as deaf, hard-of-hearing, or hearing-impaired.

usually caused by stroke, brain disease, or injury.)

Grammatically, the word deaf should only be used There are controversies within families about the

as an adjective, as in deaf person or deaf student. It best ways to deal with hearing loss. Some parents

should not be used as a noun, as in the deaf. Some adopt an oral-auditory approach for their chil-
organizations, including schools for the deaf, still dren, focusing on speech and acquisition of lan-
use the noun in their title for historical reasons.

guage. Other parents, especially those who are

deaf themselves, opt to start with American Sign

For more information about hearing aids, early

Language (ASL). For more information on com-

identification of hearing loss or deafness in the

munication considerations, go to http://www.

newborn nursery, or any other aspect of human

nidcd.nih.gov/health/hearing/commopt.asp. The first communication, visit our Web site at
http://www.

lesson of this module features a person using ASL.

nidcd.nih.gov/health. You can also call us toll-free For quick facts about ASL, go to
http://www.nidcd.

at (800) 241-1044, or send an e-mail to nidcdinfo

nih.gov/health/hearing/asl.asp. It is becoming

@nidcd.nih.gov.

Lesson 1

Engage

Getting the Message

Figure 1.1. Regardless of the language, the meaning remains the same.

Overview

At a Glance

Students are introduced to language and communication. They listen to short readings in English and other languages, and investigate why they do or do not understand what they hear. The lesson concludes with students reading two short paragraphs relating to the critical period for language development.

Major Concepts

Hearing involves sound, while communication involves the brain. There is a critical period for language acquisition to occur.

Objectives

After completing this lesson, students will

- understand that languages are composed of different types of building blocks,

- recognize that understanding spoken language requires a process that moves from sound to hearing to understanding,

- recognize that there can be communication without sound and hearing, and

- recognize that the brain is central to communication in any form.

Teacher Background

Consult the following sections in Information about Hearing, Communication, and Understanding:

1 Introduction (page 25)

2 Misconceptions Related to Sensory Perception and Hearing (page 26) 3 Major Concepts Related to Hearing and Communication (page 27) 3.1 Communication is multisensory (page 27)

3.2 Language acquisition: imprinting and critical periods (pages 28–29) 3.3 Sound has a physical basis (pages 29–32)

3.4 Perception of sound has a biological basis (pages 32–38) In Advance

Web-Based Activities

Activity

Web Version?

1

Yes

2

No

Photocopies

Activity 1

Master 1.1, The Rhythm of Language (Prepare an overhead transparency.)

Activity 2

Master 1.2, Stories of Language Development (Make 1 copy per student.)

Materials

Activity 1

computers with Internet connection and sound card

Activity 2

no materials, except photocopies

Preparation

Because this lesson involves a teacher-led discussion, the best approach is to use one computer for the entire class. This allows you to play the tracks in their recommended sequence and to control the discussion after each track is played. Before class, adjust the computer's sound system so that the entire class can hear the tracks as they are played.

The American Sign Language (ASL) video, used in Activity 1, is a large file.

If you have a slow Internet connection, you may want to load the file before class begins. To do so, proceed to http://science.education.nih.gov/

supplements/hearing/student and click on "Lesson 1—Getting the Message."

When the page comes up, click on "Track 4" to allow the video to load in a separate window. By following this procedure, you can begin Lesson 1

without waiting for the large file to download.

This lesson requires access to the Web site. If you do not have Internet access at your school, you might consider using a computer at home or the library to record the sound tracks on a cassette and playing the tape in class as described below.

Activity 1: What Did You Say?

Procedure

Teacher note

In this activity, students listen to the first sentence of the Gettysburg Address spoken in different languages. After each track is played, students are asked what they can understand. Many students will not understand any words until a track spoken in English is played. If you have students who understand Chinese, Hebrew, Spanish, or American Sign Language, they will understand those tracks, although they may not identify the track as part of the Gettysburg Address.

1. Introduce the activity by asking students how they learned language.

A common response is, "I learned from my parents." Students with younger siblings may have observed how young children acquire verbal skills by listening and imitating what they hear.

2. Ask students what their first words were.

Answers will vary, although first words will be short words with simple sounds that young children have heard repeatedly, such as

"mama" and "dada."

3. Ask students why so many of them report having the same first words.

Students may respond that this has something to do with the nature of the sounds that infants hear. Perhaps babies sense patterns of sound. Some patterns may be easier to interpret than others. Begin focusing the discussion on the brain as the body organ that interprets the environment.

Student Lesson 1

How Your Brain Understands What Your Ear Hears

4. Go to the Web site http://science.education.nih.gov/supplements/

hearing/student and click on "Lesson 1—Getting the Message."

5. Do NOT tell students that they will hear the Gettysburg Address.

Also, do NOT tell students the language in which the material is being read. Begin by playing Track 1, then proceed to Track 2 and Track 3. As you play each of the sound clips, ask students to write down what information they get from listening. For instance, is the speaker male or female? Does the speaker sound angry? Happy?

Calm? Do the students have any understanding of what is being said?

This activity features links to six tracks. Each track plays the first part of Abraham Lincoln's Gettysburg Address. In addition to reading the original wording in English (Track 6), the sentence is also read in Chinese (Track 1), Hebrew (Track 2), Spanish (Track 3), American Sign Language (Track 4), and a more modern form of English (Track 5).

6. Play Track 4 (American Sign Language). As you play the video, ask students if they can tell what is being communicated.

7. Play Track 5 (modern English). Do the students have any greater recognition of what is being read, since this track is now in English?

8. Play Track 6 (traditional English). Can the students now identify the Gettysburg Address as the material being read?

9. Ask the class why they could not understand what was being said in Chinese, Hebrew, Spanish, or American Sign Language. What makes languages different?

Students probably will reply that what they heard was in a foreign language; it was not English. Languages differ in many ways. The basic sounds of speech, as well as how they are put together to form words, may be different. Also, the rhythm of sounds and pauses, the way the voice varies in pitch, and the patterns of loudness and soft-ness vary.

10. Display the transparency made from Master 1.1, The Rhythm of

Language, to demonstrate graphically the differences that exist in the rhythms of the four languages. Point out that the dark vertical lines represent speech. The height of the dark line is related to loudness: longer equals louder, shorter equals softer. There are Figure 1.2. The power of

brief periods in which no sound is made (no dark lines) between Abraham Lincoln's Get-the periods of sound. The left-to-right distance represents the total *tysburg Address can be*

time required to read the sentence from the Gettysburg Address.

felt in any language.

54

NSES

Figure 1.3. *Speech can be represented graphically.*

Students should recognize that in each language, some elements of speech are louder than others. Students also will note that there are differences in the rhythms (the alternation of sounds and silence) among languages.

11. Even though students might not have understood the readings in Chinese, Spanish, or Hebrew, ask if they could tell whether the speaker was male or female, or whether the speaker was angry or calm. Ask if they could tell whether the male signer was angry or calm.

The brain interprets information with which it is presented. Interpre-Content Standard A:

tation relies on previous experiences. We learn that male voices are Recognize and analyze

generally lower pitched and female voices, generally higher pitched.

alternative explana-

We learn what anger, happiness, and other emotional states look and sound like. If students could not identify the Gettysburg Address as tions and predictions.

the source in the modern reading, it may be because they lack the experience to interpret the material from one context and to place it in another.

12. Ask students what would happen if they did not hear a language when they were growing up.

Many students will assume that they could learn their first language at a later age, the way they do a foreign language in school. This discussion leads to Activity 2, where the focus continues to be on the central role of the brain in communication.

Activity 2: When the Time Is Right

1. Give each student a copy of Master 1.2, Stories of Language Devel-

opment. Instruct them to silently read the first story, "Birdsong."

Figure 1.4. *To acquire*

its song, a male white-

crowned sparrow must

hear it sung repeatedly

during a critical period

between one week and two

months after hatching.

2. After the class finishes reading, ask them what this story tells about the brain and its ability to use information.

The important point is that the young, male white-crowned sparrow has a specific time, or window of opportunity, in which to learn the song. Only during this time can the brain interpret the song, enabling the bird to sing it.

3. Ask students to think about whether this story might be relevant to human development.

Students may respond that humans need to hear spoken language during a specific time to learn speech. Other students may answer that humans, with our larger brains, are not so dependent on a window of time for learning language.

4. Instruct the class to read the second story, "Wild Child." Ask students how they interpret Victor's lack of verbal language and inability to develop verbal skills.

Students may make a connection between the idea of a critical period for language acquisition from "Birdsong" to the apparent lack of exposure to human language during a critical period in Victor's situation. If students do not offer this explanation, help them understand that Victor may have had difficulty learning spoken language because he did not hear it during a critical period when he was young.

5. Ask students if they can think of another explanation for Victor's lack of verbal skills, besides his missed exposure to language during a critical period.

It is also possible that Victor might have been born with a developmental disorder that left him unable to learn well at any age. Students should realize that there is no simple explanation. Scientists still debate the reasons for Victor's inability to demonstrate normal language and communication skills.

6. Ask the class to help you develop "The Path to Understanding."

Write this as a heading on the board. Then write "Sounds" on the left side of the board. Tell students that sounds are a starting point on the path to understanding. Finally, write "Understanding" on the right side of the board, as shown in Figure 1.5.

The class will work together to construct this diagram. Refer to Figure 1.8 to see the complete diagram.

Figure 1.5

7. Ask students to name different kinds of sounds.

Many will be named. Group them into three categories: voiced, musical, and environmental (environmental is everything that is not voiced or musical).

8. Draw a forward arrow after "Sounds" on the developing "Path to Understanding" and ask students what is the next step in the pathway. Students should recognize that the ear is required to receive the sound (hearing). Write "Ear/Hearing" on the board.

Figure 1.6

9. Draw a forward arrow after "Ear/Hearing" and ask students what lies between "Hearing" and

"Understanding."

Students should recognize that the brain is necessary to interpret sounds so that we understand the meaning behind the sound.

10. Ask students what would happen if a person had a problem with hearing, ranging from a slight hearing loss to a complete hearing loss. Can a person still communicate?

Students should recognize that there are means of communication that do not require sound. An example is American Sign Language. If students do not suggest this, ask them to consider sign language.

11. Ask students what is required to understand sign language.

Students should mention that the sense of vision and an agreed-upon series of hand signs are needed. If students gloss over the role of the brain, be sure to mention that the brain is required to interpret the visual input from signing so that we understand the meaning behind the sign.

12. Ask the class where in the diagram the words "Sign Language"

Content Standard C:

should appear. If a person communicates using sign language, how *Behavior is one kind of*

does he or she take in information? Write "Eye/Vision" on the *response an organism*

board below "Ear/Hearing."

can make to an inter-

Sign language is similar to "Sounds" in the diagram. Therefore, write nal or environmental

the words "Sign Language" beneath "Sounds." A person using sign stimulus. A behavioral

language uses his or her eyes to take in the information in a manner response requires

similar to the ears taking in sounds. Draw an arrow leading from coordination and com-

"Sign Language" to the words "Eyes/Vision."

munication at many

levels, including cells,

organ systems, and

whole organisms.

Figure 1.7

13. The final diagram on the board should look like the following figure:

Figure 1.8

Teacher note

You may wish to save this diagram on the board to introduce Lesson 2.

14. Ask the class whether a person who has neither sight nor hearing can communicate with others.

Yes, though it may seem impossible, people without both sight and hearing can learn to read, write, and communicate with others. Students may have heard of Helen Keller. Although she could not see or hear, she authored many books and reached a worldwide audience.

Assessment:

She helped others understand that the abilities to communicate and Ask students to com-function in society reside in our brains and are not tied to any one of pare sounds that ani-our five senses.

mals use for

communication with

***15. Ask the class to remember the "Birdsong" story. How do animals use their ability to communicate? How is animal communication** words spoken by*

***similar to or different from human communication? Ask students if** humans. Do students*

***they think that studying animals can help us understand human** recognize that, similar*

communication. Why or why not?

to words, animal

sounds are made up

Animals need to communicate for a variety of reasons, such as to find of a series of repetitive

a mate, warn other members of their group of danger, or find their sounds or a combina-parents. Students should realize that animal communication is similar to human communication in that animals also take in sounds through tion of sounds to con-their ears and process the information using their brains. Some stu-vey meaning? Do they

dents may feel that because no other animals use spoken language, understand that, as in

they are of limited usefulness in exploring human communication.

humans, animals take

You can mention that mammals share many anatomical and physiolog-in sound through their

ical features with humans. Mammals also have similar versions of ears and interpret it in

many human genes. These similarities are being used to investigate the relationship between hearing and communication. The comparison of their brains?

the human and mouse genomes is very helpful in this regard.

Student Lesson 1

How Your Brain Understands What Your Ear Hears

Lesson 1 Organizer

Activity 1: What Did You Say?

What the Teacher Does

Procedure Reference

Review with class how they learned language as children.

Page 53

Steps 1–3

Log onto the student Web site and click on "Lesson 1—Get-

Page 54

ting the Message."

Step 4

Play Tracks 1–3 in sequence, and ask students what infor-

Page 54

mation they can gain from the readings, such as

Step 5

• Is the speaker male or female?

• Does the speaker sound angry, happy, or calm?

• Can they understand any of what is being said?

Play Track 4 (American Sign Language) and ask students

Page 54

if they can tell what is being communicated.

Step 6

Play Tracks 5 and 6 (modern and traditional English) and

Page 54

ask the class if they now can understand what is being said.

Steps 7–9

Examine sound patterns of speech on Master 1.1, The

Page 54

Rhythm of Language.

Step 10

Review the types of information that can be obtained

Page 55

without understanding the language.

Step 11

Discuss the consequences of not hearing language when

Page 55

young.

Step 12

= Involves using the Internet.

= Involves using a transparency.

Activity 2: When the Time Is Right

What the Teacher Does

Procedure Reference

Have students read "Birdsong" from Master 1.2, Stories Pages 55–56

of Language Development, and relate it to human

Steps 1–3

development.

Have students read “Wild Child” from Master 1.2, Stories of Pages 56–57

Language Development.

Steps 4 and 5

• Relate it to the concept of a critical period for language development.

• Discuss possible explanations for Victor’s lack of verbal development.

Work with students to construct “The Path to

Pages 57–59

Understanding.”

Steps 6–13

Discuss how a person who has neither sight nor hearing

Page 59

can communicate.

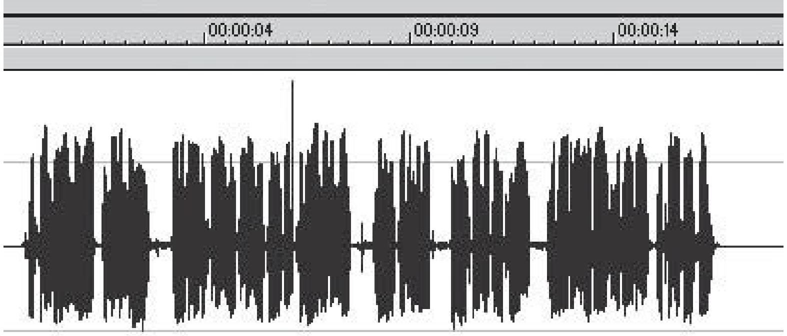
Step 14

Have the class consider how animal communication and

Page 59

human communication are alike and different.

Step 15



The Rhythm of Language

Master 1.1

Stories of Language Development

BIRDSONG

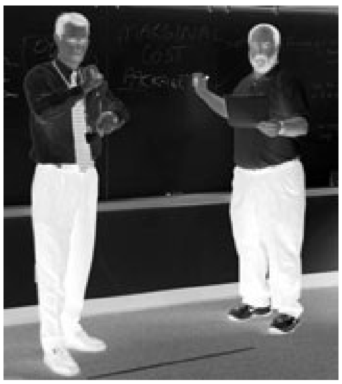
A male white-crowned sparrow usually begins singing its full song between 100 and 200 days of age.

Having the proper song is necessary for mating and marking its territory. However, to learn its song, the young bird must be exposed to an adult bird's song consistently and frequently between one week and two months after hatching. That is its critical period for learning its song. Both before and after this critical period, the male sparrow is unable to use any adult sounds to learn its characteristic song.

WILD CHILD

In 1799 in Aveyron, France, a boy thought to be about 11 or 12 years old was discovered in the woods foraging for food. He became known as the "wild child of Aveyron," because he behaved like an animal. He happily ate spoiled food, did not distinguish between hot and cold, thought nothing of romp-ing unclothed through the snow, spent much of his time rocking back and forth like a caged animal, showed and accepted no affection, and possessed no verbal language. He was taken into the care of a French scientist, who spent a number of years trying to educate the boy. Victor, as he was named, eventually learned some basic skills and developed some language comprehension. However, he learned to say only two expressions: "milk" and "Oh, God."

Master 1.2



Lesson 2

Explore/

Explain

Sound Communication

Figure 2.1. *Human communication*

can involve both sight and sound.

Overview

At a Glance

Students watch and listen to human speech and explore visual and audio cues that aid their understanding. During a short walk, students listen to the sounds around them and classify them as environmental, voiced, or musical.

Major Concepts

The most effective communication is multisensory. Sound is a powerful and important means of communication. There are three categories of sounds: environmental, voiced, and musical.

Objectives

After completing this lesson, students will

- *understand that sound is a powerful means of communication;*
- *appreciate that both audio and visual cues aid their understanding of speech;*
- *explain why the most effective communication is multisensory;*
- *realize that there are sounds around them that they take for granted; and*
- *be able to list the categories of sound (environmental, voiced, and musical).*

Teacher Background

Consult the following sections in Information about Hearing, Communication, and Understanding:

3 Major Concepts Related to Hearing and Communication (page 27) 3.1 Communication is multisensory (page 27)

3.2 Language acquisition: imprinting and critical periods (pages 28–29) 3.3 Sound has a physical basis (pages 29–32)

3.4 Perception of sound has a biological basis (pages 32–38) ***In Advance***

Web-Based Activities

Activity

Web Version?

1

No

2

No

Photocopies

Activity 1

no photocopies needed

Activity 2

Master 2.1, Sound Safari Data Sheet (Make 1 copy per student and prepare an overhead transparency.)

Materials

Activity 1

no materials (except photocopies)

Activity 2

no materials (except photocopies)

Preparation

Activity 1

No preparations needed.

Activity 2

Make photocopies and overhead transparency of Master 2.1, Sound Safari Data Sheet.

Activity 1: How Do We Understand?

Procedure

Teacher note

The purpose of this activity is twofold. First, it helps students become aware of sounds they experience and normally take for granted. Second, it sets the stage for thinking about sound in terms of its loudness, pitch, and timing. As the module concludes, students will reflect on their own sound exposure and provide recommendations about how they can minimize their risk of noise-induced hearing loss.

PART 1—VISUAL CUES

1. Remind the class that the previous lesson focused on human communication. If you have saved the Path to Understanding diagram from Lesson 1, review it with the class. Explain to students that they will now explore how humans understand what they hear.

2. Illustrate the multisensory nature of communication by silently mouthing a sentence such as, "I wonder if you can read my lips."

Ask the class if they can repeat the sentence that you mouthed*.*

Students may be able to pick out some of the words, but the meaning of the sentence will remain obscure. If you have a hearing-impaired student in the class who is adept at reading lips, ask him or her to let the rest of the class respond first.

3. Next, silently mouth a sentence such as, “You’re the best class that I’ve ever had,” while conveying a happy facial expression. As before, the exact meaning of the sentence will be obscure. Ask the class if they think the sentence was conveying a happy, sad, or angry thought. On what did the students base their impression?

You should stress that facial expressions help represent the emotion behind speech.

4. Finally, silently mouth a sentence such as, “I’ve just won $1 million in the lottery.” This time use a facial expression that conveys an angry or sad emotional state and ask the class to identify the emotion behind the sentence. Again, ask students to explain the basis for their answers.

The mixed messages sent by the mouthed words and the facial expression make the meaning of the sentence more difficult to establish.

5. Ask the class to summarize how visual cues influence communication and understanding.

Students should realize that visual cues, such as facial expressions, affect how others interpret what is said.

Figure 2.2. *Facial expressions can convey emotion.*

PART 2—INTONATION CUES

1. Ask the class whether they can think of any other aspects of speech (aside from the words spoken and visual cues) that help convey meaning.

Answers may vary. Be alert to answers that speak to characteristics about the speaker and not the meaning of what is being spoken (for example, accents and vocabulary).

2. Write the following sentence on the board, "The blue fish is too big for that tank." Read the sentence aloud to the class, stressing the word "blue" as depicted in example a below, and have students discuss the meaning. Repeat the sentence stressing different words and discuss how the meaning of the sentence changes. Does this sentence always convey the same meaning?

For example:

a. The blue fish is too big for that tank. (Meaning: The blue fish is too big, but fish of other colors are the appropriate size.) b. The blue fish is too big for that tank. (Meaning: The blue fish is too big, but other blue creatures are the appropriate size.) c. The blue fish is too big for that tank. (Meaning: The blue fish is too big for that tank but may be the appropriate size for some other tank.)

3. Ask students to suggest another sentence that can take on different meanings depending on how it is said. Write the sentence on the board, and ask the class to see how many ways it can be read to give different meanings.

Another sentence that can take on different meanings depending on which words are stressed is, "We are going to the mall tomorrow."

4. Ask the class to summarize how the manner in which words are spoken can affect our understanding.

Review the idea of how word stress changes the meaning of a sentence. Relate to students that actors often practice saying a line in different ways that change the meaning of the words being spoken.

Figure 2.3. *The*

meaning of spoken

words can change

depending on how the

words are spoken.

PART 3—EMOTIONAL CUES

1. Ask the class, Can you detect the emotional state of the person speaking by his or her tone alone, or do you need to understand the words being spoken?

Answers will vary, though many students will believe that they can identify the speaker's emotional state just by hearing the tone and not the words.

2. Test this idea by speaking a random string of numbers to the class, such as 7, 52, 12, 39, 75. Use a voice that suggests a specific emotion, such as anger, and ask the students to identify the emotion.

To avoid giving the class any visual cues from your facial expression, you might face away from the class while speaking.

3. Ask for a volunteer to repeat the test by speaking a different string of numbers and using a different emotion. See if the class can identify the emotion. Repeat the test using different students, numbers, and emotions.

How Your Brain Understands What Your Ear Hears

Again, have the speaker face away from the class to eliminate cues from facial expressions.

4. To reinforce the importance of multisensory communication, ask Content Standard C:

the class what other factors, besides hearing, help us communicate with others.

Behavior is one kind of

response an organism

Answers should include the idea that visual cues, such as facial can make to an inter-expressions and body language, help our brain interpret the speech nal or environmental

that we hear.

stimulus

5. Wrap up the activity by asking students to list ways, other than speech, in which we can communicate.

Answers will vary but may include

reading and writing

body language

sign language

gestures

facial expressions

whistling

Activity 2: Sound Safari

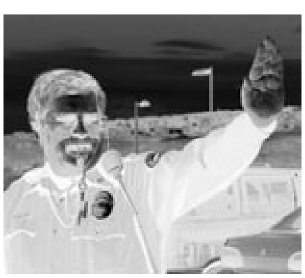
Teacher note

The sound safari consists of a simple, five-minute walk down the school hallway. Decide ahead of time where the class will walk. Ideally, students will walk by areas that have a wide variety of sounds, such as the cafeteria, music class, and shop class. If weather permits, you might consider taking part of the walk outdoors.

1. Remind the class that we categorize sounds as voiced, musical, or environmental. Ask students to give some examples of each category.

2. Explain to the class that they will take a short walk. Instruct students not to talk to each other during the walk and to keep noise to a minimum.

The goal is to concentrate on the number and types of sounds around them and list as many of them as possible. For the purposes of this activity, students should ignore any sounds made by students in the class (such as talking, coughing, feet shuffling, and writing) and only pay attention to those sounds that aren't produced by the class.



3. Give each student a copy of Master 2.1, Sound Safari Data Sheet.

Explain that each of the sounds they list can be classified as voiced, musical, or environmental. Instruct students to list each of their sounds in the appropriate column on their data sheet.

Content Standard A:

Environmental sounds are simply those that are not voiced or musical.

Different kinds of

questions suggest dif-

4. After returning to the classroom, place an overhead transparency *ferent kinds of scien-of Master 2.1, Sound Safari Data Sheet,* ***on the overhead projector.***

tific investigations.

Ask students to call out the voiced sounds from their data sheets and write them down on the transparency. Repeat this process for *Some investigations*

the musical and environmental sounds.

involve observing and

describing objects,

5. Ask students whether their list of sounds was the same as *organisms, or events;*

that written on the transparency. Ask the class to account for *some involve collect-differences.*

ing specimens; some

Students will have many of the same sounds on their lists. Differ-involve experiments;

ences arise when sounds are hard to hear or are ever present and some involve seeking

therefore difficult to notice.

more information;

some involve discovery

6. To conclude this activity, remind the class that visual and audio *of new objects and*

cues help us better understand speech. Ask the class if they can *phenomena; and*

think of similar cues that help us understand musical and environ-some involve making

mental sounds.

models.

Context is important. A piece of music played during a parade may convey a different emotion from the same music played at a funeral.

A whistle blown by a policeman directing traffic has a different meaning from a whistle blown by an official at a sporting event.

Assessment:

Ask students to sum-

marize, in writing, their

thoughts about how

audio and visual cues

influence our ability to

gain meaning from

sound. Ask them to

provide specific exam-

ples of sounds that

Figure 2.4. The same sound can have different meanings that depend on can have different

context.

meanings depending

upon their context. Ask

students to share their

ideas with the class.

How Your Brain Understands What Your Ear Hears

Lesson 2 Organizer

Activity 1: How Do We Understand?

What the Teacher Does

Procedure Reference

Review the Path to Understanding diagram from Lesson 1.

Page 67

Part 1, Step 1

Silently mouth the sentence, “I wonder if you can read my Page 67

lips,” to the class.

Part 1, Step 2

• Ask students if they can repeat the sentence.

Use a happy expression to mouth the sentence, “You’re the Page 67

best class that I’ve ever had.”

Part 1, Step 3

• Ask students to identify the emotion.

Use an angry or sad expression to mouth the sentence, “I’ve Page 67

just won $1 million in the lottery.”

Part 1, Step 4

• Ask students to identify the emotion.

Ask the class to summarize the roles of visual cues in

Page 68

human communication.

Part 1, Step 5

Ask the students whether other aspects of speech convey

Page 68

meaning.

Part 2, Step 1

Write the sentence, “The blue fish is too big for that tank,” *Page 68*

on the board.

Part 2, Step 2

• Discuss how emphasizing different words can affect

meaning.

Have students suggest another sentence that can convey

Page 69

different meanings depending on how it is said.

Part 2, Step 3

= Involves copying a master.

= Involves using a transparency.

72

Summarize how word stress and intonation can affect

Page 69

meaning.

Part 2, Step 4

Ask if a speaker's emotion affects understanding.

Page 69

Part 3, Step 1

Recite a random series of numbers using a voice that

Pages 69–70

conveys a specific emotion.

Part 3, Steps 2 and 3

• Ask students to identify the emotion.

• Repeat the activity having a student recite numbers

using a different emotion.

Reinforce the importance of multisensory communication.

Page 70

• What factors, besides hearing, help us communicate?

Part 3, Steps 4 and 5

• How can we communicate without using speech?

Activity 2: Sound Safari

What the Teacher Does

Procedure Reference

Have students give examples of voiced, musical, and environ-Pages 70–71

mental sounds.

Steps 1–3

Take class on a short walk through the school.

Pages 70–71

• Have students record the sounds they hear on Master

Steps 2 and 3

2.1, Sound Safari Data Sheet.

After returning to classroom,

Page 71

• Construct a list of sounds heard on the transparency of Steps 4 and 5

Master 2.1, Sound Safari Data Sheet.

• Have students compare their lists with the master list.

Have students discuss how they use their senses to interpret Page 71

musical and environmental sounds.

Step 6

Student Lesson 2

Sound Safari Data Sheet

Name____

Date___________________________

VOICED

MUSICAL

ENVIRONMENTAL

Master 2.1

Lesson 3

Explore/

Explain

Do You Hear

ou Hear

What I Hear?

Figure 3.1. Children enjoy playing with sound.

Overview

At a Glance

Students learn how loudness is measured. Using a Web-based loudness-pitch square, students generate a hearing-response curve. They also listen to recordings that simulate hearing loss. Students investigate the relationships among loudness, pitch, and hearing.

Major Concepts

Loudness and pitch are distinct properties of sound. Loudness is related to the amplitude of the sound wave; pitch is related to its frequency. Humans do not hear all pitches equally well. Specifically, the loudness of very-low-and very-high-pitched sounds must be increased to detect them. A healthy sense of hearing is characterized by an ability to recognize a wide spectrum of pitches. Hearing loss may involve failure to detect specific pitches.

Objectives

After completing this lesson, students will

- *be able to identify the decibel scale as the tool scientists use to describe a sound's relative loudness,*

- *be able to explain that loudness is related to the amplitude of the sound wave, while pitch is related to its frequency, and*

- *understand that humans do not hear all pitches equally well; loudness must be increased to detect certain pitches.*

Teacher Background

Consult the following sections in Information about Hearing, Communication, and Understanding:

3.3 Sound has a physical basis (pages 29–32)

3.4 Perception of sound has a biological basis (pages 32–38) In Advance

Web-based Activities

Activity

Web Version?

1

No

2

Yes

Photocopies

Activity 1

Master 3.1, The Decibel Scale (Make 1 copy per student.) Master 3.2, Sound Intensity Table (Make 1 copy per student and prepare an overhead transparency.)

Activity 2

Master 3.3, Loudness and Pitch (Make 1 copy per student.) Master 3.4, Hearing Response (Make 1 copy per student and prepare an overhead transparency.)

Materials

Activity 1

a small bell

Activity 2

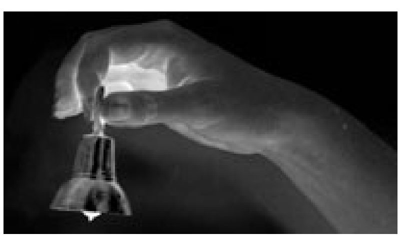
a computer with an Internet connection and a sound card

Preparation

To achieve the best results, calibrate the computer sound levels with the Web activity. To do this, go to http://science.education.nih.gov/supplements/

hearing/web click on "Web Portion of Student Activities." Then click on

"Lesson 3—Do You Hear What I Hear?" After listening to the introduction, you will advance automatically to a page containing a large graph, the loudness-pitch square. Play the 2,000-Hz (2-kHz) tone at a value of about 20 on the loudness scale (y-axis). Adjust the volume control on the speakers so that the tone is barely audible. This will ensure that your computer plays the tones at appropriate volumes for the activity.



Activity 1: Measuring Intensity

Procedure

Teacher note

This activity is concerned with measuring levels of sound intensity. Sound intensity is a scientific measurement representing power per unit of area and is expressed as watts per meter squared (W/m2). Loudness, on the other hand, is a subjective impression of sound intensity. Perception of loudness varies from person to person. It is influenced by factors such as sound frequency (we don't hear all frequencies equally well) and the performance of our hearing (a person with a partial hearing loss may perceive a given sound as being less loud than a person with normal hearing does).

Although sounds of greater intensity are louder than sounds of lesser intensity, use of the term loudness does not permit us to make quantitative comparisons. Therefore, in this activity, we will focus on measuring and comparing sound intensity rather than loudness.

1. Begin the activity by ringing a small bell until the class gives you their attention.

The bell serves as a vehicle to engage students' interest in the activity.

Figure 3.2. A bell may be rung loudly or softly.

2. Challenge the class to name different ways to make the bell sound louder.

Students may suggest

• ringing the bell more vigorously so the clapper hits the side with more force,

• ringing the bell closer to their ears,

• cupping their hands around their ears to better focus the bell's sound waves into them,

• placing the ringing bell at the small end of a megaphone to better project the sound waves toward the class, and

• placing the bell in front of a microphone that's wired to an amplifi-cation system.

3. Explain that students will investigate the physical basis of loudness. However, before they can investigate loudness, they need to understand how scientists measure it. Distribute 1 copy of Master 3.1, The Decibel Scale, and Master 3.2, Sound-Intensity Table, to each student.

4. Explain that Master 3.2 contains a partially filled-out table that lists increasing sound levels (measured in decibels) with a description of a reference sound at some levels. Instruct students to complete the missing entries in the first two columns of the table.

If students have trouble understanding the relationship between sound intensity and decibels, use the first few entries on Master 3.2

as examples to clarify the relationship. Completing the worksheet will help students better understand the decibel scale and also reinforce the meaning of sound intensity and the large range of sound intensities that the human ear can detect. Only a few reference sounds are presented here. Students will have the opportunity to relate more sounds to the decibel scale during Lesson 5, Too Loud, Too Close, Too Long.

5. Show the class the overhead transparency of Master 3.2 and ask them how they filled in the first

two columns of the table.

Sound Intensity	***Decibels (dB)***	***Sounds***
1	***0***	***just detectable***
10	***10***	
100	***20***	
1,000	***30***	
10,000	***40***	***quiet room***
100,000	***50***	
1,000,000	***60***	***normal conversation***
10,000,000	***70***	
100,000,000	***80***	

alarm clock

1,000,000,000

90

10,000,000,000

100

100,000,000,000

110

rock concert (90–130 dB)

1,000,000,000,000

120

shout into ear at 20 cm

10,000,000,000,000

130

100,000,000,000,000

140

air raid siren

78

NS ES

Students should respond that the sound levels increase by powers of 10. Furthermore, the number of decibels (dB) corresponds to the number of zeros in the sound-intensity column, followed by a zero.

That is, a sound intensity of 1,000 in the table has a decibel value of 3 (as in 3 zeros) followed by a zero, or 30 dB.

6. To assess students' understanding of the decibel scale, instruct them to answer the questions on Master 3.1, The Decibel Scale.

Answers to questions on Master 3.1, The Decibel Scale, follow:

Question 1. How many times more intense is a sound of 30 dB than a

sound of 20 dB? A sound of 40 dB than a sound of 20 dB?

A sound of 30 dB is 10 times more intense than a sound of 20 dB. A sound of 40 dB is 100 times more intense than a sound of 20 dB.

Question 2. How many times more intense is the sound of an alarm

Content Standard A:

clock than a quiet room?

Use mathematics in all

aspects of scientific

The sound of an alarm clock is 10,000 times more intense than a inquiry.

quiet room.

7. Ask the class why a sound will seem "too loud" to one person but not to another person.

People have different preferences for sound intensities. For example, some people prefer to listen to music at higher intensities than others. Differences in loudness perception can also result from damage to the hearing pathway. A person with a partial hearing loss will hear a given sound as less intense compared to a person with normal hearing. People who prefer to listen to loud music put themselves at risk for noise-induced hearing loss.

8. Ask the class how sound intensity is used in speech to communicate with others.

Sound intensity plays an important role in human speech. First, speaking loudly can convey an emotional state such as urgency or anger. Second, as seen in Lesson 2, putting greater stress (sound intensity) on a particular word can change the meaning of a sentence. Third, stressing a different syllable within a word can sometimes change its meaning.

Student Lesson 3

How Your Brain Understands What Your Ear Hears

Figure 3.3. Speech can be either

loud or soft.

Activity 2: Pitch Me a Curve

Teacher note

In this activity, students generate a hearing-response curve, which depicts the threshold of hearing as a function of frequency. This technique is the basis for a test commonly used to detect hearing loss. However, this activity should not be used as a diagnostic tool in any way. Students will likely generate curves that differ from each other. These differences are much more likely to be caused by differences between computers than differences between students' hearing.

PART 1—LOUDNESS AND PITCH

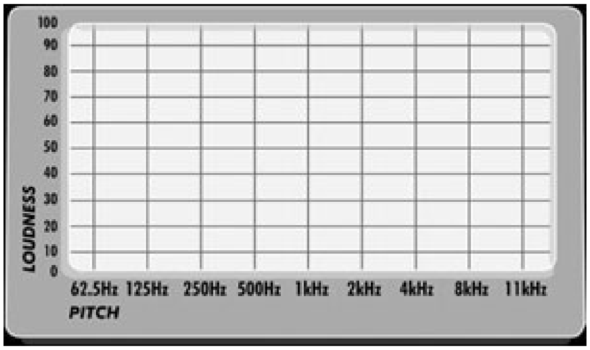
1. Ring the small bell again until the class gives you their attention.

Challenge the students to name as many ways as possible of making the bell sound higher in pitch.

Although they may not be able to explain the physical basis for the bell's pitch, most students will probably know that its pitch is related to its size, and that the only way to increase the bell's pitch would be to change (decrease) its size or somehow to electronically change the sound waves that it produces.

2. Explain to the class that they are now ready to study the relationship between loudness and pitch. Challenge students to explain the difference between these two properties of sound and to provide some practical illustrations of this difference.

80



Students should understand already that loudness is described using words such as loud and soft, whereas pitch is described by words such as high and low. Students should be able to explain that both the low-pitched keys on the left of a piano keyboard and the high-pitched keys on the right can be played softly or loudly. Similarly, males (with lower-pitched voices) can sing as loudly or as softly as females (with higher-pitched voices).

3. Ask the class to recall that sound travels as vibration. Explain that the physical basis of a sound's pitch is its frequency, or the number of vibrations per second.

Sounds of rapid vibrations are perceived as higher in pitch than sounds of slower vibrations. The unit hertz (abbreviated Hz) is used to measure the pitch (frequency) of sound. For example, a sound with a pitch of 262 Hz vibrates at a rate of 262 times per second, which corresponds to middle C on a piano.

4. Explain to the class that they will use a Web-based activity to investigate the relationship between loudness and pitch and to understand the human hearing response to sound.

5. Have students proceed to http://science.education.nih.gov/supple-

ments/hearing/student and click on "Lesson 3—Do You Hear What I Hear?" After listening to the introduction, you will advance automatically to a page containing a large graph, the loudness-pitch square.

Students should pay close attention to the introduction. It explains how changes in wave amplitude reflect soft versus loud sounds, and how changes in frequency reflect low- versus high-pitched sounds.

Figure 3.4. The loudness-pitch square.

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Student Lesson 3

NSES

6. Explain to the class that they will perform two tasks using a loudness-pitch square. First, they will investigate the relative loudness of sounds at different pitches. Then, in Part 2, they will construct a hearing-response curve.

Content Standard A:

Use appropriate tools

Students may work in teams, although each student should collect his or her own data.

and techniques to

gather, analyze, and

7. Distribute to each student a copy of Master 3.3, Loudness and Pitch.

interpret data.

8. In the first task, students select the lowest frequency (62.5 Hz) and click on a point halfway up the y-axis (50 on the loudness axis).

Depending on your computer, sound card, and speakers, you may not be able to hear the lowest or highest frequencies, even at the maximum intensity. Also, students might hear a very short "squeak"

initially. Tell them to ignore this noise and listen for a constant, uniform tone.

9. For the first constant, uniform tone that students hear at 50 on the loudness axis, tell them to assign that tone a value of 1 (on a scale of 1 to 10).

Other tones may be louder than this one, and they will be assigned an arbitrary number relative to 1.

10. Students should then select the next higher frequency on the graph, clicking on the point at the same vertical height as before (50 on the loudness axis). Instruct students to assign the tone a numerical value based on its loudness relative to the first detectable tone (see Step 9). For example, if you think the second tone is twice as loud as the first, then you should assign the second tone a value of 2. This process is repeated for each of the remaining frequencies, always clicking on the same point on the loudness axis (at 50) for each frequency. Students should then enter their results on Master 3.3, Loudness and Pitch.

11. Instruct the students to answer the discussion questions on Master 3.3, Loudness and Pitch.

Question 1. Did the sounds produced at each frequency seem equally *loud? How did the loudness change with frequency?*

Sounds vary in loudness as pitch (frequency) increases. At the low end of the spectrum, the sounds seem louder as frequency increases.

As one moves up the spectrum, however, loudness seems to decrease at the higher frequencies.

Question 2. Why did you hear variation in loudness with changing

pitch?

The hearing system's sensitivity to loudness varies with the frequency of the sound. Generally, the ear is most sensitive to sounds in the 3-to-4-kHz region. Sounds outside of this range must be more intense to be perceived as loud. Any student answer that relates this phenomenon to the functioning of the human hearing system is acceptable.

PART 2—HEARING-RESPONSE CURVE

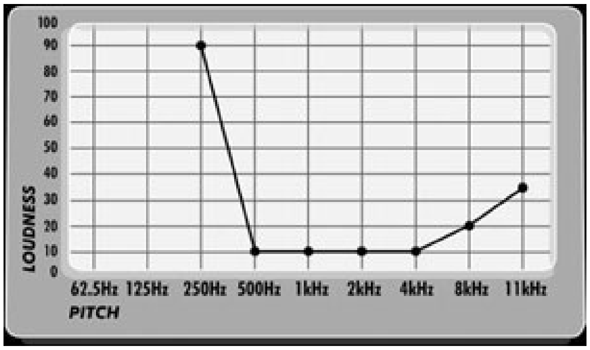
Teacher note

In this second task, students generate a hearing-response curve. This curve has no clinical value and should not be viewed by students as an indication of whether or not they have a hearing impairment. However, if a student has responses that are well outside the norm and is concerned, encourage him or her to see the school nurse, a doctor, or an audiologist. The purpose of this task is to explore the different sensitivities of the human ear to different pitches. If you or the students have not already calibrated the sound level of their computer as described in the Preparation section at the beginning of this activity, instruct them to do so now.

1. Give each student a copy of Master 3.4, Hearing Response.

2. Instruct students to start with the 62.5-Hz frequency and play the tone at the lowest setting for loudness. If they do not hear the tone, they should increase the loudness by clicking on a higher point on the vertical axis at that same frequency. They should continue this process until they find the loudness setting at which they can first hear the tone. Direct students to enter this loudness value in the appropriate space on Master 3.4, Hearing Response.

Note: the lowest frequency the students hear may be at 250 Hz, 125 Hz, or 62.5 Hz depending on the quality of the computer's sound card and speaker system.



How Your Brain Understands What Your Ear Hears

3. Students repeat this process for each of the higher frequencies by clicking on the lowest loudness setting and gradually increasing the volume. As before, they should record the loudness at which Content Standard A:

they first hear the tone. In the end, students will collect data repre-Use mathematics in all

senting the minimum relative loudness at which tones of various frequencies first can be heard.

aspects of scientific

inquiry.

Note: that at the two highest frequencies, students might hear a very short "squeak" initially. Instruct them to ignore this noise and listen for the loudness setting at which they hear a constant, high-pitched tone.

4. Direct students to plot their results on the graph template provided on Master 3.4, Hearing Response. You can use an overhead transparency of Master 3.4 to explain how to create the graph.

Student results will vary, although the shapes of their curves should be similar. The values on the y-axis are high at the lowest frequencies, drop for frequencies from 500 to 4,000 Hz, and slowly rise beginning around 8,000 Hz .

Figure 3.5. A sample hearing-response curve.

5. Instruct the students to answer the discussion questions on Master 3.4, Hearing Response.

Answers to questions on Master 3.4, Hearing Response, follow:

Question 1. At what frequencies is your hearing most sensitive? Circle

these frequencies on your graph.

Hearing is most sensitive at those frequencies for which sound can be detected at the lowest loudness levels. Human hearing is most sensitive at frequencies associated with human speech (between 250

and 4,000 Hz).

Question 2. As we get older or are repeatedly exposed to loud sounds,

we tend to lose hearing at higher frequencies. How might the hearing-

response curve change for an individual with high-pitched hearing

loss?

As hearing loss occurs, progressively louder sounds are required for higher-pitched sounds to be heard. The hearing-response curve for a person with high-pitched hearing loss would show a steeper curve on the part of the graph corresponding to high frequencies. Because louder sounds cause damage to hair cells, a mild hearing loss can lead to even greater hearing loss.

PART 3—HIGH-PITCHED HEARING LOSS

1. Explain to the class that they are now ready to investigate the effect of high-pitched hearing loss on the understanding of sounds.

Challenge students to predict how speech would sound if the high pitches are removed, or "filtered," from a sound file.

2. Explain that, as in the first lesson, students will again listen to someone reading the first sentence of President Lincoln's Gettysburg Address. Explain that the first reading will be an unfiltered version. (This is the same track used in Lesson 1 and labeled

"traditional.") The second reading has removed pitches above 4,000 Hz. The third reading has removed pitches above 2,000 Hz.

Instruct students not to change sound level settings while listening to the three recordings.

3. Have students proceed to http://science.education.nih.gov/supple-

ments/hearing/student and click on "Lesson 3—Do You Hear What I Hear?" Near the top of the screen, click on the link labeled "Filtered Sound." Have students play each of the three sound tracks in the following order: normal; filtered 4,000 Hz; and filtered 2,000

Hz.

4. After the students have had an opportunity to listen to the unfiltered and filtered sound tracks, reconvene the class and ask the students the following questions:

a. Which sound track might simulate how an older person with high-pitched hearing loss would hear the passage?

How Your Brain Understands What Your Ear Hears

Both the filtered 4,000-Hz and the filtered 2,000-Hz sound tracks simulate how a person with high-pitched hearing loss might hear the passage being read. The filtered 2,000-Hz sound track corresponds to a more severe hearing loss than does the filtered 4,000-Hz sound track.

b. Which sound track, filtered 4,000-Hz or filtered 2,000-Hz, is missing more pitches?

Pitches ranging from 2,000 Hz and above have been removed from the filtered 2,000-Hz sound track, while pitches ranging from 4,000 Hz and above have been removed from the filtered 4,000-Hz sound track. Therefore, the filtered 2,000-Hz sound track is missing pitches between 2,000 Hz and 4,000 Hz, which are present in the filtered 4,000-Hz sound track.

c. How does loudness change as the higher pitches are removed?

Loudness seems to decrease as pitches are removed.

d. How does your understanding of the words change as the higher pitches are removed?

Understanding becomes more difficult. Words seem to be less distinct. This is because some of the information provided by the sound has been lost.

e. How can a person compensate for such a hearing loss? What is the result of this compensation?

Assessment:

As hearing loss occurs, progressively louder sounds are required for Have students investi-hearing. An individual may turn up the volume on a television, gate the hearing

stereo, or radio or ask a speaker to talk louder. Students may have responses of another

noticed such behaviors exhibited by their grandparents or other animal such as a dog,

older adults. A person with such a hearing loss may elect to use a bat, or whale. Ask

hearing aid, which uses a microphone to collect and amplify sounds them to report on

coming into the ear. The hearing aid does not restore normal hearing their animal's hearing

but can greatly aid hearing and communication.

range and compare it

with that of humans.

Ask them to predict

how high-pitched

hearing loss might

affect the animal.

Lesson 3 Organizer

Activity 1: Measuring Intensity

What the Teacher Does

Procedure Reference

Ring a small bell and challenge the class to suggest ways of Page 77

making the bell ring louder.

Steps 1 and 2

Introduce the concept of the physical basis of loudness and Page 78

the decibel scale using Masters 3.1, The Decibel Scale, and Step 3

Master 3.2, Sound-Intensity Table.

Have the class complete Master 3.2, Sound-Intensity Table, Pages 78–79

and discuss their answers.

Steps 4 and 5

Instruct the class to answer the questions on Master 3.1, The Page 79

Decibel Scale.

Step 6

Discuss the relationship of loudness to human communication.

Page 79

• Ask why a sound may seem loud to one person but

Steps 7 and 8

not to another.

• Ask how sound intensity is used in human communication.

Activity 2: Pitch Me a Curve

What the Teacher Does

Procedure Reference

Ring the small bell again and challenge the class to suggest Page 80

ways of making the bell sound at a higher pitch.

Part 1, Step 1

Ask the class to distinguish between loudness and pitch and Pages 80–81

relate their answers to the concept of sound waves.

Part 1, Steps 2 and 3

Have students log onto the Web site and click on the button Page 81

labeled "Lesson 3—Do You Hear What I Hear?"

Part 1,

Steps 4 and 5

= Involves copying

= Involves using

= Involves using

a master.

a transparency.

the Internet.

Have students collect data on the relative loudness of

Page 82

sounds using the loudness-pitch square and Master 3.3,

Part 1,

Loudness and Pitch.

Step 6–10

Have students answer questions on Master 3.3, Loudness Pages 82–83

and Pitch.

Part 1, Step 11

Have students collect data on a hearing-response curve

Pages 83–84

using Master 3.4, Hearing Response.

Part 2, Steps

1–3

Have students plot their data and answer the questions on Pages 84–85

Master 3.4, Hearing Response.

Part 2, Steps 4 and 5

Challenge students to describe how speech would sound

Page 85

with high pitches removed.

Part 3, Step 1

Have students return to the Web site and play unfiltered and Page 85

filtered sound tracks.

Part 3, Steps

2 and 3

Reconvene the class and discuss the following questions:

Pages 85–86

• Which sound track might simulate how an older person

Part 3, Step 4

with high-pitched hearing loss would hear the passage?

• Which sound track, filtered 4,000-Hz or filtered

2,000-Hz, is missing more pitches?

• How does loudness change as the higher pitches are

removed?

• How does your understanding of the words change as

the higher pitches are removed?

• How can a person compensate for high-pitched hearing

loss?

• What is the result of this compensation?

The Decibel Scale

Name____

Date_____________________________

Imagine hearing the softest sound that you can possibly hear. Then imagine that this sound is made louder and louder until it is so loud, it is physically painful to hear it. How much louder do you think the loudest sound would be compared with the softest?

You may be surprised to learn that a painfully loud sound would be more than 16,384 times as intense as the softest sound. In other words, your ears can hear a range of sounds that increase from a sound intensity of 1 unit to an intensity of 100 trillion units. To think of it another way, you began life as a single cell. But by the time you reach adulthood, you'll be made of 100 trillion cells.

Because such an enormous range of numbers (from 1 to 100 trillion) can be difficult to work with, scientists have devised a special scale to use when measuring the intensity of sounds. This scale is called the decibel scale.

Study the patterns made by the numbers in the first two columns of the table on the next page. Then *fill in the missing numbers in the columns labeled "Sound Intensity" and "Decibels (dB)."*

Answer the questions below to learn more about the decibel scale.

1. How many times more intense is a sound of 30 dB than a sound of 20 dB? A sound of 40 dB than a sound of 20 dB?

2. How many times more intense is the sound of an alarm clock than a quiet room?

Master 3.1

Sound-Intensity Table

*Name*____

*Date*____________________________

Sound Intensity

Decibels (dB)

Sounds

1

0

just detectable

10

10

100

20

1,000

30

10,000

40

quiet room

normal conversation

alarm clock

rock concert (90–130 dB)

shout into ear at 20 cm

100,000,000,000,000

140

air raid siren

Master 3.2

Loudness and Pitch

*Name*____

*Date*___________________________

Enter the results of your investigation of the relative loudness of sounds at different pitches (frequencies) as measured in hertz (Hz).

Frequency

62.5 125 250 500 1,000

2,000

4,000

8,000

11,000

(Hz)

Relative

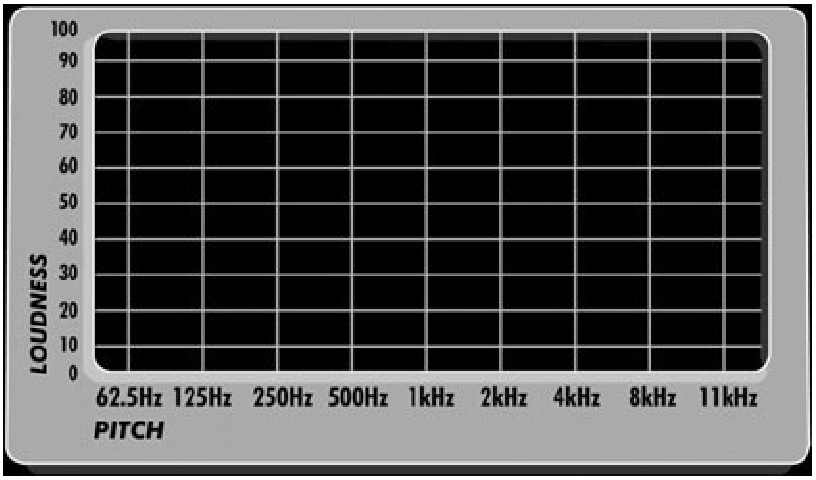
loudness

Discussion Questions

1. Did the sounds produced at each frequency seem equally loud? How did the loudness change with frequency?

2. Why did you hear variation in loudness with changing pitch?

Master 3.3



Hearing Response

Name____

Date_____________________________

Frequency

62.5 125 250 500

1,000

2,000

4,000

8,000

11,000

(Hz)

Loudness

Value on

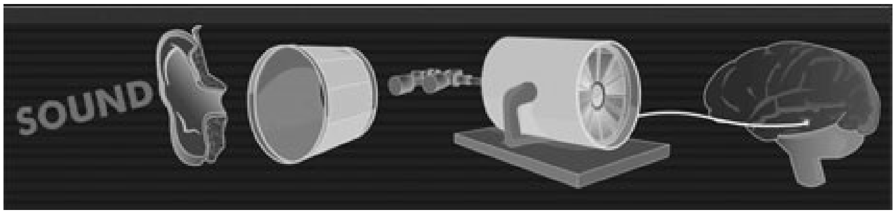
y-axis

Discussion Questions

1. At what frequencies is your hearing most sensitive? Circle these frequencies on your graph.

2. As we get older or are repeatedly exposed to loud sounds, we tend to lose hearing at higher frequencies. How might the hearing-response curve change for an individual with high-pitched hearing loss?

Master 3.4



Lesson 4

Elaborate

A Black Box Problem:

How Do I Hear?

Figure 4.1. Sound energy must be converted into a form that can be processed by the brain.

Overview

At a Glance

Students assemble a diagram of the hearing pathway using information about its parts and their functions, describe how sound is represented at various points along the pathway, and predict the changes in hearing that might result from specific changes to the pathway.

Major Concepts

The hearing pathway processes sound in a series of steps that involve different structures within the ear. Hearing requires the passage of vibrational energy from one medium to another, as well as its conversion to electrical energy in the form of nerve impulses. Transduction, which occurs in the cochlea, is the conversion of vibrational energy to electrical energy. Damage to specific parts of the hearing pathway results in predictable changes in hearing. The interpretation of what one hears occurs in the brain.

Objectives

After completing this lesson, students will

- *be able to describe the structure and function of the major parts of the hearing pathway,*

- *understand that hearing requires the conversion of vibrational energy to electrical energy,*

- *be able to describe changes in hearing associated with specific changes to the hearing pathway, and*

- *understand how technology can be used to compensate for hearing loss.*

Teacher Background

Consult the following sections in Information about Hearing, Communication, and Understanding:

3.4 Perception of sound has a biological basis (pages 32–38) 4.6 Cochlear implants (pages 40–41)

In Advance

Web-Based Activities

Activity

Web Version?

1

Yes

2

No

Photocopies

Activity 1

Master 4.1, The Mysterious Black Box (Prepare an overhead transparency.)

Master 4.2, A Few Questions (Prepare an overhead transparency.)

Master 4.3, Black Box Cards (Make 1 set of 8 cards per team for print version.)

Master 4.4, The Bell Card (Make 1 copy for print version.) Activity 2

Masters 4.5, Understanding Form and Function (Make 1

copy per team.)

Materials

Activity 1

a small bell

a lamp without a shade

a computer with Internet connection and sound card

Activity 2

no materials needed (except photocopies)

Preparation

Activity 1 (print version)

To prepare the Black Box Cards, make copies from Master 4.3 and cut the cards along the dotted lines.

Activity 2 (print version)

No preparations are needed except photocopying.

NSES

Activity 1: The Mysterious Black Box

Procedure

Teacher note

The following procedure describes how to conduct the Web-based version of this activity, the preferred form of instruction. Instructions for conducting the alternative print-based version follow the Web-based instructions.

1. Explain to the class that they will use a Web-based activity to explore the hearing pathway and the process by which it converts Content Standard A:

sound waves into signals that can be understood by the brain.

Think critically and log-

ically to make the rela-

If you feel that your students would benefit from a more extensive tionships between

introduction to the activity, consider having the class proceed evidence and explana-through Steps 1–4 from the print-based procedure (pages 96–98).

tions.

2. Explain to the class that they will view eight pictures, each representing a different part of the hearing pathway. As they position the Content Standard B:

cursor over each picture, they can read a brief description of that Energy is a property of

part's role in the hearing process. The students' task is to arrange many substances and

the pictures in their proper sequence in the hearing pathway.

is associated with

heat, light, electricity,

After students arrange the pictures in a sequence, they can test them-mechanical motion,

selves by clicking on the “Try it” button. If a mistake has been made, only those pictures that are in the correct order remain where they sound, nuclei, and the

are, while those that are incorrect move back to the starting position nature of a chemical.

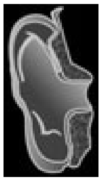
for the student to try again. When the correct sequence is assembled, the hearing pathway fades away and a cartoon animation appears.

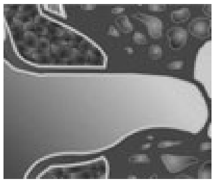
The animation shows how the sound is represented along the hearing pathway. A sound is heard only after the electrical impulse reaches the brain.

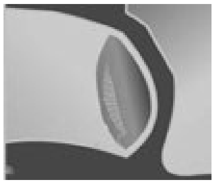
3. Instruct students to proceed to http://science.education.nih.gov/sup-

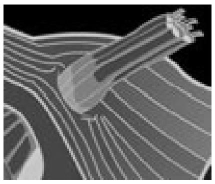
plements/hearing/student and click on “Lesson 4—A Black Box Problem: How Do I Hear?”

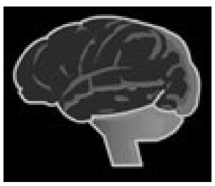
Students should pay particular attention to the introduction, which includes a cartoon that depicts how sound waves travel through the hearing pathway and introduces the term transduction. Transduction is the process by which sound is converted into a form that the brain can understand.











How Your Brain Understands What Your Ear Hears

Figure 4.2. The parts of the human hearing pathway in their proper sequence.

As students perform this activity, circulate around the room and ask each team to explain why they put the pictures in the order they did.

Alternate version of Activity 1 for classes

without access to computers:

1. Turn on the lamp and ask the class how the light bulb produces its light.

Student responses will vary. Direct the discussion to how electrical energy flows through a wire to the light bulb filament where light, as well as heat, is generated.

2. Write the word "transduction" on the board and explain that it refers to the process by which energy is converted from one form into another. Ask students if they can name other examples of transducers.

Students' examples may include flashlights, microphones, photocells, stereo speakers, engines, and other such devices. If no one mentions a biological system, ask the class if living things can transduce energy. Examples of biological transduction may include the process of photosynthesis, which converts light energy into chemical energy, or the process of respiration, which converts chemical energy into mechanical energy.

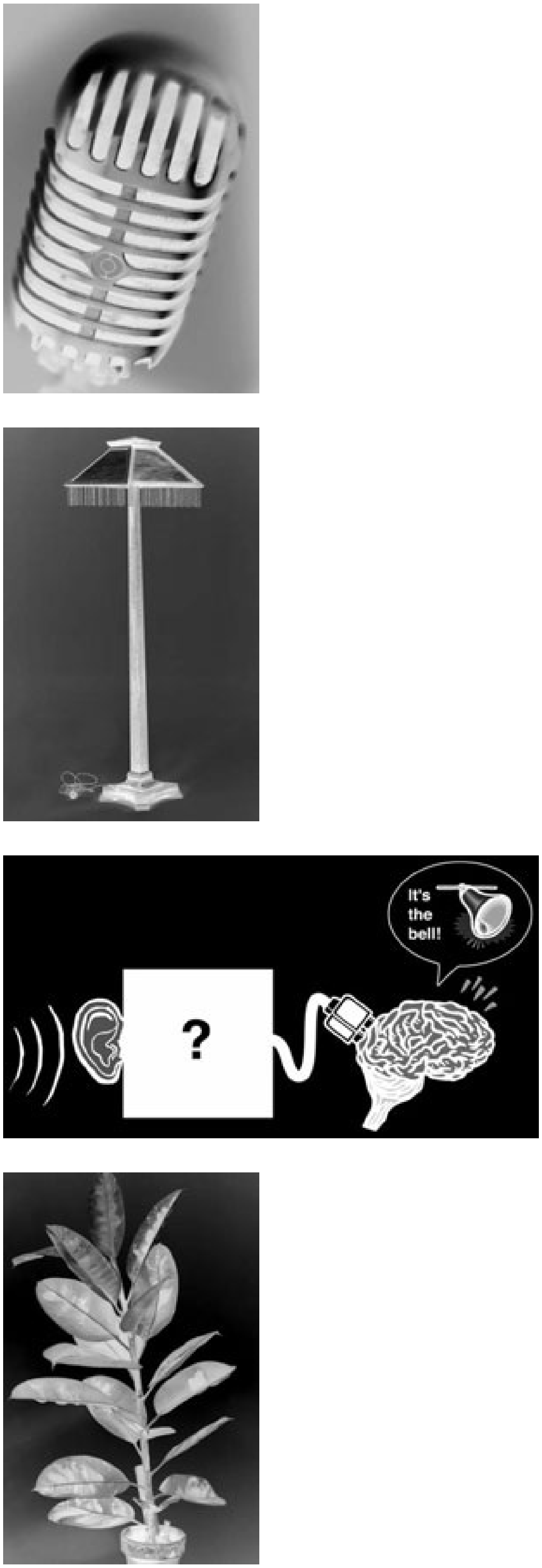


Figure 4.3. Examples of transducers.

3. Display an overhead transparency made from Master 4.1, The Mys-

terious Black Box. Ask students to describe the picture and to identify the question it raises.

Content Standard B:

Energy is a property of

many substances and

is associated with

heat, light, electricity,

mechanical motion,

sound, nuclei, and the

nature of a chemical.

Content Standard A:

Identify questions that

can be answered

Figure 4.4. The Mysterious Black Box.

through scientific

investigations.

Guide the discussion so that students ask a focused question pertain-ing to hearing, such as, "What happens inside the hearing pathway to allow sound to be heard in the brain?"

Ask students to rephrase the question to include the concept of transduction: "How is sound converted to a signal that the brain can understand?"

Students should understand that the black box represents the parts of the hearing pathway that they cannot see. You may wish to explain that scientists are often able to observe only the beginning of a process and its outcome but not the events that lead from one to the other. The challenge of the black box is to identify and describe all of the intermediate steps.

4. Display an overhead transparency made from Master 4.2, A Few

Questions. Uncover the questions one at a time as the discussion proceeds. Invite students to speculate as to what happens inside the black box of hearing.

Sample answers to Master 4.2, A Few Questions, follow:

Question 1. What do the lines between the bell and the ear indicate?

The lines depict sound waves (vibrational energy) moving from the bell to the ear.

Question 2. What is a sound wave?

A sound wave is a wave of vibrational energy (or a pressure wave) that moves through a medium such as air or water.

Question 3. Do vibrations reach all the way into the brain to let us

hear sound?

This question is analogous to the example of the lamp as a transducer. Just as light doesn't travel through wires to the light bulb, students should recognize that the actual vibrations do not travel to the brain. Instead, the ear converts the vibrational energy of sound into electrical energy, the energy of nervous impulses. To help students formulate this answer, you may wish to ask the analogous questions,

"Does the light that enters our eyes go all the way to the brain?" and

"When you touch someone's skin and they feel it, does the 'touch' go all the way to the brain?"

5. Explain that in this activity, students will construct a flow chart that shows what happens inside the black box of hearing. Hold up a set of Black Box Cards and explain that each team will receive a set of eight cards that provides information about the structures and functions of the hearing pathway.

Each card includes a picture of a part of the hearing pathway and a brief explanation of the part's function. The team's first challenge is to assemble the cards in the correct order so that the sound of the bell will be heard in the brain.

NSES

6. Organize the class into teams of two or three students. Distribute a set of Black Box Cards to each team. Announce that teams have 10

minutes to put the cards in the correct sequence. During that time, while students are working, you will circulate through the room with a "testing device" (hold up the large Bell Card and the bell).

Explain that when a team decides it has assembled the pictures in the proper order, you will use the device to test the sequence.

7. To test each team's pathway, give one team member the Bell Card and ask him or her to place it at the start of the flow chart. The Bell Card illustrates the vibrations produced as the bell rings. After the student puts the Bell Card in position, have the students explain what happens to the sound as it is transmitted through the Content Standard A:

hearing pathway. If the students' sequence of cards and explana-Think critically and log-

tion of events are correct, ring the bell to indicate that the impulse reached the brain, where it is interpreted. If the pathway is not cor-ically to make the rela-

rect, do not ring the bell and ask the team to try again.

tionships between

evidence and explana-

8. Write the names of the hearing-pathway components on the board tions.

as follows:

a. tympanic membrane (eardrum)

b. ossicles (bones of the middle ear)

c. pinna (outer ear)

d. cochlea

Assessment:

e. brain

As students perform

f. auditory nerve

this activity, circulate

g. organ of Corti (containing hair cells)

around the room and

h. ear canal

ask each team to

Instruct the teams to match the letter that corresponds to each explain why they put *component of the hearing system with its image.*

the pictures in the

order they did. If a

Figure 4.5 provides a visual guide for the correct order of Black Box team struggles to

Cards.

place the pictures in

the correct order, ask

As you review the functions of the components of the hearing path-the students various

way, draw attention to each part's name. After you have reviewed all eight components, introduce the terms "outer ear," "middle ear," and guiding questions to

"inner ear," and ask students to place these labels at the appropriate help them overcome

points in the sequence of pictures that depicts the hearing pathway.

their difficulties. If nec-

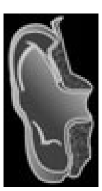
Ask students to name the parts of the hearing pathway that are not essary, point out to the

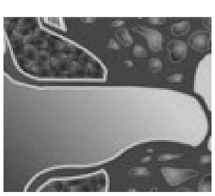
part of the ear, such as the auditory nerve and the brain.

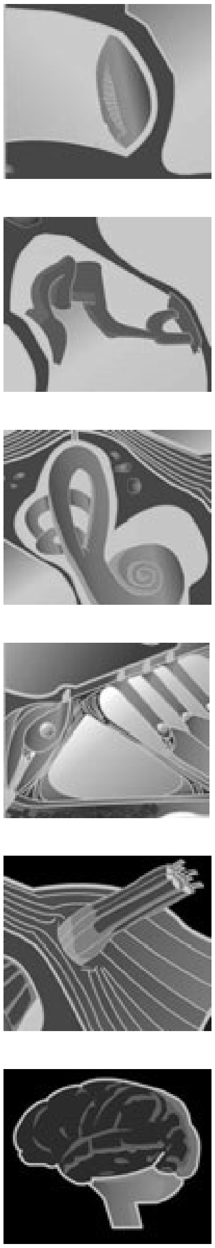
team that their

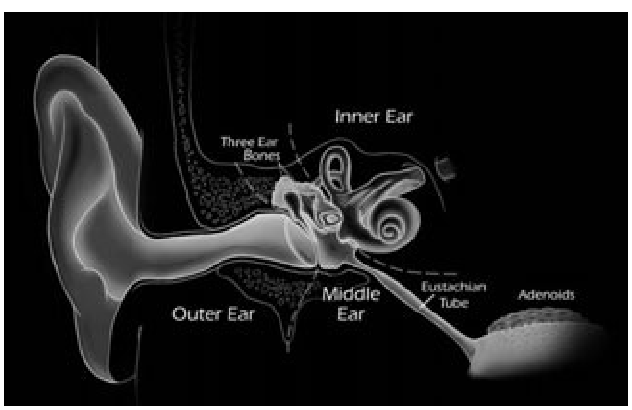
sequence is correct up

to a certain point.









How Your Brain Understands What Your Ear Hears

Figure 4.5. The Black Box Cards in their proper sequence.

Figure 4.6. The hearing pathway showing the outer, middle, and inner ear.

9. Before proceeding, construct the hearing pathway on the board so that students may refer to it while engaged in Activity 2.

Activity 2: Understanding Form and Function

1. Review transduction with the class. Make sure students understand that transduction is the conversion of energy from one form into another. Ask the class where in the hearing pathway transduction occurs.

Students may respond that transduction occurs either in the cochlea or in the organ of Corti. If there is confusion, help students understand that the organ of Corti is found within the cochlea. Explain how the hair cells are organized in the cochlea, how they detect the pressure waves moving through the cochlea, and how they trigger Content Standard C:

the formation of electrical impulses.

Living systems at all

levels of organization

demonstrate the com-

The following points provide information that will help you guide the plementary nature of

discussion.

• The cochlea is the hearing (as opposed to balance) part of the structure and function.

inner ear.

• When the bones of the middle ear (ossicles) vibrate in response to sound, they generate pressure waves in the fluid inside the cochlea.

• The organ of Corti, located within the cochlea, houses the hair cells that convert (transduce) sound from vibrational energy into electrical impulses.

• The base of the cochlea, near the ossicles, is stiff and narrow and responds to high-frequency sounds.

• The apex of the cochlea, away from the ossicles, is flexible and broad and responds to lower-frequency sounds.

2. To ensure that students understand how sound is represented at various points along the hearing pathway, write the terms "vibration," "pressure wave," and "electrical impulse" on the board. Ask students to use the terms to identify the form in which sound energy is represented at each of the eight points pictured.

• pinna

vibration

• ear canal

vibration

• eardrum

vibration

• ossicles

vibration

• cochlea

pressure wave

• organ of Corti

pressure wave

• auditory nerve

electrical impulse

• brain

electrical impulse

3. Distribute to each team 1 copy of Master 4.5, Understanding Form

and Function. Instruct team members to work together to complete the handouts.

These masters contain tasks related to the hearing pathway and the treatment of hearing loss. Students may find it helpful to refer to the Black Box sequence of the hearing pathway as they answer the 101

questions. In Part 2, if students have difficulty describing how hearing would be affected by the different situations, use probing questions to elicit answers.

Sample answers to tasks on Master 4.5, Understanding Form and Function, follow:

Part 1

Now that you have properly identified the ear’s transducer, write

“yes” beside each phrase that correctly describes one of its characteristics. Write “no” beside each phrase that does not.

yes

responds to pressure waves in a liquid

no

vibrates in response to sound waves

yes

converts vibrational energy to electrical energy

no

increases the force of vibrations inside the ear

yes

generates nervous impulses

yes

is located in the cochlea

Part 2

Use your understanding of the hearing pathway to predict the effect each of the following would have on hearing. Use the choices below for your answers.

For each of the following situations, hearing would

- ***be unaffected***

- ***gain loudness***

- ***lose loudness***

- ***lose information about pitch***

- ***be lost completely***

lose loudness

fingers blocking the ear canal

lose loudness

ruptured eardrum

be lost completely

cut the auditory nerve

lose loudness

link between the incus and stapes broken

lose loudness

buildup of ear wax

gain loudness

hand cupped behind the pinna

lose loudness and lose

damage to hair cells in the cochlea

information about pitch

lose information about

damage to part of the brain that processes

pitch or be lost

electrical impulses arriving from the cochlea

completely (depending

on location)

Part 3

Identify which statements refer to a hearing aid, which refer to a cochlear implant, or both.

a. It works as a transducer, converting vibrational energy to electrical (electrochemical and electromechanical) energy. Cochlear implant

b. It helps people whose hearing loss is caused by problems in the outer or middle ear. Hearing aid

c. It increases the vibrational energy entering the ear. Hearing aid d. It helps sounds bypass injured or absent hair cells. Cochlear implant

e. It helps people whose hearing loss is caused by problems in the inner ear. Cochlear implant

f. It can help profoundly deaf people communicate using sound.

Cochlear implant

Content Standard C:

4. Conclude the activity by reviewing students' answers to the tasks posed on Master 4.5. During the discussion, supplement the infor-Disease is a break-

mation students have already been given about the hearing path-down in structure or

way as appropriate.

function of an organ-

ism.

For example, students may be interested to learn that hair cells are unparalleled in their ability to detect the minute levels of vibrational energy in sound waves, and that they respond 1,000 times faster to stimulation than do visual-receptor cells.

Student Lesson 4

How Your Brain Understands What Your Ear Hears

Lesson 4 Organizer: Web Version

Activity 1: The Mysterious Black Box

What the Teacher Does

Procedure Reference

Introduce the concept of transduction as it relates to human Page 95

hearing and explain that they will complete a Web-based

Steps 1 and 2

activity about the hearing pathway.

Have students log onto Web site and click on "Lesson 4—A

Pages 95–96

Black Box problem: How Do I Hear?"

Step 3

• Instruct students to follow the directions and place the images of the hearing pathway in their proper sequence.

Activity 2: Understanding Form and Function

What the Teacher Does

Procedure Reference

Review the concept of transduction.

Pages 100–101

Step 1

Write the terms "vibration," "pressure wave," and "electrical Page 101

impulse" on the board and have the class apply them to each Step 2

part of the hearing pathway.

Have students complete the tasks on Master 4.5, Under-Pages 101–103

standing Form and Function.

Step 3

Review and discuss student responses to the tasks posed on Page 103

Master 4.5.

Step 4

= Involves using the Internet.

= Involves copying a master.

Lesson 4 Organizer: Print Version

Activity 1: The Mysterious Black Box

What the Teacher Does

Procedure Reference

Turn on a lamp and ask how the light bulb produces light.

Page 96

Step 1

Write “transduction” on the board.

Page 96

• Explain that it refers to the process by which energy is Step 2

converted from one form to another.

• Ask students if they can name other examples of

transducers.

Display a transparency of Master 4.1, The Mysterious Black Pages 97–98

Box.

Step 3

• Ask students to identify the question it raises.

Display a transparency of Master 4.2, A Few Questions.

Page 98

• Ask students to answer the questions.

Step 4

Explain that students will use Black Box Cards to construct a Page 98

flow chart of the hearing pathway.

Step 5

Distribute Black Box Cards (from Master 4.3) to each stu-

Page 99

dent team and instruct them to put the cards into the cor-Step 6

rect sequence.

Test each student team's card sequence.

Page 99

• Have each team explain their sequence.

Step 7

• If the sequence is correct ring the bell.

= Involves using a transparency.

= Involves copying a master.

105

Student Lesson 4

How Your Brain Understands What Your Ear Hears

Write the names of the hearing-pathway components on the

Pages 99–100

board.

Step 8

• Have students match the names with the images on

their cards.

Construct the hearing pathway on the board.

Page 100

Step 9

Activity 2: Understanding Form and Function

What the Teacher Does

Procedure Reference

Review the concept of transduction.

Pages 100–101

Step 1

Write the terms “vibration,” “pressure wave,” and “electrical Page 101

impulse” on the board and have the class apply them to

Step 2

each part of the hearing pathway.

Have students complete the tasks on Master 4.5, Under-Pages 101–103

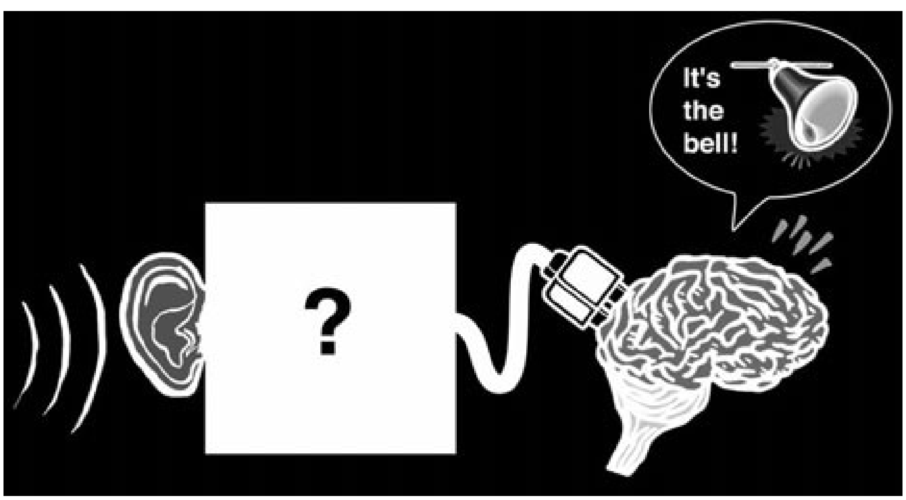
standing Form and Function.

Step 3

Review and discuss student responses to the tasks posed on Page 103

Master 4.5.

Step 4



The Mysterious Black Box

Master 4.1

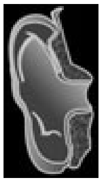
A Few Questions

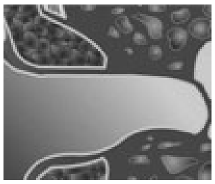
1. What do the lines between the bell and the ear indicate?

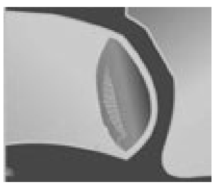
2. What is a sound wave?

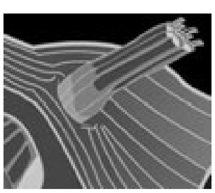
3. Do vibrations reach all the way into the brain to let us hear sound?

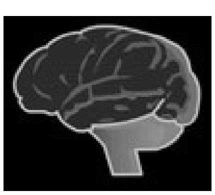
Master 4.2











Black Box Cards

Focuses sound waves; helps in determining

Conducts sound waves to the eardrum.

the direction from which sound waves arrive.

System of bones that works as a lever system

Vibrates in response to arriving sound waves.

to transmit vibrations deeper into the ear and

to increase the vibrations' force.

Tiny hairlike extensions on the cells in this

structure move in response to pressure waves

Liquid inside this structure transmits pres-

in surrounding liquid, causing cells to make

sure waves in response to vibrations.

generate electrical impulses that vary accord-

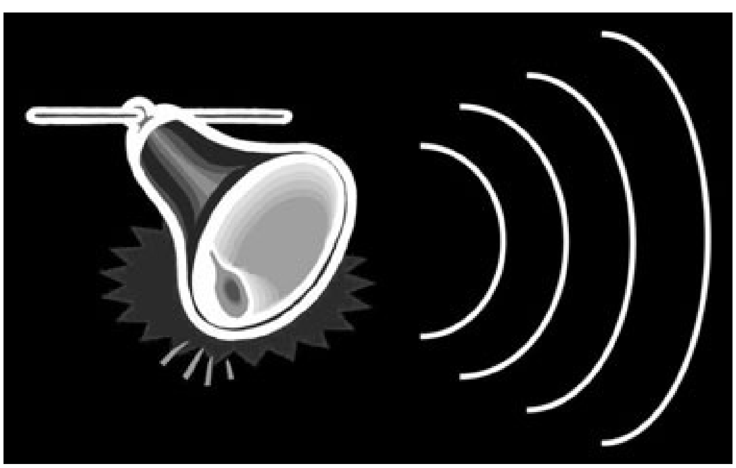
ing to the waves' amplitude and frequency.

Interprets electrical impulses as sounds of

Carries electrical impulses to the brain.

varying pitch, loudness, and timing.

Master 4.3



The Bell Card

Master 4.4

Understanding Form and Function

*Name(s)*____

*Date*___________________________

Part 1

Now that you have properly identified the ear's transducer, write "yes" beside each phrase that correctly describes one of its characteristics. Write "no" beside each phrase that does not.

_____ responds to pressure waves in a liquid

_____ vibrates in response to sound waves

_____ converts vibrational energy to electrical energy

_____ increases the force of vibrations inside the ear

_____ generates nervous impulses

_____ is located in the cochlea

Part 2

Use your understanding of the hearing pathway to predict the effect each of the following would have on hearing. Use the choices below for your answers.

For each of the following situations, hearing would

- ***be unaffected***
- ***gain loudness***
- ***lose loudness***
- ***lose information about pitch***
- ***be lost completely***

____

fingers blocking the ear canal

____

ruptured eardrum

____

cut the auditory nerve

____

link between the incus and stapes broken

____

buildup of ear wax

____

hand cupped behind the pinna

____

damage to hair cells in the cochlea

____

damage to part of the brain that processes electrical impulses arriving from the cochlea

Master 4.5a

Understanding Form and Function

Part 3

People with hearing loss can sometimes be helped by technology. The two most common devices used by people with hearing loss are hearing aids and cochlear implants.

A hearing aid uses a small microphone to collect sound, which is then amplified as an electrical signal that is reconverted to sound using a small loudspeaker.

A cochlear implant uses a small microphone to collect sound, which is then electronically processed into a form that the brain can interpret. The information is then transmitted through a collection of electrodes.

Identify which statements refer to a hearing aid, which refer to a cochlear implant, or both.

a. It works as a transducer, converting vibrational energy to electrical (electrochemical and electromechanical) energy. __________

b. It helps people whose hearing loss is caused by problems in the outer or middle ear.

____

c. It increases the vibrational energy entering the ear. __________

d. It helps sounds bypass injured or absent hair cells. __________

e. It helps people whose hearing loss is caused by problems in the inner ear.

____

f. It can help profoundly deaf people communicate using sound. __________

Master 4.5b

Lesson 5

Elaborate/

Evaluate

Too Loud,

oo Loud,

Too Close,

oo Close,

Too Long

Figure 5.1. Sounds can be too loud, too close, and too long.

Overview

At a Glance

Students begin with an analysis of loudness. They estimate the loudness of common environmental sounds, and then use their knowledge of hearing and loudness to evaluate the risk of noise-induced hearing loss for fictitious individuals. The module concludes with students evaluating their own sound exposure and providing "sound advice" to minimize their risk of noise-induced hearing loss.

Major Concepts

Noise-induced hearing loss leads to an inability to hear and understand speech and other sounds at normal loudness levels. Noise-induced hearing loss can be temporary or permanent. Noise-induced *hearing loss can result from a one-time exposure to an extremely loud sound, repeated or long-term exposure to loud sound, or extended exposure to moderate sound.*

Noise-induced hearing loss can happen to people of all ages. The best way to protect one's hearing is to avoid loud noise whenever possible.

113

How Your Brain Understands What Your Ear Hears

Objectives

After completing this lesson, students will

- *be able to define noise-induced hearing loss as a diminished ability to hear and understand speech and other sounds at normal loudness levels resulting from exposure to loud noise;*
- *understand that noise-induced hearing loss can be temporary or permanent;*
- *recognize that people are vulnerable to noise-induced hearing loss if they are exposed to noise that is too loud, if they are too close to the source of noise, or if they are exposed to noise for an extended period of time;*
- *understand that noise-induced hearing loss can happen to people of all ages; and*
- *appreciate that noise-induced hearing loss is preventable and that the best way to protect one's hearing is to avoid loud noise whenever possible.*

Teacher Background

Consult the following sections in Information about Hearing, Communication, and Understanding:

4 Hearing Loss (page 38)

4.1 Noise exposure (pages 38–39)

4.2 Aging (page 39)

4.3 Ototoxic drugs (page 39)

4.4 Disease and infections (pages 39–40)

4.5 Heredity (page 40)

4.6 Cochlear implants (pages 40–41)

5 Prevention of Noise-Induced Hearing Loss (pages 41–42) In Advance

Web-Based Activities

Activity

Web Version?

1

No

2

No

3

No

114

Photocopies

Activity 1

Master 5.1, Electron Micrographs of Hair Cells (Make 1 copy per student.)

Master 5.2 , Loud, Louder, and Loudest (Make 1 copy per student.)

Master 5.3, Answer Key to Loud, Louder, and Loudest (Make an overhead transparency.)

Master 5.4, Dangerous Sound Levels (Make an overhead transparency.)

Activity 2

Master 5.5, Some Everyday Sounds (Make 1 copy per student.)

Master 5.6, Sound Diary Summary—Joe, the Guitarist

(Make 1 copy per team.)

Master 5.7, Sound Diary Summary—Maria, the Woodworker (Make 1 copy per team.)

Master 5.8, Sound Diary Summary—Michael, the Land-

scaper (Make 1 copy per team.)

Master 5.9, Sound Diary Summary—George, the Firefighter (Make 1 copy per team.)

Master 5.10, Hearing-Risk Evaluation Form (Make 1 copy per student.)

Master 5.11, Ten Ways to Recognize Hearing Loss (Optional: Make 1 copy per student.)

Activity 3

No photocopies needed.

Materials

Activity 1

no materials needed (except photocopies)

Activity 2

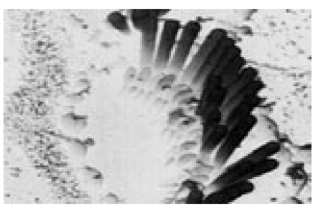
no materials needed (except photocopies)

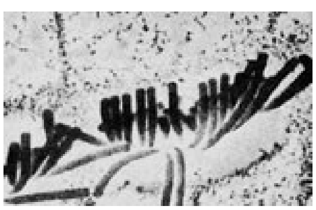
Activity 3

no materials needed

Preparation

No preparations needed (except photocopying).





How Your Brain Understands What Your Ear Hears

Procedure

Teacher note

The sound levels at which hearing damage occurs (often reported by different sources as 80 dB or 85 dB) is not precise for every individual. We know that prolonged exposure (that is, over many years) to sounds over 85 dB, especially in work settings, does cause damage. Because some sources do cite exposures at 80 dB and lower, it is important for students to think about these numbers as a frame of reference for prevention awareness.

They absolutely need to understand the permanent and irreversible damage caused by such things as *exploding firecrackers, guns, and jackhammers.*

Activity 1: It's Too Loud!

1. Review with the class the components of the hearing pathway introduced in Lesson 4. Be sure that students recall the function of the hair cells in the organ of Corti.

2. Begin the activity by having students proceed to http://science.

education.nih.gov/supplements/hearing/student. Students should then click on the button labeled "Lesson 5—Too Loud, Too Close, Too Long" and then on "watch video."

3. After students view the video of the hair cells, give each student a copy of Master 5.1, Electron Micrographs of Hair Cells. Ask students if they can tell which picture shows healthy hair cells and which shows damaged ones. Ask them to explain their reasoning.

Figure 5.2. Healthy hair cells (left) and damaged hair cells (right). Diameter of hair cells is approximately 10 µm (micrometers). (One micrometer is one-millionth of a meter.) Diameter of one stereocilium is approximately 250 nm (nanometers). (One nanometer is one-billionth of a meter.) For a video clip of the magnified version of healthy hair cells, go to this Web site: http://science.education.nih.gov/supplements/hearing/student and click on the button labeled "Lesson 5—Too Loud, Too Close, Too Long"

NSES

Students should be able to recognize that the left-hand micrograph shows healthy hair cells. Healthy hair bundles (stereocilia) stand nearly straight up, while the micrograph featuring the unhealthy hair cells shows some damaged stereocilia lying down flat.

4. Ask the class what might have caused the hair cells in the right-hand picture to become damaged.

Responses may include a disease (either genetic or infectious), an injury, or exposure to hazardous chemicals. If no one suggests loud noise as a possible cause, turn the discussion to that topic. Explain that the hair cells in the right-hand micrograph were damaged by exposure to loud noise.

5. Ask the class to name some loud sounds.

Accept any reasonable answer. Possibilities include the sounds of airplane engines, power tools, rock concerts, car horns, and music played through stereo headphones.

Content Standard C:

Living systems at all

6. Ask students what is meant by a sound that is "too loud" and levels of organization whether everyone's definition of "too loud" is the same.

demonstrate the com-

plementary nature of

Students likely will answer that a sound is too loud if it hurts or damages a person's ears or disturbs another person. Students should structure and function.

recognize that the phrase "too loud" is commonly used, and its definition varies greatly from person to person and situation to situation.

To stimulate discussion, you may wish to invite several students to offer examples of situations in which their definition of "too loud"

was very different from another person's definition.

7. Ask students what might happen if a person is exposed to very loud sounds.

Sound that is too loud can permanently damage hearing, leading, for example, to difficulties in understanding speech and enjoying music.

Scientists refer to such damage as noise-induced hearing loss.

8. Explain that in this lesson, students will investigate the relationship between loudness and hearing loss.

9. Distribute 1 copy of Master 5.2, Loud, Louder, and Loudest, to each student. Direct students to follow the instructions on the worksheet to identify each sound as typically low- or high-pitched and also to rank the sounds in each list from softest to loudest.

Give students approximately five minutes to complete this task.

How Your Brain Understands What Your Ear Hears

10. Display a transparency made from Master 5.3, Answer Key to Loud,

Louder, and Loudest, and invite students to compare their rankings with those on the transparency. Invite students to share differences between their ranking and the ranking on the transparency. Discuss the possible reasons for these differences.

Answers will vary. For example, students may make different assumptions based on the distance from which the sound is heard.

Students will also display variation in their interpretation of terms (for example, differences in what people call a "quiet" neighborhood).

11. Make sure students notice the number that describes the difference in sound intensity between the loudest sound a healthy human ear can tolerate and the softest sound the human ear can hear. (The difference, 100 trillion times, appears in the footnote at the bottom of the answer key on Master 5.3.)

Students may be surprised to learn that the normal, undamaged human ear has such a wide range of hearing.

12. Ask students to estimate where on the table some of the sounds to which they are commonly exposed might fall. For example, ask them where the following sounds might appear on the table: the school cafeteria during lunch, the sound in the halls between periods, the sound in the classroom during a test, and the sound going into their ears when they're listening to music using headphones.

As an option, you can task students with using an inexpensive sound meter to record actual sound levels in their environment. Sound meters can be purchased from some electronics stores for as little as $35. If you are going to use a decibel meter, remember to set it on the A setting. The A scale reduces the less harmful low-frequency sounds, emphasizing the higher-frequency sounds that are most harmful to hearing.

13. Ask students to speculate whether low- or high-pitched sounds are more likely to produce noise-induced hearing loss.

The hearing pathway is more sensitive to higher-pitched frequencies.

This means that high-pitched sounds can produce more damage at lower volumes than low-pitched sounds can. If necessary, remind students that in Lesson 3, Do You Hear What I Hear? , they demon-

Figure 5.3. An inexpen-

strated that higher-pitched sounds could be heard more easily at sive sound meter.

lower sound volumes.

14. Ask students if there are factors other than loudness and pitch that contribute to noise-induced hearing loss. If necessary, prompt them to consider the length of time for which they are exposed to sound.

On the board, write

• Single exposure to a very loud sound

• Repeated or long-term exposure to loud sound

• Extended exposure to moderate sound levels

15. Ask students to offer examples of sounds and exposure lengths that might produce noise-induced hearing loss for each category listed on the board.

Students can refer to Master 5.3, Answer Key to Loud, Louder, and Loudest, to help them think of examples. Help students recognize that the noises that have the highest potential for noise-induced hearing loss are listed toward the top of Master 5.3. Ask students to distinguish situations in which even a single exposure would likely produce noise-induced hearing loss, situations in which repeated or long-term exposure might produce noise-induced hearing loss, and situations in which constant exposure may lead to noise-induced hearing loss.

16. Display a transparency of Master 5.4, Dangerous Sound Levels, and point out the various decibel levels and exposure times that scientists consider to be hazardous. Ask students to describe the differences between their assessments and the assessments of the scientists.

17. Ask the class to think of ways to lower the risk for noise-induced hearing loss.

Students will suggest using some type of ear protection such as earplugs. They also may suggest reducing the noise level either by turning the volume down or moving farther away from the noise Content Standard F:

source.

The potential for acci-

dents and the exis-

tence of hazards

Activity 2: Assessing Risk for Hearing Loss

imposes the need for

injury prevention.

1. Explain to the class that they will evaluate the risk for noise-induced hearing loss in fictitious individuals. Distribute 1 copy of Master 5.5, Some Everyday Sounds, to each student and explain that it lists loudness levels for some everyday sounds.

How Your Brain Understands What Your Ear Hears

2. Organize students into teams of four. Provide each team with 1

copy of Masters 5.6, 5.7, 5.8, and 5.9, which contain sound diaries summarizing the sound exposure for different fictitious individuals. Instruct team members to individually pick a different person and analyze the sound diary for that individual.

Explain that:

• Each team should use the information on Master 5.4, Dangerous Sound Levels (from the previous activity); Master 5.5, Some Everyday Sounds; and the information about their fictitious individuals to fill in the columns labeled "Estimated dB level" and "Suggestions for lowering risk of hearing loss."

• Some of the activities that appear in the individual's sound diary are not specifically listed in Master 5.5, Some Everyday Sounds.

Therefore, instruct students to make estimates about the loudness of unlisted sounds where necessary. They can use the column labeled "Comments" to indicate reasons for their choice of a particular dB level.

• After students have finished their analysis, they can exchange their summaries, discuss their reasoning with each other, and modify the summaries as needed.

• After the sound-diary summaries are completed, distribute copies of Master 5.10, Hearing-Risk Evaluation Form. Teams should place Content Standard F:

a checkmark next to the risk statement that they believe charac-Students should

terizes each of their fictitious individuals. Students should also understand the risks

justify their evaluations based on the information found in the sound diaries.

associated with per-

sonal hazards.

3. After teams have completed their evaluations, convene the class and invite teams to discuss their work.

Content Standard F:

Important personal

Although different teams may associate different dB levels with var-and social decisions

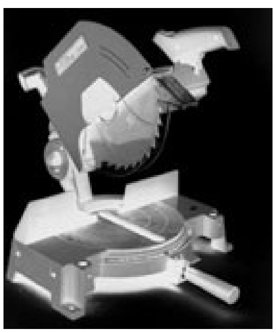
ious activities, their evaluations should be similar. All four of the are made based on

fictitious individuals are at risk for hearing loss for the following reasons:

the perception of ben-

efits and risks.

120



Joe, the guitarist: Joe is exposed to sound

levels above 80 dB on a constant and pro-

longed basis. His exposure to loud sounds

is primarily through his occupation as a

musician. Using earplugs would eliminate *his risk for noise-induced hearing loss. His long freeway commute and his frequent pit stops for food may also provide constant exposure to sounds in the higher-risk range. When listening to music or watching TV, Joe should set the sound volume to an appropriately low level.*

Figure 5.4. Joe’s guitar.

Maria, the woodworker: Maria is exposed to sound levels above 80 dB on a constant and prolonged basis. Her exposure to loud noise is primarily through her occupational use of power tools. Using earplugs would eliminate her risk for noise-induced hearing loss. Also of concern is her use of a personal stereo for listening to music. She should ensure that the volume is kept at an appropriately low setting.

Figure 5.5. Maria’s power saw.

Michael, the landscaper: Michael also is exposed to sound levels above 80 dB on a constant and prolonged basis. His exposure to loud sounds is principally *through his occupational use of lawn mowers and a chain saw. Using earplugs would eliminate his risk for noise-induced hearing loss. While at home, he should keep the TV sound volume at an appropriately low level. Students might remark about his exposure to loud noise from the occasional screaming of his two-year-old twins. Sometimes there are*

Figure 5.6. Michael's chain saw.

sounds that you just have to cope with.

How Your Brain Understands What Your Ear Hears

George, the firefighter:

George is exposed to sound levels above 80 dB on a constant and prolonged basis. His expo-

sure to loud noise is

primarily through his

occupational use of a

farm tractor and his con-

tact with sirens and other

loud noises in his role as

a firefighter. Using

earplugs would eliminate

his risk for noise-induced

Figure 5.7. George's tractor.

hearing loss. His remodel-

ing work involves the use of power tools. Earplugs should be used to eliminate exposure to hazardous sound from these sources as well. When listening to music or watching TV, the sound volume should be set at an appropriately low level.

Activity 3: Sound Advice

1. Close the lesson by asking students to consider the implications of what they have learned on their own lives. Ask them to identify Content Standard A:

sounds that they are exposed to that might be classified as "too Students should

loud."

develop descriptions,

explanations, predic-

2. Ask students to consider sounds they might be exposed to on tions, and models

weekends and during vacation periods. Are there any sounds that using evidence.

might be considered too loud or potentially hazardous?

3. To help students think about how to protect themselves, you may wish to draw their attention to the title of the lesson. Write the phrase Too Loud, Too Close, Too Long on the board. Ask the class to explain how it relates to noise-induced hearing loss.

4. As a means of wrapping up this module, ask each student to write a statement to include the *following:*

a. sounds they are exposed to that might put them at risk for noise-induced hearing loss and why they think those sounds put them at risk, and

b. advice to themselves about what they can do to reduce their risk for hearing loss.

122

Possibilities include limiting the volume on radios, TVs, and personal music players; avoiding loud noises from tools, appliances, and traffic; increasing distance from the source of loud noises one can't avoid; wearing hearing protection when necessary; limiting exposure to loud sounds; and watching for and responding to warning signs that a sound is too loud.

5. (Optional) Supply students with a copy of Master 5.11, Ten Ways

to Recognize Hearing Loss.

Assessment:

Ask students to

include information

about parts of the

hearing pathway that

are susceptible to

damage from noise-

induced hearing loss.

Also, ask students to

describe how such

hearing loss might

impact their everyday

lives.

123

Student Lesson 5

How Your Brain Understands What Your Ear Hears

Lesson 5 Organizer

Activity 1: It's Too Loud

What the Teacher Does

Procedure Reference

Review the parts of the hearing pathway.

Page 116

Step 1

Have students log onto Web site and click on "Lesson 5—Too Page 116

Loud, Too Close, Too Long."

Step 2

• Students view video of hair cells.

Distribute Master 5.1, Electron Micrographs of Hair Cells.

Pages

Ask students to identify which are healthy and which are

116–117

damaged, and speculate about what caused the damage.

Steps 3 and 4

Discuss loud sounds. Ask the students,

Page 117

• Can they name some loud sounds?

Steps 5–7

• What is "too loud"?

• Is everyone's idea of "too loud" the same?

• What happens when a person is exposed to sounds that

are too loud?

Investigate the relationship between loudness and hearing loss. Page 117

• Have students identify sounds on Master 5.2, Loud,

Steps 8 and 9

Louder, and Loudest, as low- or high-pitched.

• Rank the sounds from softest to loudest.

Have the class compare and contrast their sound rankings

Page 118

with those on Master 5.3, Answer Key to Loud, Louder, and Step 10

Loudest.

= Involves using

= Involves copying

= Involves using

the Internet.

a master.

a transparency.

124

Make sure that students notice the difference in sound inten-Page 118

sity between the softest and loudest sounds a human can

Step 11

hear without damage.

Ask the class to estimate the loudness of some common

Page 118

sounds.

Step 12

Introduce the concept of noise-induced hearing loss.

Pages 118–119

• Ask the class whether low- or high-pitched sounds are

Steps 13–15

more likely to produce noise-induced hearing loss.

• Have students consider how the duration of noise expo-

sure is associated with noise-induced hearing loss.

• Ask for examples of each type of noise exposure.

Have the class compare their responses with those from

Page 119

scientists using Master 5.4, Dangerous Sound Levels.

Step 16

Ask the class to suggest ways to lower risk for noise-induced Page 119

hearing loss.

Step 17

Activity 2: Assessing Risk for Hearing Loss

What the Teacher Does

Procedure Reference

Organize the class into teams of four students.

Pages 119–120

• Distribute Master 5.5, Some Everyday Sounds, to each Steps 1 and 2

student.

• Provide teams with sound diaries from different ficti-

tious individuals (Masters 5.6, 5.7, 5.8, and 5.9).

• Have teams analyze sound-level exposures for their individual and identify sounds that put them at risk for

noise-induced hearing loss using Master 5.10, Hearing-Risk Evaluation Form.

Reconvene class and have teams report their conclusions.

Page 120

Step 3

Activity 3: Sound Advice

What the Teacher Does

Procedure Reference

Ask the class to list some sounds that they are exposed to Page 122

that might be considered potentially hazardous.

Steps 1 and 2

Ask the class to relate noise-induced hearing loss to the Page 122

phrase "too loud, too close, too long."

Step 3

Ask students to write statements

Pages 122–123

• that identify sounds they are exposed to that might put Step 4

them at risk for noise-induced hearing loss.

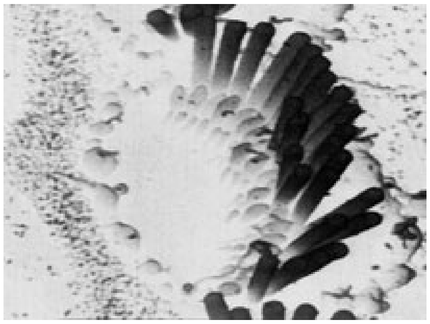
• that list ways they can reduce their risk for noise-

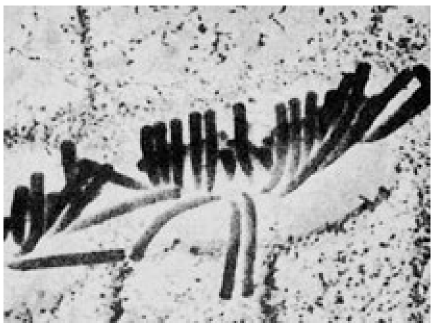
induced hearing loss.

(Optional) Discuss ways to recognize hearing loss using

Page 123

Master 5.11, Ten Ways to Recognize Hearing Loss.





Electron Micrographs of Hair Cells

Healthy hair cells (left) and damaged hair cells (right). Diameter of hair cells is approximately 10 µm (micrometers). (One micrometer is one-millionth of a meter.) Diameter of one stereocilium is approximately 250 nm (nanometers). (One nanometer is one-billionth of a meter.) For a video clip of the magnified version of healthy hair cells, go to this Web site: http://science.education.nih.gov/supplements/

hearing/student and click on the button labeled "Lesson 5—Too Loud, Too Close, Too Long."

Master 5.1

Loud, Louder, and Loudest

Name____

Date______________________________

Approximately how loud are the sounds listed below? Write each sound where you think it belongs on the page. Two sounds are provided as examples.

jet plane during takeoff, lawn mower, waterfall (at the base), large 18-wheel truck, quiet neighborhood, train, third row at an amplified rock concert, car horn, your living room at home, low whisper, electric vacuum cleaner, fire siren, traffic at a busy intersection

Sound Intensity (dB)

Type of Sound

140 (very painful)

130

120 (painful)

110

chain saw

100

90 (extremely loud)

80

70 (very loud)

60

50 (moderate)

40

30

low whisper

20

10

0 (softest sound humans can hear)

Master 5.2

Answer Key to Loud, Louder, and Loudest

Sound Intensity (dB)

Type of Sound

140 (very painful)*

jet plane during takeoff, fire siren

130

third row at an amplified rock concert

120 (painful)

110

chain saw

100

90 (extremely loud)

traffic at a busy intersection, waterfall (at its base)

train, lawn mower

80

18-wheel truck

70 (very loud)

electric vacuum cleaner

60

living room at home

50 (moderate)

car horn

40

quiet neighborhood

30

low whisper

20

10

0 (softest sound humans can hear)

**140 decibels (dB) is 100,000,000,000,000 (or 100 trillion) times more intense than 0 dB.*

Master 5.3

Dangerous Sound Levels

dB

Type of Sound

140

Threshold of pain

130

Threshold of pain

120

Threshold of pain

110

Regular exposure of more than 1 minute risks permanent hearing loss.

100

No more than 15 minutes of exposure is recommended.

90

Prolonged exposure to any noise above 90 dB can cause gradual hearing loss.

Level at which hearing damage after 8 hours exposure begins: 85 dB.

80

Constant exposure may cause damage.

70

60

Comfortable: under 60 dB

50

40

30

20

10

0

Master 5.4

Some Everyday Sounds

Sound

dB level

Sound

dB level

hearing threshold

0

table saw

95

breathing

10

hand drill

100

rustling leaves

20

tractor

100

whispering

25

diesel truck

100

library 30

circular saw

100

refrigerator

45

jackhammer

100

average home

50

gas-powered mower

105

normal conversation

60

helicopter

105

clothes dryer

60

chain saw

110

washing machine

65

amplified rock concert

90–130

car

70

shout into ear

120

vacuum cleaner

70

car horn

120

busy traffic

75

siren

120

noisy restaurant

80

threshold of pain

120–140

outboard motor

80

gunshot

140

inside car in city traffic

85

jet engine

140

electric shaver

85

12-gauge shotgun

165

screaming child

90

rocket launching

180

passing motorcycle

90

convertible ride on highway

95

Master 5.5

Sound Diary Summary—Joe, the Guitarist

Name(s)_______________________________________

Date_____________________________

Joe is 20 years old, and he has been the lead guitarist in a rock band for four years. The group is doing well; they rehearse a lot and play at local clubs on weekends. Joe commutes on busy freeways quite a bit. He is single and likes his quiet life at home but still enjoys the fast pace of the big city when he's there.

Use Some Everyday Sounds and the table below to analyze Joe's exposure to sound. Enter an estimated dB level for each sound listed in the first column. Where appropriate, indicate how the risk of hearing loss might be lowered. In the right column, enter any information that explains your dB estimates. For example, your choice of a dB level for eating lunch assumes either a quiet or a noisy environment.

Source of sound

Time per week Estimated

Suggestions for

Comments

(major activities)

(minutes)

dB level

lowering risk

of hearing loss

morning activities

210

breakfast at home

140

freeway commute

300

to/from work

morning rehearsal

900

lunch at restaurant

420

lunch at home

120

afternoon rehearsal

1020

dinner at restaurant

600

dinner at home

120

gigs at local night spots

480

listening to music

1300

watching TV

480

reading

120

Master 5.6

Sound Diary Summary—Maria, the Woodworker

Name(s)____

Date_____________________________

Maria is 19 years old and single. Her father, a master craftsman, introduced her to tools and woodwork-ing when she was in elementary school. She now works for a small business, designing and construct-ing cabinets and other fine wood products for the home. She lives in a small town and has a very short drive to work.

Use Some Everyday Sounds and the table below to analyze Maria's exposure to sound. Enter an estimated dB level for each sound listed in the first column. Where appropriate, indicate how the risk of hearing loss might be lowered. In the right column, enter any information that explains your dB estimates. For example, your choice of a dB level for eating lunch assumes either a quiet or a noisy environment.

Source of sound

Time per week Estimated

Suggestions for

Comments

(major activities)

(minutes)

dB level

lowering risk

of hearing loss

morning activities

315

breakfast at home

150

commute to/from work

50

working in office

900

designing projects

using power tools

1500

to make cabinets

lunch in office

300

lunch at home

120

dinner at home

420

college night classes

600

listening to rock music

900

on Walkman

watching TV

600

reading

850

Master 5.7

Sound Diary Summary—Michael, the Landscaper

Name(s)____

Date___________________________

Michael is 26 years old, a graduate of a local college, and the owner of his own landscaping and lawn-care service. He is married and the father of two-year-old twins. He drives a large pickup truck, which pulls a trailer containing his mowers, chain saw, shovels, and other equipment for work. Business is good, and he has many clients around town.

Use Some Everyday Sounds and the table below to analyze Michael's exposure to sound. Enter an estimated dB level for each sound listed in the first column. Where appropriate, indicate how the risk of hearing loss might be lowered. In the right column, enter any information that explains your dB estimates. For example, your choice of a dB level for eating lunch assumes either a quiet or a noisy environment.

Source of sound

Time per week Estimated

Suggestions for

Comments

(major activities)

(minutes)

dB level

lowering risk

of hearing loss

morning activities,

320

caring for twins

breakfast at home

120

commute to/from jobs

700

mowing lawns

1500

tree trimming

300

dinner at home

420

watching TV

1320

helping with twins

800

at night

Master 5.8

Sound Diary Summary—George, the Firefighter

Name(s)____

Date_____________________________

George is 23 years old and married. After graduating from college, he joined the local fire department.

When he is not on duty, he works on his farm. He is also remodeling the basement of their home.

George's wife is a violinist. Music is important to both of them.

Use Some Everyday Sounds and the table below to analyze George's exposure to sound. Enter an estimated dB level for each sound listed in the first column. Where appropriate, indicate how the risk of hearing loss might be lowered. In the right column, enter any information that explains your dB

estimates. For example, your choice of a dB level for eating lunch assumes either a quiet or a noisy environment.

Source of sound

Time per week Estimated

Suggestions for

Comments

(major activities)

(minutes)

dB level

lowering risk

of hearing loss

morning activities

180

breakfast at home

100

breakfast at fire station

120

tending animals

840

plowing fields

1020

lunch at home

150

lunch at fire station

90

time on firetruck

240

dinner at home

600

remodeling work

960

listening to music

1000

watching TV

500

reading

500

Master 5.9

Hearing-Risk Evaluation Form

Name_______________________________________

Date___________________________

Name of fictitious individual:_________________________________

My evaluation is that this individual is (check one)

_____ not at risk for noise-induced hearing loss.

_____ at risk for noise-induced hearing loss.

Justify your evaluation based on all of the information in the individual's sound diary.

If you suggested a way to decrease the risk of hearing loss, indicate specifically how this action will help.

Master 5.10

Ten Ways to Recognize Hearing Loss

Name_______________________________________

Date___________________________

The following questions will help you determine whether you need to have your hearing evaluated by a medical professional.

1. Do you have a problem hearing over the telephone?

Yes No

2. Do you have trouble following the conversation when two or more people are talking at the same time?

Yes No

3. Do people complain that you turn the TV volume up too high?

Yes No

4. Do you have to strain to understand conversation?

Yes No

5. Do you have trouble hearing in a noisy background?

Yes No

6. Do you find yourself asking people to repeat themselves?

Yes No

7. Do many people you talk to seem to mumble (or not speak clearly)?

Yes No

8. Do you often misunderstand what others are saying and respond inappropriately?

Yes No

9. Do you have trouble understanding the speech of women and children?

Yes No

10. Do people get annoyed because you misunderstand what they say?

Yes No

If you answered "yes" to three or more of these questions, you may want to see an otolaryngologist (an ear, nose, and throat doctor) or an audiologist for a hearing evaluation.

The material on this page is for general information only and is not intended for diagnostic purposes. A doctor or other healthcare professional must be consulted for diagnostic information and advice regarding treatment.

Master 5.11

Additional Web

Resources for

Resources for

Teachers

National Institute on Deafness and Other Com-

Speech and Language Developmental Milestones *munication Disorders*

http://www.nidcd.nih.gov/health/voice/

http://www.nidcd.nih.gov

speechandlanguage.asp

An information resource for researchers as well

Swat'z New? A Fly That's Setting the Hearing *as the general public. It features:*

World Abuzz

American Sign Language: Quick Facts

http://www.nidcd.nih.gov/health/education/

http://www.nidcd.nih.gov/health/hearing/asl.asp

news/swatz.asp

Cochlear Implants

Ten Ways to Recognize Hearing Loss (bookmark

http://www.nidcd.nih.gov/health/hearing/coch.asp

quiz)

English http://www.nidcd.nih.gov/health/

Gen "Y" Asks Why Not?

hearing/10ways.asp

http://www.nidcd.nih.gov/health/education/

Spanish http://www.nidcd.nih.gov/health/

news/patterson.asp

Spanish/10w_sp.asp

Has Your Baby's Hearing Been Screened?

Travel Inside the Ear (video clip)

http://www.nidcd.nih.gov/health/hearing/

http://www.nidcd.nih.gov/health/education/video/

screened.asp

travel_vid.asp

How Loud Is Too Loud? (bookmark)

What Are the Communication Considerations for

English http://www.nidcd.nih.gov/health/hearing/

Parents of Deaf and Hard-of-Hearing Children?

ruler.asp

http://www.nidcd.nih.gov/health/hearing/

Spanish http://www.nidcd.nih.gov/health/Spanish/

commopt.asp

ruler_sp.asp

What Is Sound? (video clip)

How Loud Is Too Loud? (interactive sound ruler)

http://www.nidcd.nih.gov/health/education/video/

http://www.nidcd.nih.gov/health/education/decibel/

sound_vid.asp

decibel.asp

How Loud Is Too Loud? (video clip)

Eisenhower National Clearinghouse

http://www.nidcd.nih.gov/health/education/video/

http://www.enc.org/

loud_vid.asp

ENC's mission is to identify effective curricu-

Silence Isn't Always Golden

lum resources, create high-quality profes-

English http://www.nidcd.nih.gov/health/hearing/

sional development materials, and

silence.asp

disseminate useful information and products

Spanish http://www.nidcd.nih.gov/health/Spanish/

to improve K–12 mathematics and science

silence_span.asp

teaching and learning.

Vietnamese http://www.nidcd.nih.gov/health/

hearing/VietSilence.pdf

• Science links:

cation through the use of technology.) You

http://www.enc.org/weblinks/science/

can click on the following sections:

• Sound links:

• How We Perceive Sound: The Ear

http://www.enc.org/weblinks/sci-

• The Timeline

ence/0,1578,1%2DSound,00.shtm

• The Physics of Sound

• The Interactive Sound Lab

League for the Hard of Hearing Noise Center

• Applications of Sound

http://www.lhh.org/noise/index.htm

WISE EARS! National Campaign Web Site

Contains fact sheets and other information

http://www.nidcd.nih.gov/health/wise/index.asp *resources on noise, from the League for the*

Hard of Hearing, a nonprofit organization

A national campaign sponsored by the

whose mission is to improve the quality of life

National Institute on Deafness and Other

for infants, children, and adults with all

Communication Disorders and the National

degrees of hearing loss.

Institute of Occupational Safety and Health. It

includes links to about 90 member organiza-

The Soundry

tions and information about the prevention of

http://library.thinkquest.org/19537/

noise-induced hearing loss.

An interactive, educational site about sound.

Have WISE EARS! for Life

It was developed by students as part of a

English http://www.nidcd.nih.gov/health/hearing/

ThinkQuest science competition.

wiseears.asp

(ThinkQuest Inc. is a nonprofit organization

Spanish http://www.nidcd.nih.gov/health/Spanish/

that offers programs designed to advance edu-

wiseears_span.asp

Appendix I

More About the National

out the National

Institutes of Health

Begun as a one-room Laboratory of Hygiene in

research and training in more than 2,000

1887, the National Institutes of Health today is

research institutions throughout the United

one of the world's foremost medical research cen-

States and abroad. In fact, NIH grantees are

ters and the federal focal point for medical

located in every state in the country. These

research in the United States.

grants and contracts make up the NIH Extra-

mural Research Program.

What Is the NIH Mission

Approximately 10 percent of the budget goes to

and Organization?

NIH's Intramural Research Programs, the more

The NIH mission is to uncover new knowledge

than 2,000 projects conducted mainly in its own

that will lead to better health for everyone. NIH

laboratories.

works toward that mission by

• conducting research in its own laboratories;

The Intramural Research Programs are central to

• supporting the research of nonfederal scientists

the NIH scientific effort. First-rate intramural sci-

in universities, medical schools, hospitals, and

entists collaborate with one another regardless of

research institutions throughout the country

institute affiliation or scientific discipline and

and abroad;

have the intellectual freedom to pursue their

• helping in the training of research investigators;

research leads in NIH's own laboratories. These

and

explorations range from basic biology, to behav-

• fostering communication of medical information.

ioral research, to studies on treatment of major

NIH is one of eight health agencies of the Public

diseases. NIH scientists conduct their research in

Health Service, which, in turn, is part of the U.S.

laboratories located on the NIH campus in

Department of Health and Human Services. NIH's

Bethesda and in several field units across the

institutes and centers encompass 75 buildings on

country and abroad.

more than 300 acres in Bethesda, Md. The NIH

budget has frown from about $300 in 1887 to

NIH Research Grants

more than $23.5 billion in 2002.

Final decisions about funding extramural research

are made at NIH headquarters. But long before

What Is the Goal of NIH Research?

this happens, the process begins with an idea that

Simply described, the goal of NIH research is to

an individual scientist describes in a written appli-

acquire new knowledge to help prevent, detect,

cation for a research grant.

diagnose, and treat disease and disability, from the

rarest genetic disorder to the common cold.

The project might be small, or it might involve

millions of dollars. The project might become use-

How Does NIH Help

ful immediately as a diagnostic test or new treat-

Scientists Reach This Goal?

ment, or it might involve studies of basic

Approximately 82 percent of the investment is

biological processes whose practical value may

made through grants and contracts supporting

not be apparent for many years.

Peer Review

Five Nobelists made their prize-winning discover-

Each research grant application undergoes a peer-

ies in NIH laboratories. You can learn more about

review process.

Nobelists who have received NIH support at

http://www.nih.gov/about/almanac/nobel/index.htm.

A panel of scientific experts, primarily from out-

side the government, who are active and produc-

What Impact Has NIH Had

tive researchers in the biomedical sciences, first

on the Health of the Nation?

evaluates the scientific merit of the application.

NIH research has played a major role in making

Then, a national advisory council or board, com-

possible the following achievements of the last

posed of eminent scientists as well as public mem-

few decades:

bers who are interested in health issues or the

• Mortality from heart disease, the number one

biomedical sciences, determines the project's

killer in the United States, dropped by 36 per-

overall merit and priority in advancing the

cent between 1977 and 1999.

research agenda of the particular NIH funding

• Death rates from stroke decreased by 50 percent

institute.

during the same period.

• Improved treatments and detection methods

Altogether, about 38,500 research and training

increased the relative five-year survival rate for

applications are reviewed annually through the

people with cancer to 60 percent.

NIH peer-review system. At any given time, NIH

• Paralysis from spinal cord injury is significantly supports 35,000 grants in universities, medical

reduced by rapid treatment with high doses of a

schools, and other research and research training

steroid. Treatment given within the first eight

institutions both nationally and internationally.

hours after injury increases the likelihood of

recovery in severely injured patients who have

Who Are the Scientists NIH Supports?

lost sensation or mobility below the point of

Scientific progress depends mainly on the scien-

injury.

tist. About 50,000 principal investigators—work-

• Long-term treatment with anticlotting medi-

ing in every state and in several foreign countries,

cines cuts stroke risk by 80 percent from a com-

from every specialty in medicine, every medical

mon heart condition known as atrial fibrillation.

discipline, and at every major university and

• In schizophrenia, where patients suffer fright-

medical school—receive NIH extramural funding

ening delusions and hallucinations, new med-

to explore unknown areas of medical science.

ications can reduce or eliminate these

Supporting and conducting NIH’s extramural and

symptoms in 80 percent of patients.

intramural programs are about 15,600 employees,

• Chances for survival increased for infants with

more than 4,000 of whom hold professional or

respiratory distress syndrome, an immaturity

research doctorate degrees. The NIH staff includes

of the lungs, due to development of a substance

intramural scientists, physicians, dentists, veteri-

to prevent the lungs from collapsing. In general,

narians, nurses, and laboratory, administrative,

life expectancy for a baby born today is almost

and support personnel, plus an ever-changing

three decades longer than one born at the begin-

array of research scientists in training.

ning of the century.

• With effective medications and psychotherapy,

The NIH Nobelists

the 19 million Americans who suffer from

The roster of those who have conducted NIH

depression can now look forward to a better,

research or who have received NIH support over

more productive future.

the years includes the world's most illustrious sci-

• Vaccines protect against infectious diseases that entists and physicians. Among them are 97 scien-
once killed and disabled millions of children

tists who have won Nobel Prizes for achievements

and adults.

as diverse as deciphering the genetic code and

• Dental sealants have proved 100 percent effec-

identifying the causes of hepatitis.

tive in protecting the chewing surfaces of chil-

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dren's molars and premolars, where most cavi-

kidney diseases, Alzheimer's disease, communi-

ties occur.

cation disorders, mental illness, drug abuse and

• In 1990, NIH researchers performed the first

alcoholism, and AIDS, and other unconquered

trial of gene therapy in humans. Scientists are

diseases.

increasingly able to locate, identify, and describe

• Ways to continue improving the health of

the functions of many of the genes in the human

infants and children, women, and minorities.

genome. The ultimate goal is to develop screen-

• Better ways to understand the aging process and

ing tools and gene therapies for cancer and

behavior and lifestyle practices that affect

many other diseases.

health.

NIH Research in the 21st Century

These are some of the areas where NIH's invest-

NIH has enabled scientists to learn much since its

ment in health research promises to yield the

humble beginnings. But many discoveries remain

greatest good for the greatest number of people.

to be made:

• Better ways to prevent and treat cancer, heart

For more about NIH, visit its Web site at http://

disease, stroke, blindness, arthritis, diabetes,

www.nih.gov.

Appendix I

Appendix II

More about the NIDCD

and Its Research

In 1988, Congress established the National Insti-

What Are Some of the Problems the

tute on Deafness and Other Communication Dis-

NIDCD Addresses?

orders as a separate Institute within the National

In this information age, communication and tech-

Institutes of Health (NIH). Commonly referred to

nology skills will be central to a successful life for

as the NIDCD, this Institute supports and con-

all Americans. The labor force of the 21st century

ducts research and research training on normal

will require intense use of these skills. However,

mechanisms as well as diseases and disorders of

for the one in six Americans who has communi-

hearing, balance, smell, taste, voice, speech, and

cation disabilities, as well as their families who

language. These processes of sensing and inter-

support them, each day can be a challenge. The

preting are fundamental to the way individuals

simple acts of speaking, listening, and making

perceive the world around them and to their abil-

wants and needs understood are often impossible.

ity to communicate effectively with others.

The days are often very challenging

- *for the individual who has dizziness (vertigo);*

In the past few years, NIDCD-supported scientists

- *for people who find themselves suddenly unable*

have made remarkable progress in research on *to hear;*

human communication and its disorders. This

• for the person who cannot speak without stut-

progress has been further accelerated by research

tering, or who is unable to express ideas clearly

supported by other institutes at NIH and is now

after a stroke;

providing the foundation for current and future

• for the adult who cannot use his or her voice to

research to achieve an important goal: to help

talk with a friend on the phone due to throat

individuals with communication and sensory-sys-

cancer;

tem disorders.

• for the child with autism or the young deaf child

who struggles with language and speech;

The NIDCD has developed a strategic plan to

• for the individual whose ringing in the ear (tin-

draw attention to extraordinary research opportu-

nitus) is overwhelming;

nities and compelling needs in the area of com-

• for an older person with a loss of balance that

munication and sensory disorders. While this

results in falls and fractured bones; and

plan assists the NIDCD in focusing on specific

• for an older person whose loss of hearing results

areas of research, it is not intended to be an

in isolation and depression, or whose dimin-

all-encompassing master plan for funding. The

ished sense of taste or smell affects nutrition and

NIDCD's first priority continues to be the funding

poses a danger.

of high-quality research conceived and initiated

by members of the research community that will

Communication disorders have a major impact on

help achieve the goals and objectives of the

education, employment, and the well being of

NIDCD.

Americans.

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How Your Brain Understands What Your Ear Hears

A Few Vital Statistics

day life. For example, a substantial fraction of

Birth and Early Childhood

older adults loses the ability to detect the foul-

• More than 12,000 babies are born each year

smelling agent that is added to natural gas to

with a significant hearing loss, which can affect

warn of a potential leak.

speech and language development.

• Two-thirds of children with acquired deafness

What Progress Has Been Made?

also have some loss of balance.

What We Know

• About 8 percent of American school-age chil-

Past research has produced many significant dis-

dren have problems developing and using lan-

coveries and technologies that improve our ability

guage. These language difficulties underlie not

to identify and treat people with communication

only speaking problems but also the ability to

problems. Because of research advances,

read and write.

• Vaccines now prevent many illnesses from

• Middle ear infection (otitis media) is the most

occurring, such as measles, mumps, meningitis,

frequently cited reason that a sick child visits a

and rubella, which were once major causes of

physician. In the United States, the estimated

hearing loss.

cost of otitis media each year is $5 billion in

• Much more is known about inherited (genetic)

medical bills and lost wages. Children with oti-

forms of hearing loss.

tis media suffer hearing loss during infection

• Much more is known about how exposure to

and often for an extended period of time after

noise and toxins can damage hearing.

treatment is initiated.

People with communication problems now have

• An estimated 2 million Americans stutter. Ten

access to a wealth of new tools to improve com-

percent of children entering the first grade have

munication, including cochlear (inner ear)

moderate to severe speech disorders, including

implants, better hearing aids, electronic larynxes

missing and substituted speech sounds and stut-

(voice boxes), and computerized speech devices.

tering.

• We can now identify newborn babies with hear-

ing loss and toddlers with language problems at

Adulthood

a much earlier age than in the past.

• Nearly 1 million American adults have a lan-

guage disorder due to stroke or other brain

What We Don't Know

injury.

But research findings also teach us how much

• An estimated 2 million adults with progressive

more there is to know. For example, we need to *dementia (for example, Alzheimer's) experience*

learn

significant language impairment.

• how to best help newborn children with hearing

• Tens of thousands of Americans each year

loss;

develop cancer of the head and neck. Conven-

• which new devices or treatments are most ben-

tional cancer treatment usually damages organs

eficial for certain individuals and why a treat-

critical for human speech and swallowing.

ment works well for some people but not for

• Balance disorders may contribute to as many as

others; and

half of all falls experienced by older people and

• how new tools for diagnosis, such as brain-

cost the nation more than $8 billion per year in

imaging methods, can also help doctors choose

patient care. For individuals over age 75, bal-

the best treatment for people with communica-

ance disorders are the single most common

tion problems of varying causes.

symptom presented to primary-care physicians.

• More than 2 million adults have disorders of

To achieve the greatest benefit from finite research *taste and smell. These problems are more preva-*

dollars, the NIDCD considers the effects that com-

lent in older people and affect a person's every-

munication disorders have on the American

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people as well as areas that offer the greatest

genes may one day allow us to diagnose and clas-

opportunity for significant progress at this time.

sify patients with communication disorders based

After weighing these factors with scientists and

on specific genetic changes, in addition to recog-

representatives of the public, the NIDCD has iden-

nizable symptoms. This knowledge could be

tified a number of future research opportunities.

directly applied to a clinical setting. For example,

children diagnosed at birth with a mild hearing

Future Research Opportunities

loss, who have a gene mutation that will cause

Why All This Interest in Research on Genes?

progressive hearing loss and deafness by their

Doctors and scientists have long known that

teens, might be given additional educational help

well-defined disorders of hearing and other aspects

early in life so they may function better in the

of human communication (language, speech, *future. Such children and their parents might also*

voice, etc.) often run in families. Changes called

be instructed to avoid noisy settings (rock con-

mutations in one or a few genes can have a dra-

certs, loud radios, etc.), certain occupations, or

matic effect on very complex functions, including

certain medications that could cause the hearing

hearing, speech, and language. Genes contain all

loss to progress more rapidly.

the information that tells a cell how to make pro-

Scientists and Physicians Can Find the Genes

teins. These proteins are the building blocks that

To use genetics to prevent, diagnose, and treat

determine the structure and function of all living

communication disorders, we must first learn

cells, which in turn form the tissues, organs, and

which genes are essential for the communication

organ systems within the human body. Humans

senses to function normally. Researchers can pin-

have 30,000 to 35,000 different genes. (This recent

point which genes are critical to hearing by study-

finding was somewhat surprising for researchers;

ing mice that are deaf due to mutations in certain

previous predictions had ranged from 80,000 to

genes since these same genes often affect hearing

150,000 genes.) As scientists and physicians define

in humans. In mice, scientists can determine the

the structure of the human genome, the identifica-

function of a single gene by systematically altering

tion of genes involved in human communication

the gene and observing any changes that occur.

and communication disorders becomes more

Much more can be learned about human hearing

straightforward. Finally, learning about the nature

by applying the powerful tools of genetics to mice.

of proteins made from these genes allows us to

understand more about new and unsuspected cel-

Many communication disorders are complex,

lular processes that are essential for effective com-

with multiple components and causes. Some dis-

munication. Once understood, these proteins may

orders are caused by complex genetic traits in

someday be targets for new treatment strategies.

which multiple genes are involved. Others are

The willingness and generosity of families with

directly associated with a single underlying prob-

hereditary communication disorders who agree to

lem that has multiple effects. One gene can affect

participate in studies with clinicians and scientists

how other genes function, and small differences in

are what makes this research on gene discovery

several genes can cumulatively affect one's suscep-

possible.

tibility to a disorder. Thus, it is necessary to

understand the complex interactions of these

Understanding Leads to Education and Prevention

genetic factors. Such knowledge could lead to the

Changes in genes contribute to many communi-

development of effective prevention and treat-

cation disorders, either directly, by causing a crit-

ment strategies.

ical group of cells to malfunction, or indirectly, by

increasing sensitivity to damage caused by envi-

Nongenetic Factors

ronmental factors such as noise, drugs and med-

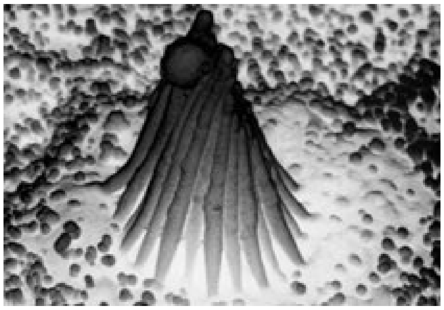
Not all communication disorders have a genetic

ications, or infections. Research aimed at

basis. For example, hearing loss can be caused by

understanding the identity and function of these

infections, noise damage, or certain medications.



How Your Brain Understands What Your Ear Hears

Infants who experience hearing loss can have dif-

whether the same processes that produce inner

ficulty learning to speak or understanding lan-

ear hair cells during development of the human

guage later in life, if appropriate education and

embryo could be reactivated to achieve hair-cell

training are not provided. Impaired language

regeneration in older individuals.

skills affect all aspects of our ability to function in

Sensory and Nerve Cells in the Nose

today's communication-driven society. Language

In contrast to the hair cells of the inner ear and

impairment also can be caused by brain-injury or

many other sensory cells and neurons, the sensory

brain-developmental problems, in addition to

nerve cells of the human olfactory system, our

childhood hearing impairment. Diseases of the

sense of smell, shows a remarkable ability to regen-

larynx (voice box) can be caused by infections or

erate. The ability of these newly restored cells to *by the presence of a tumor. More research is*

make appropriate connections to brain regions that

needed to identify additional nongenetic causes of

respond to specific odors needs to be intensively

communication disorders.

studied. Research identifying what factors make

this possible could lead to the design of interven-

Increasing Potential for Recovery: How

tion strategies promoting the regeneration of nerve

the Body Creates New Cells

cells in other parts of the nervous system.

Recovering Speech and Language Ability

Adults who suffer brain damage as a result of a

stroke often have problems expressing their

thoughts. These speech and language disorders

severely compromise their ability to communicate

and decrease their quality of life. In contrast,

infants and young children who have suffered

comparable brain damage from birth injuries,

childhood trauma, or extensive brain surgery

sometimes develop or recover speech and lan-

guage abilities. If researchers can determine why

young children have the ability to recover from

Electron micrograph of a healthy hair cell.

severe brain damage, then they may learn how *adults can be helped to do the same.*

Hair Cells in the Inner Ear

Most parts of the body that are damaged due to

Sensory cells in the hearing and balance organs in

illness or injury have the ability to heal by regen-

the inner ear develop connections with specific

erating healthy cells to replace those that have

brain regions early in life. We know that the brain

been damaged or lost. Until the recent past, the

is particularly receptive to forming these connec-

highly specialized hair cells of the inner ear, which

tions at certain times in the young child's life. If

are critical to hearing and balance, were consid-

these time-sensitive opportunities are missed

ered irreplaceable if injured or destroyed. Recent

because sensory information is not being trans-

discoveries in birds, however, confirm that spe-

mitted to the brain, the ability to develop critical

cialized inner ear hair cells that have been

brain connections or pathways may be lost for-

destroyed by very loud noises can be replaced

ever. This could occur, for example, in an infant

by regeneration of healthy hair cells. This research

with undetected severe hearing loss. Research is

has inspired hope that damaged inner ear hair

needed to identify these critical "windows of

cells in humans, one of the major underlying

opportunity" for developing brain connections

causes of hearing loss, could be repaired or

essential for communication. Important research

replaced. Future research is needed to explore

findings in this area have already stimulated inter-

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est in major public health efforts, such as the

nature of chemicals that are found in the nerve-

screening of millions of newborn babies for hear-

cell networks devoted to human communication.

ing loss each year.

This knowledge could lead to new treatment

strategies for individuals with communication

From Sensing to Interpreting

disorders caused by abnormalities in critical

Understanding Human Communication

nerve-cell networks.

Human communication relies on complicated per-

ceptual skills—taking information from the out-

Applying New Knowledge

side world through the senses (hearing, vision,

As described in the previous sections, scientists

touch, taste, and smell) and interpreting it in a *have made great progress in recent years toward*

meaningful way. Human communication also

the goal of understanding human communication

requires mental abilities, such as attention and

and its disorders. These advances have occurred

memory. We still do not understand exactly how

as a result of unprecedented breakthroughs in

all of these processes work and interact, or how

genetics, other basic sciences, and technology. We

they malfunction in the case of communication

can expect continued progress to be made as addi-

disorders. But we do know that many communica-

tional genes associated with specific communica-

tion disorders are caused by problems that occur

tion disorders are identified and their functions

even when the senses (such as hearing) are com-

revealed, and as more is learned about the func-

pletely functional. Recently, new methods have

tion of the brain and other organs that are impor-

been developed to study what happens after infor-

tant for communication.

mation is received by the sense organs. It is now

possible to view parts of the brain directly while

Although advances in basic research are of great

they're at work through computerized imaging

theoretical and scientific importance, they repre-
technology, and to see changes as information
sent only a first step toward improving the lives of
flows from sensory organs to the brain. For
individuals with communication disorders. The
example, a functional magnetic resonance imaging
next step is to apply knowledge gained from basic
(fMRI) scan of the brain can be used to observe
research to clinical studies in which the ultimate
activity as language information is received,
goal is to develop the most appropriate and effec-
processed, and interpreted. Research studies that
tive means of preventing, diagnosing, and treating
use powerful imaging techniques such as fMRI are
communication disorders. For example, you may
especially valuable in the study of speech and lan-
be familiar with hearing screening programs that
guage because these important forms of communi-
have been established around the country to iden-
cation cannot be studied in animals.
tify infants and young children who have signifi-
cant hearing loss. The technology that enables us
Processing Information in the Brain
to screen newborns is a result of basic laboratory
Aside from the advances being made in brain

studies that measure the electrical signals from

imaging, new ways are emerging for studying the

auditory centers in the brain (auditory brainstem

basic organization and operation of human com-

response, or ABR) and tiny sounds generated by

munication. Information processing in the brain

involves the successive activation or stimulation

the inner ear (otoacoustic emissions). Because

of nerve cells. In other words, information moves

babies who are hearing-impaired can now be iden-

continuously from one nerve cell to another like

tified in their infancy, researchers can conduct

electricity moving along a wire. This activation

clinical trials to establish and validate the most

process takes place when chemicals in one nerve

effective educational programs and treatments

cell are released, stimulating activity in the adja-

(including hearing aids or cochlear implants) and

cent nerve cell. Research advances have provided

to determine the age at which treatment should

new tools that allow scientists to determine the

begin for maximal success.

***Clinical research is also needed to describe the
of the electrolarynx to restore speech after the
range of differences that occur in human commu-
removal of the voice box (larynx); digital, pro-
nication over a person's life span, such as produc-
grammable hearing aids that fit inside the ear
tion of speech sounds, hearing acuity, odor
canal; cochlear and brainstem implants to
detection (sense of smell), and ability to maintain
improve the communication abilities of adults
balance. These differences may then be related to
and children with severe-to-profound hearing
an underlying gene or genes, which may help iden-
loss; and video-game-like computer programs for
tify people who are at greater risk of developing
treatment of disorders that may be associated with
problems. Clinical trials are also necessary to tell us
learning disabilities. Although these inventions
which medical and behavioral interventions are
emerged from basic knowledge regarding human
safe and effective treatment methods for communi-
communication, the ultimate success of current
cation disorders. These may include evaluations of
and future devices can only be determined by
medications to treat Ménière's disease and autoim-***

carefully designed clinical research studies. These

mune hearing loss, light therapy to treat warts on

clinical research studies are an important priority

the vocal cords (laryngeal papillomas), electrical

for the NIDCD.

stimulation and medications to treat ringing in the

For more information, contact

ears (tinnitus), imaging techniques to assess brain

Office of Health Communication and

damage and predict recovery from stroke, and

Public Liaison

physical therapy involving special positioning of

National Institute on Deafness and

the head for loss of balance (positional vertigo).

Other Communication Disorders

The NIDCD is committed to supporting research

National Institutes of Health

to develop devices that improve or restore com-

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munication abilities, or prevent communication

Bethesda, MD 20892-2320

disorders. Advances in basic science research and

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in bioengineering contributed to the development

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