ZAP! SURGERY

BEYOND THE CUTTING EDGE

EDUCATION MATERIALS MANUAL

Carnegie Science Center
One of the four Carnegie Museums of Pittsburgh

ZAP! SURGERY

BEYOND THE CUTTING EDGE

Special thanks to:

UPMC HEALTH SYSTEM

Richard King Mellon Foundation

SONY Technology Center - Pittsburgh

CONTENTS

INTRODUCTION

Zap! Surgery Beyond the Cutting Edge is a 6,000-square-foot traveling exhibit offering a unique look at how light, sound, and other forms of energy are being applied in today's faster, safer, less-invasive surgical procedures. Carnegie Science Center (CSC) has developed this exhibit in collaboration with advisors from UPMC Health System, other regional and national medical advisors, and local educators.

This manual has been developed to provide your staff with a detailed description of the *Zap! Surgery* exhibit, its educational objectives, and suggestions for supplemental, hands-on activities. The information in this manual may be copied and used by your staff for training, classes, workshops, overnighters, outreach activities, theater and floor activities. Copies may also be sent to teachers who are preparing their classes for field trips to your facility. Page numbers have been omitted to allow staff to arrange the information in custom documents that meet these different needs.

This document will continue to evolve based on feedback from the staff at venues featuring *Zap! Surgery*. CSC welcomes suggestions and additions from your staff.

Digital copies of this document have been provided on floppy disk. A searchable database containing the information in this document will be available on CSC's *Zap! Surgery* web site (**http://www.zapsurgery.org**).

For more information, contact:

Linda Ortenzo
Traveling Exhibit Manager
Carnegie Science Center
Tel 412.237.1819

ortenzol@csc.clpgh.org

EXHIBIT OVERVIEW

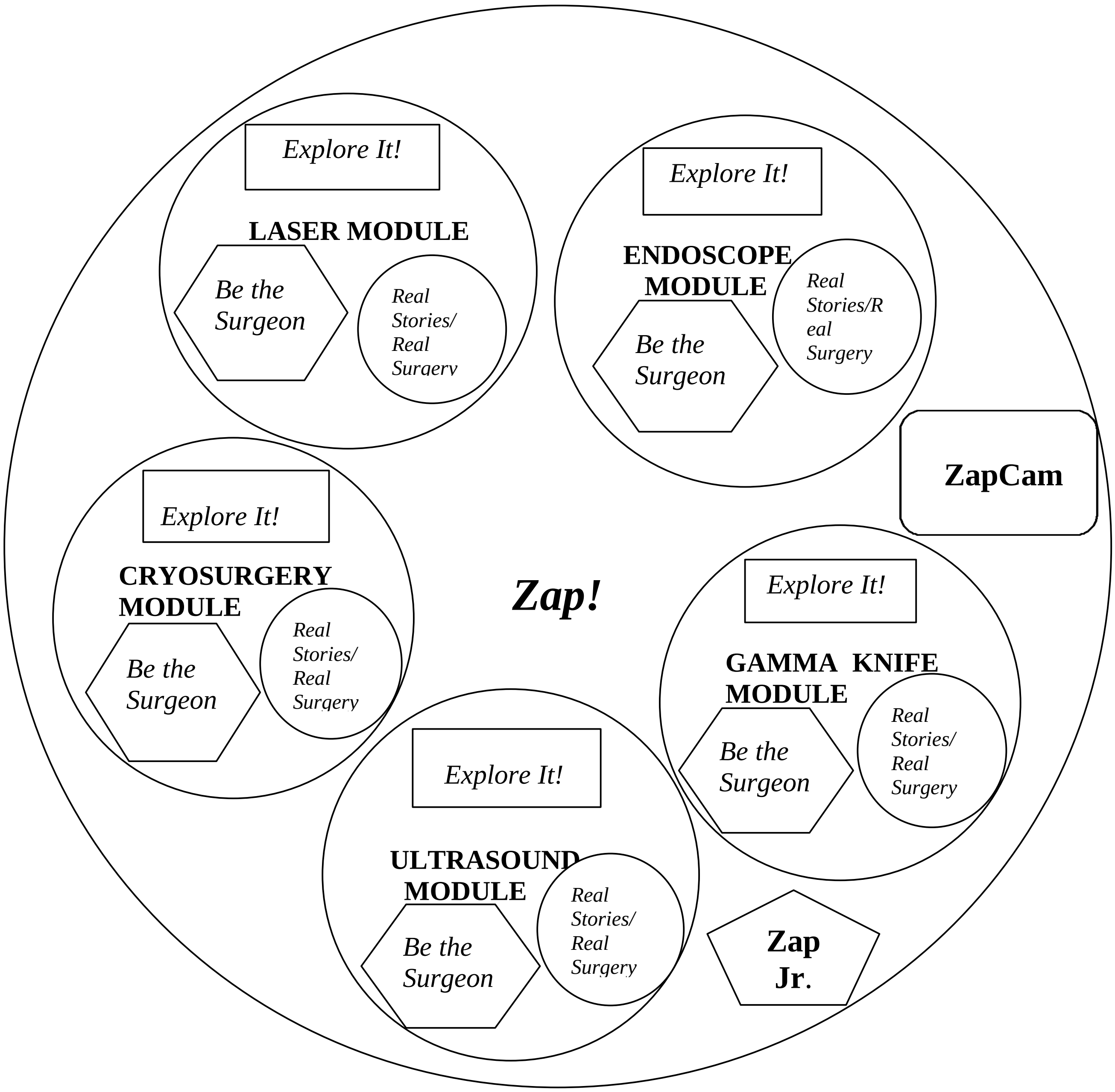
Zap! Surgery Beyond the Cutting Edge is organized into five modules, each presenting a specific surgical technology: **lasers**, **endoscopes**, **ultrasound**, **cryosurgery**, and the **Gamma Knife**. Each module consists of three areas:

> ***Explore It!*** prompts visitors to experiment with basic science principles, particularly the properties of energy.
>
> ***Be the Surgeon*** encourages visitors to discover how the *Explore It!* science principles underlie the surgical technologies while performing simulated procedures.
>
> ***Real Stories / Real Surgery*** offers video clips of actual surgical procedures; human interest stories from patients, doctors, and scientists; and information on patient issues.

Twenty-four of the components in *Zap!* are organized according to this module system. Color-coding and signage identify each module and its three exhibit areas, thereby creating a visual connection among the various activities.

In addition to the five modules, *Zap!* features two supplementary components:

> **ZapCam** is a fifteen-person, cabin simulator ride that offers an exciting, immersive experience for visitors. A pre-show video establishes the ride premise: visitors are going on the first manned test mission for ZapCam, a tiny remote-controlled camera that allows visitors to witness the featured surgical technologies from vantage points inside the body.
>
> **Zap Jr.** is designed for families with children ages 5-8 and will encourage exploration and learning through play. Families can investigate the basics of human anatomy and medical technologies in a safe and secure environment.



Organization of *Zap! Surgery Beyond the Cutting Edge*

EXHIBIT COMPONENTS

ENTRANCE PIECE

GAMMA KNIFE MODULE

Explore It!:	Wave Launcher How it Works
Be the Surgeon:	Targeting
Real Stories / Real Surgery	

LASER MODULE

Explore It!:	The Light Zone
Be the Surgeon:	Match 'em Zap It
Real Stories / Real Surgery	

ENDOSCOPE MODULE

Explore It!:	Fiber Optic Fun Picture Perfect 3D Maze Tiny Tools Grab It
Be the Surgeon:	Inside Moves Scope It Out Virtual O.R.
Real Stories / Real Surgery	

ULTRASOUND MODULE

Explore It!:	Sound in the Round Visible Vibes
Be the Surgeon:	Tissue Tremors
Real Stories / Real Surgery	

CRYOSURGERY MODULE

Explore It!:	Fast Freeze
Be the Surgeon:	Cool Surgery
Real Stories / Real Surgery	

ZAPCAM

ZAP JR.

instructions, and to reinforce the links between science and technology.

Relevant **National Science Education Content Standards**[1] have been assigned to each component in *Zap!* to support educators who are using this exhibit as a teaching tool (see Table 1). Further, to help educators and science center staff accommodate the different **learning styles** of visitors, CSC has paired each exhibit component with the applicable learning styles proposed by Howard Gardner in his Theory of Multiple Intelligences.[2] These seven learning styles are described below.

linguistic: Having highly developed auditory skills. These learners like to read, play word games, and create stories or poetry. They learn best using books, lectures, audio recordings, computers, games, and multimedia.

musical: Being sensitive to rhythm and sound. They learn best using musical instruments, music, radio, stereo, and multimedia.

logical-mathematical: Thinking conceptually and abstractly. These learners are reasoning and calculating and learn best through logic games, puzzles, investigations and mysteries.

spatial: Thinking in terms of physical space. They learn best using the following tools: graphics, charts, photographs, drawings, 3D modeling, video, and multimedia.

bodily-kinesthetic: Learning through movement and touch. These learners benefit from physical activity, hands-on learning, and role-playing.

interpersonal: Interacting with other people. They learn best through group activities, seminars and dialogues.

intrapersonal: Learning independently. They benefit by using tools such as books and creative materials.

---

[1] *National Science Education Standards* (Washington, DC: National Research Council, 1996), pp. 103-207.

[2] Howard Gardner, *Frames Of Mind: The Theory of Multiple Intelligences* (New York: Basic Books, 1983).

Table 1. Components in *Zap!* support the National Science Education Content Standards and appeal to a variety of learning styles.

Science Education Content Standard		Exhibit Component	Learning Style: Bodily-kinesthetic	Interpersonal	Intrapersonal	Linguistic	Logical-Mathematical	Musical	Spatial
Understandings about Scientific Inquiry (K-4)	Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.	Zap Jr.	•	•	•				•
Properties of Objects and Materials (K-4)	Materials can exist in different states – solid, liquid, and gas. Water can be changed from one state to another by heating or cooling.	Fast Freeze	•			•			•
		Cool Surgery	•		•				•
Position and Motion of Objects (K-4)	The position of an object can be described by locating it relative to another object or the background.	Targeting			•		•		•
		Inside Moves	•						•
		Virtual O.R.	•		•				
		Cool Surgery	•		•				•
	Sound is produced by vibrating objects.	Sound in the Round							•
	The frequency (pitch) of the sound can be varied by changing the rate of vibration.	Sound in the Round							•
		Visible Vibes	•					•	•
Light, Heat, Electricity, and Magnetism (K-4)	Light travels in a straight line until it strikes an object. Light can be reflected, refracted, or absorbed.	The Light Zone		•			•		•
		Fiber Optic Fun				•	•		
The Characteristics of Organisms (K-4)	Each plant or animal has different structures that serve different functions in growth, survival and reproduction.	Targeting			•		•		•
		Zap Jr.	•	•	•				•
		ZapCam	•	•	•			•	•
Understandings about Science and Technology (K-4)	People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.	Targeting			•		•		•
		Zap It	•		•				•
		Scope It Out	•		•				•
		Virtual O.R.	•		•				
		Cool Surgery	•		•				•
		Real Stories / Real Surgery				•			•
		ZapCam	•	•	•			•	•
	Scientists and engineers often work in teams with different individuals doing different things that contribute to the results.	Real Stories / Real Surgery				•			•
	Tools help scientists make better observations, measurements, and equipment for investigation. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.	How it Works							•
		Picture Perfect				•	•		•
		Grab It	•						
		3D Maze	•	•			•		•
		Tiny Tools							•
Personal Health (K-4)	Individuals have some responsibility for their own health. Students should engage in personal care - dental hygiene, cleanliness, and exercise - that maintain and improve health.	Zap Jr.	•	•	•				•

Table 1. Components in *Zap!* support the National Science Education Content Standards and appeal to a variety of learning styles.

Science Education Content Standard		Exhibit Component	Learning Style						
			Bodily-kinesthetic	Interpersonal	Intrapersonal	Linguistic	Logical-Mathematical	Musical	Spatial
Science and Technology in Local Challenges (K-4)	People continue inventing new ways of doing things, solving problems, and getting work done.	Real Stories / Real Surgery				•			•
Science as a Human Endeavor (K-4)	Science and technology have been practiced by people for a long time.	ZapCam	•	•	•			•	•
	Many people choose science as a career and devote their entire lives to studying it.	ZapCam	•	•	•			•	•
		Zap Jr.	•	•	•				•
Transfer of Energy (5-8)	Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.	ZapCam	•	•	•			•	•
	Energy is associated with heat.	Cool Surgery	•		•				•
	Energy is associated with light.	Wave Launcher							•
		Match'em					•		•
	Energy is associated with sound.	Visible Vibes	•					•	•
		Tissue Tremors	•				•		•
	Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.	Fast Freeze	•			•			•
		Cool Surgery	•		•				•
	Light interacts with matter by transmission, absorption, or scattering.	The Light Zone		•			•		•
		Match'em					•		•
		Fiber Optic Fun				•	•		
		Picture Perfect				•	•		•
Structure and Function in Living Systems (5-8)	Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells.	How It Works							•
		Fast Freeze	•			•			•
		Cool Surgery	•		•				•
	Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue. 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.	Targeting			•		•		•
		Virtual O.R.	•		•				
		Zap It	•	•					•
		Cool Surgery	•		•				•
	Disease is a breakdown in structures or functions of an organism.	Zap It	•	•					•

Table 1. Components in *Zap!* support the National Science Education Content Standards and appeal to a variety of learning styles.

Science Education Content Standard		Exhibit Component	Learning Style: Bodily-kinesthetic	Interpersonal	Intrapersonal	Linguistic	Logical-Mathematical	Musical	Spatial
Understandings about Science and Technology (5-8)	Technological designs have constraints. Some constraints are unavoidable; other constraints limit choices in the design, for example environmental protection, human safety, and aesthetics.	Targeting			•		•		•
		Inside Moves	•						•
		Virtual O.R.	•		•				
		Cool Surgery	•		•				•
	Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world. Reducing risk often results in new technology.	Targeting			•		•		•
		Virtual O.R.	•		•				
		Inside Moves	•						•
		Cool Surgery	•		•				•
	Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.	Targeting			•		•		•
		Virtual O.R.	•		•				
		Cool Surgery	•		•				•
Risks and Benefits (5-8)	Risk analysis considers the type of hazard and estimates the number of people that might be exposed and the number likely to suffer consequences. The results are used to determine the options for reducing or eliminating risks.	Real Stories / Real Surgery				•			•
	Individuals can use a systematic approach to thinking critically about risks and benefits.	Targeting			•		•		•
		Scope It Out	•		•				•
		Virtual O.R.	•		•				
		Cool Surgery	•		•				•
	Important personal and social decisions are made based on perceptions of benefits and risks.	Real Stories / Real Surgery				•			•
Science and Technology in Society (5-8)	Technology influences society through its products and processes. Technology influences the quality of life and the ways people act and interact.	Real Stories / Real Surgery				•			•
	Science and technology have advanced through contributions of many different people, in different cultures, at different times in history.	ZapCam	•	•	•			•	•
	Science cannot answer all questions and technology cannot solve all human problems or meet all human needs. New technologies often will decrease some risks and increase others.	Real Stories / Real Surgery				•			•
Science as a Human Endeavor (5-8)	Women and men of various social and ethnic backgrounds engage in the activities of science, engineering, and related fields such as the health professions.	Real Stories / Real Surgery				•			•

Table 1. Components in *Zap!* support the National Science Education Content Standards and appeal to a variety of learning styles.

Science Education Content Standard		Exhibit Component	Learning Style						
			Bodily-kinesthetic	Interpersonal	Intrapersonal	Linguistic	Logical-Mathematical	Musical	Spatial
History of Science (5-8)	Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.	ZapCam	•	•	•			•	•
Structure of Atoms (9-12)	Radioactive isotopes emit particles and/or wavelike radiation.	How it Works							•
Interactions of Energy and Matter (9-12)	Waves have energy and can transfer energy when they interact with matter.	Wave Launcher							•
		Match'em					•		•
		Visible Vibes	•					•	•
		Tissue Tremors	•				•		•
		ZapCam	•	•	•			•	•
	Electromagnetic waves include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays, and gamma rays.	Wave Launcher							•
		How it Works							•
		Targeting			•		•		•
	The energy of electromagnetic waves is inversely proportional to the wavelength.	Wave Launcher							•
The Cell (9-12)	Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world.	Fast Freeze	•			•			•
Understandings about Science and Technology (9-12)	Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.	ZapCam	•	•	•			•	•
	Technological design is driven by the need to meet human needs and solve human problems.	Targeting			•		•		•
		3D Maze	•	•			•		•
		Inside Moves	•						•
		Scope It Out	•		•				•
		Virtual O.R.	•		•				
		Cool Surgery	•		•				•
		ZapCam	•	•	•			•	•
Science as a Human Endeavor (9-12)	Individuals and teams have contributed and will continue to contribute to the scientific enterprise.	Real Stories / Real Surgery				•			•
Historical Perspectives (9-12)	In history, diverse cultures have contributed scientific knowledge and technologic inventions.	ZapCam	•	•	•			•	•

COMPONENT DESCRIPTIONS

ENTRANCE PIECE

This dramatic presentation of the exhibit logo will establish the state-of-the-art, high-tech atmosphere of the entire exhibit gallery. Names of the major funders of the exhibit will be displayed on this component and a changeable panel will be available for displaying the names of local funders at each venue.

GAMMA KNIFE MODULE

This module presents:
- **the electromagnetic spectrum, with a focus on high-energy electromagnetic waves (gamma rays)**
- **the use of gamma rays in surgery**

Background information

The Leksell Gamma Knife® is used to treat disorders of the brain (such as tumors and malformed blood vessels) when conventional surgery would be too risky or too difficult. Treatment with the Gamma Knife requires no surgical incision because gamma rays are used to destroy the target. Gamma rays, which are high-energy electromagnetic waves, are produced by certain radioactive elements. The Gamma Knife apparatus uses a radioactive form of cobalt as its source of gamma rays.

Gamma Knife radiosurgery can precisely concentrate 201 gamma rays at a specific target in the patient's head without damaging the surrounding tissues. In order to protect specific healthy structures (such as the optic nerve), the patient's head is held stationary by a stereotactic frame. A targeting helmet is then fixed to this stereotactic frame. The Gamma Knife helmet contains 201 holes that can be closed to prevent specific gamma rays from reaching healthy structures. Before treating a patient with the Gamma Knife, medical professionals and physicists plan the procedure to decide which holes in the helmet should be left open and which holes should be closed.

Activities in the Gamma Knife Module introduce the electromagnetic spectrum and focus on the use of gamma rays in Gamma Knife radiosurgery. Applications of other electromagnetic waves in surgery are presented in the Laser Module (visible, ultraviolet, and infrared light) and the Endoscope Module (visible light).

GAMMA KNIFE MODULE

Explore It!: WAVE LAUNCHER

What You See / What You Do:

This is a tall, lighted panel representing the spectrum of electromagnetic (EM) waves, their different energy levels and wavelengths. The spectrum is presented so that gamma rays, which are associated with the highest amount of energy, are at the top of the panel. The remaining waves are listed in decreasing order of energy.

The visitor uses a mallet to hit a pressure-sensitive plate to see how high s/he can illuminate a column of lights on the panel. The harder the visitor hits the plate, the more lights turn on.

Text and graphics define wavelength and provide information about the properties of each EM wave. Familiar applications of EM waves are also presented.

What You Learn:

- The electromagnetic spectrum includes electromagnetic (EM) waves that have a variety of wavelengths.
- Electromagnetic waves carry energy.
- The energy associated with electromagnetic waves varies with wavelength.
- Gamma rays are used by the Gamma Knife to perform surgery.

National Science Education Content Standards:

- **Transfer of energy (5-8)**
  - Energy is associated with light.

- **Interactions of energy and matter (9-12)**
  - Waves have energy and can transfer energy when they interact with matter.
  - Electromagnetic waves include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays.
  - The energy of electromagnetic waves is inversely proportional to the wavelength.

GAMMA KNIFE MODULE

Explore It!: HOW IT WORKS

What You See / What You Do:
This large graphics panel displays a mock-up of the Gamma Knife apparatus. Specialized lighting effects represent the radioactive cobalt-60 pellets and emitted gamma rays. Included on this graphics panel are photographs of the actual Gamma Knife and of the 3D computer models used to generate a treatment plan for each patient. Text relates that a gamma ray is electromagnetic radiation that is emitted naturally by certain radioactive substances. The effects of radiation on the body are also briefly explained.

What You Learn:
- A gamma ray is a form of electromagnetic energy.
- Gamma rays are produced by certain radioactive elements.
- There is a distinction between radiation and radioactivity.
- The Gamma Knife uses gamma rays to destroy unwanted structures in the brain.

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - Tools help scientists make better observations, measurements, and equipment for investigation. They help scientists see, measure, and do things that could not otherwise see, measure, and do.

- **Structure and function in living systems (5-8)**
  - Cells carry on the many functions needed to sustain life.

- **Structure of atoms (9-12)**
  - Radioactive isotopes emit particles and/or wavelike radiation.

- **Interactions of energy and matter (9-12)**
  - Electromagnetic waves include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays.

GAMMA KNIFE MODULE

Be The Surgeon: TARGETING

What You See / What You Do:
This computer activity simulates the planning and treatment stages of Gamma Knife surgery. Visitors act as both medical physicist and physician to treat a patient suffering from an acoustic tumor that could lead to loss of hearing. Visitors must determine which holes in the Gamma Knife helmet to close to prevent gamma rays from hitting healthy structures in the patient.

The simulation begins with a 3D, computer-animated graphic of a patient (head and shoulders) who is fixed into the Gamma Knife helmet. The patient's body is transparent so the brain is visible. The electronic presenter appears simultaneously on the screen (as a picture-in-picture) to provide instructions. She introduces the Gamma Knife and explains that the patient has an acoustic tumor. The visitor must plan the procedure properly to destroy the tumor while protecting the auditory nerve, facial nerve, and brain stem.

To plan the procedure, the visitor decides which helmet holes should be left open so that the gamma rays destroy the tumor. Visitors select the holes by pushing buttons on a small model of the helmet. (Although an actual Gamma Knife helmet has 201 holes, the number of holes in this activity is limited to ten.) When visitors open a hole in the helmet, the path of the corresponding gamma ray appears on screen. Anatomical structures in the path of the gamma ray blink, indicating contact with the gamma ray, and the visitor must decide if the hole should be closed to block that gamma ray. The activity has been designed so that all ten gamma rays converge on the tumor. Visitors only need to evaluate whether or not the gamma ray will strike healthy tissue.

After planning the procedure, the visitor presses the Zap! button to initiate the surgery. When the visitor plans the procedure correctly, the electronic presenter provides a congratulatory message. If healthy tissue has been affected, the electronic presenter explains the consequences. (For more information, see the electronic presenter script for this component.)

What You Learn:
- The Gamma Knife directs gamma rays to a target in the brain, but careful planning ensures that it does not damage key anatomical structures.
- The Gamma Knife is used to treat certain tumors and other abnormalities in the brain that are inaccessible by conventional surgery.

TARGETING (CONTINUED)

National Science Education Content Standards:

- **Position and motion of objects (K-4)**
  - The position of an object can be described by locating it relative to another object or the background.

- **The characteristics of organisms (K-4)**
  - Each plant or animal has different structures that serve different functions in growth, survival and reproduction.

- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

- **Structure and function in living systems (5-8)**
  - Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue. 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.

- **Understandings about science and technology (5-8)**
  - Technological designs have constraints. Some constraints are unavoidable; other constraints limit choices in the design, for example environmental protection, human safety, and aesthetics.
  - Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world.
  - Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

- **Risks and Benefits (5-8)**
  - Individuals can use a systematic approach to thinking critically about risks and benefits.

- **Interactions of energy and matter (9-12)**
  - Electromagnetic waves include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays, and gamma rays.

- **Understandings about science and technology (9-12)**
  - Technological design is driven by the need to meet human needs and solve human problems.

GAMMA KNIFE MODULE

Real Stories / Real Surgery

What You See / What You Do:
This kiosk allows visitors to select and view short video clips of human interest stories and Gamma Knife procedures.

Items presented in the videos are
- the steps involved in treatment with the Gamma Knife
- patients' stories (from diagnosis through procedure to postoperative life)
- the various professionals involved in planning and performing the procedure
- risks and benefits associated with Gamma Knife radiosurgery

What You Learn:
- The Gamma Knife is used to treat disorders of the brain when conventional surgery is too risky or too difficult.
- There are limitations to surgery performed with the Gamma Knife.
- There are various professionals involved in planning and performing the procedure.
- There are risks and benefits associated with Gamma Knife radiosurgery.

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

LASER MODULE

This module presents:

- **properties of light**
- **the use of lasers in surgery**

Background information

A laser (Light Amplification by Stimulated Emission of Radiation) is a device that emits a beam of a *specific* (monochromatic) wavelength. The emitted electromagnetic radiation may be visible light or invisible (infrared or ultraviolet) light. The laser beam is extremely intense and can transmit tremendous amounts of energy when focused at close range. Laser light is *coherent* (all of the waves are in phase) and nearly *non-divergent* (it remains a narrow beam over very large distances). These unique properties of laser light have contributed to the widespread use of lasers as surgical tools.

Activities in the Laser Module compare the properties of laser light and white light, introduce different types of surgical lasers, and explain some of the effects of lasers on the body.

LASER MODULE

Explore It!: THE LIGHT ZONE

What You See / What You Do:
This recessed tabletop features multiple, open-ended activities that explore and compare the properties of white light and laser light. Visitors can reflect, refract, or transmit both types of light using mirrors, lenses and prisms. The text panel will introduce properties of light and prompt visitors to try different activities.

What You Learn:

- Light can be transmitted, refracted, and reflected.
- Laser light is more focused and easier to control than white light.
- The ability to control and target laser light makes lasers ideal for use in surgery.

National Science Education Content Standards:

- **Light, heat, electricity, and magnetism (K-4)**
  - Light travels in a straight line until it strikes an object. Light can be reflected, refracted, or absorbed.

- **Transfer of energy (5-8)**
  - Light interacts with matter by transmission, absorption, or scattering.

LASER MODULE

Be The Surgeon: MATCH 'EM

What You See / What You Do:
The electronic presenter tells visitors that there are different kinds of lasers as she ducks to avoid animated laser beams coming from all directions on the screen. She explains that wavelength is one important property of lasers as a simple screen animation illustrates wavelength. The electronic presenter tells visitors to match three surgical lasers with the appropriate procedures. (For more information, see the electronic presenter script for this component.)

Three buttons on a console are each labeled with the name of a surgical laser (CO_2, short-pulsed, or holmium:YAG). A vertical panel displays a large graphic of a human body with three "targets" for laser surgery: a tattoo that needs to be removed, vocal cords that need to be repaired, and damaged knee cartilage that needs to be eliminated. Visitors press a button to choose one of the surgical lasers and use a joystick to aim the laser beam toward a target on the body. Once visitors choose a laser, a clue about that laser appears on the screen (e.g. "This type of laser doesn't leave a lot of scars and comes in different colors."). Each target contains a photocell that reacts when struck by the correct laser beam. When visitors use the correct laser to perform a surgery, the electronic presenter provides a simple explanation of how that laser reacts with the tissue.

What You Learn:
- There are different types of surgical lasers.
- Lasers have different wavelengths and colors, which are related to the energy of the laser.
- The response of tissue treated with a laser depends on the energy of that laser.
- These characteristics are important when choosing a laser for a surgical procedure.

National Science Education Content Standards:
- **Transfer of energy (5-8)**
  - Energy is associated with light.
  - Light interacts with matter by transmission, absorption, or scattering.

- **Interactions of energy and matter (9-12)**
  - Waves have energy and can transfer energy when they interact with matter.

LASER MODULE

***Be The Surgeon*: ZAP IT**

What You See / What You Do:
A large model eyeball has an array of lights (LEDs) mounted in the retinal area to represent the leaking blood vessels characteristic of one type of retinopathy. (The retina is a layer of specialized cells in the back of the eye.) Visitors attempt to correct the retinopathy by aiming a diode laser at the leaking vessels. When the visitor correctly aims the laser, the LEDs turn off to indicate that the leaking vessels have been sealed (coagulated). Text identifies anatomical structures and describes what visitors are trying to achieve and the importance of this activity.

What You Learn:
- Visitors learn some basic anatomy of the human eye.
- One surgical application of lasers is the correction of retinopathy. (This particular type of laser eye surgery does not correct vision, but prevents further loss of vision.)

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

- **Structure and function in living systems (5-8)**
  - Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue. 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.
  - Disease is a breakdown in structures or functions of an organism.

LASER MODULE

Real Stories / Real Surgery

What You See / What You Do:
This kiosk allows visitors to select and view short video clips of human interest stories and laser surgery.

Items presented in the videos are
- basic science regarding surgical lasers
- interviews with patients who have undergone the following procedures:
  - vision correction surgery (LASIK)
  - tattoo removal
  - skin resurfacing to remove facial wrinkles
  - vocal cord repair
- interviews with medical professionals
- some associated risks and benefits

What You Learn:
- Lasers are used in multiple surgical procedures that are performed on many structures of the body.
- Risks and benefits associated with laser surgery.
- Laser surgery requires the combined skills of a variety of professionals.

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

ENDOSCOPE MODULE

This module presents:

- **how fiber optic cables transmit light**
- **how fiber optic cables transmit an image**
- **the structure and function of endoscopic surgical instruments**

Background information

The development of fiber optic cables has contributed to the evolution of endoscopes, which are rigid or flexible tubes used to view and to work inside the body through small openings. Endoscopes have bundles of fiber optic cables that either direct light into the body or transmit an image back from the body to the physician. Advancements in the design of endoscopes launched the category of minimally invasive surgical procedures.

Activities in this module demonstrate how fiber optic cables transmit light and images. The design and function of endoscopes and their associated instruments are also explored.

ENDOSCOPE MODULE

Explore It!: FIBER OPTIC FUN

What You See / What You Do:
Fiber Optic Fun allows visitors to explore how light travels through two types of flexible fiber optic cables. Visitors control filtered light sources to illuminate three bundles of *end-emitting* fiber optic cables. This type of fiber optic cable is shielded along its entire length so that the light it transmits escapes (and is visible) only at the end. In this activity, the cables in each bundle are arranged to form a simple image, which glows as visitors introduce light into the cables. Intertwined among the end-emitting cables are thicker, *architectural* fiber optic cables that are continually illuminated by varying colors of light. These unshielded cables emit light from their sides, and the alternating colors allow visitors to trace the path of the light through the cable.

An illustration of light traveling through a lengthwise cross-section of an end-emitting fiber optic cable is featured on the text panel. Supporting text explains that the light is transmitted along the cable by internal reflections off of the cable's coating, even when the cable is bent. This ability to transmit light along a non-linear path is integral to the use of fiber optic cables in endoscopes.

What You Learn:
- Light travels through fiber optic cables.
- Fiber optic cables can bend and still transmit light.
- These are key factors in the design and function of endoscopes.

National Science Education Content Standards:
- **Light, heat, electricity, and magnetism (K-4)**
  - Light travels in a straight line until it strikes an object. Light can be reflected, refracted or absorbed.

- **Transfer of energy (5-8)**
  - Light interacts with matter by transmission, absorption, or scattering.

ENDOSCOPE MODULE

Explore It!: PICTURE PERFECT

What You See / What You Do:
Visitors discover how fiber optic cables transmit images and learn that resolution is the ability to differentiate fine details in an image. The screen-saver for this activity introduces visitors to pixelation by displaying a picture of the electronic presenter that is made up of large pixels (dot segments). When a visitor starts the activity, the electronic presenter explains pixelation and provides instructions for the activity.

Visitors use three large bundles of fiber optic cables to view a hidden picture. The first bundle contains only 427 fiber optic cables, and as a result visitors are not able to decipher the image. The second bundle has 747 cables, revealing a somewhat incomplete image. The third bundle contains 1,924 cables, tightly packed together, providing a complete image. The bundles are encased in transparent acrylic to allow visitors to see the difference in the number of fiber optic cables. Small text panels provide visitors with the number of fiber optic cables in each bundle.

On-screen animation demonstrates how each fiber optic cable transmits only a fraction of an image. The electronic presenter explains this is why thousands of fiber optic cables are used in endoscopes to produce images of high resolution. Since these images are the surgeon’s “eyes” during a procedure, high-quality resolution is critical to the success of endoscopic surgeries.

What You Learn:

- Resolution is the ability to differentiate fine details in an image.
- Because each fiber optic cable transmits only a fraction of an image, endoscopes require thousands of cables bundled together to generate a clear image of the inside of the body.

National Science Education Content Standards:

- **Understandings about science and technology (K-4)**
  - Tools help scientists make better observations, measurements, and equipment for investigation. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

- **Transfer of energy (5-8)**
  - Light interacts with matter by transmission, absorption, or scattering.

ENDOSCOPE MODULE

Explore It!: 3D MAZE

What You See / What You Do:

This activity prompts visitors to explore key factors in the design and function of endoscopic tools and to appreciate the challenge of technological development. Visitors must choose from a selection of tools that allow them to maneuver a block through a maze in a large, multi-level cube. The tools vary in length and shape and resemble endoscopic instruments. Visitors have access to the maze through holes in the sides of the cube. To succeed, visitors must think about the position of the block with respect to the holes and select tools of the appropriate size and shape to overcome obstacles presented by the maze. Photographs and functions of actual endoscopic instruments are included on the text panel to reinforce the concept that each instrument is designed for a specific purpose.

What You Learn:

- Visitors explore key factors involved in the design and function of endoscopic tools and appreciate the problems of technological development.

National Science Education Content Standards:

- **Understandings about science and technology (K-4)**
  - Tools help scientists make better observations, measurements, and equipment for investigation. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

- **Understandings about science and technology (9-12)**
  - Technological design is driven by the need to meet human needs and solve human problems.

ENDOSCOPE MODULE

Explore It!: TINY TOOLS

What You See / What You Do:
A variety of endoscopic instruments (graspers, suturers, staplers,…) are mounted to a graphics panel that describes the function of each instrument. Visitors manipulate the handles and compare the shape and movement of each instrument with its function. Visitors can also look through actual endoscopes.

What You Learn:
- This component emphasizes the link between the design of an endoscopic instrument and its function.

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - Tools help scientists make better observations, measurements, and equipment for investigation. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

ENDOSCOPE MODULE

Explore It!: GRAB IT

What You See / What You Do:
Visitors experience the challenge of manipulating objects from a distance using simulated endoscopic instruments. Visitors use the exposed handles of oversized endoscopic graspers encased in an acrylic dome. Blocks and other objects are under the dome for visitors to manipulate in open-ended exploration, leading them to appreciate the critical relationship between function and instrument design.

What You Learn
- There is a relationship between the design of an instrument and its function.
- Doctors who perform endoscopic surgery must rely on endoscopic instruments designed to manipulate objects from a distance.

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - Tools help scientists make better observations, measurements, and equipment for investigation. They help scientists see, measure, and do things that they could not otherwise see, measure, and do.

ENDOSCOPE MODULE

Be The Surgeon: INSIDE MOVES

What You See / What You Do:
Visitors use simulated endoscopic instruments to pass items with different shapes through rings that are mounted inside an opaque box. A camera inside the box displays the visitor's movements on a monitor outside the box. Watching the screen is the only way the visitor can see what s/he is doing in the box. Text informs visitors that surgeons practice similar activities when they train to perform endoscopic surgery. Exercises like this one incorporate the limited view and remote sense of touch that are features of actual endoscopic surgery.

What You Learn:
- One challenge of endoscopic surgery is manipulating the instruments to perform remote, complex tasks while simultaneously relying on a video monitor to see what you are doing.

National Science Education Content Standards:
- **Properties of objects and materials (K-4)**
  - The position of an object can be described by locating it relative to another object or the background.

- **Understandings about science and technology (5-8)**
  - Technological designs have constraints. Some constraints are unavoidable; other constraints limit choices in the design, for example environmental protection, human safety, and aesthetics.
  - Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world.

- **Understandings about science and technology (9-12)**
  - Technological design is driven by the need to meet human needs and solve human problems.

ENDOSCOPE MODULE

***Be The Surgeon*: SCOPE IT OUT**

What You See / What You Do:

Visitors can test their eye-hand coordination and perform simulated endoscopic surgery on a fabricated patient who has aspirated an object into a lung. Visitors try to retrieve the item using a simulated endoscopic instrument. The activity is surrounded by X-ray images of people who have swallowed or aspirated an object.

What You Learn:

- Endoscopic procedures are performed with specialized instruments through small openings in the body (including naturally occurring openings like the mouth).
- Endoscopic procedures require skill to manipulate the instruments and to complete a task from a distance.

National Science Education Content Standards:

- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

- **Risks and Benefits (5-8)**
  - Individuals can use a systematic approach to thinking critically about risks and benefits.

- **Understandings about science and technology (9-12)**
  - Technological design is driven by the need to meet human needs and solve human problems.

ENDOSCOPE MODULE

***Be The Surgeon*: VIRTUAL O.R.**

What You See / What You Do:
Prior to starting this activity, visitors view a short video clip of the electronic presenter, who is holding an endoscopic instrument called a high-frequency scalpel. The scalpel blade on this instrument vibrates 55,000 times per second, allowing it to cut and seal blood vessels at the same time and enabling surgeons to perform virtually bloodless surgery. The electronic presenter invites the visitor to use this scalpel to assist in a virtual surgery.

The video cuts to an operating room (O.R.) where an endoscopic surgery is underway. The surgeon briefly describes the procedure to the visitor. The screen image changes into a computer-animated endoscopic view of the patient's abdomen. The visitor assists in the surgery by controlling a joystick that looks like the handle of the high frequency scalpel. Voice-over of the surgeon provides directions, and multiple scenarios are built into the program to demonstrate the effects of the visitor's mistakes and successes.

What You Learn:
- There is a relationship between the design of an instrument and its function.
- The blade of this endoscopic instrument vibrates so quickly that it cuts through tissue and coagulates blood at the same time, allowing virtually bloodless surgery.

National Science Education Content Standards:
- **Position and motion of objects (K-4)**
  - The position of an object can be described by locating it relative to another object or the background.

- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

- **Structure and function in living systems (5-8)**
  - Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue. 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.

VIRTUAL O.R. (CONTINUED)

- **Understandings about science and technology (5-8)**
  - Technological designs have constraints. Some constraints are unavoidable; other constraints limit choices in the design, for example environmental protection, human safety, and aesthetics.
  - Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world.
  - Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

- **Risks and Benefits (5-8)**
  - Individuals can use a systematic approach to thinking critically about risks and benefits.

- **Understandings about science and technology (9-12)**
  - Technological design is driven by the need to meet human needs and solve human problems.

ENDOSCOPE MODULE

Real Stories / Real Surgery

What You See / What You Do:
This kiosk allow visitors to select and view short video clips of human interest stories and endoscopic procedures.

Items presented in the videos are
- pre- and post-operative interviews with patients who have undergone the following endoscopic procedures:
  - ACL repair
  - back surgery
  - retrieval of an aspirated object
  - female infertility treatment
- interviews with medical professionals involved in the procedures
- some risks and benefits of the procedures

What You Learn:
- There are a vast number of endoscopic procedures that are performed on many parts of the body.
- Risks and benefits associated with endoscopic procedures.
- Endoscopic procedures require the skill of a variety of professionals.

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

ULTRASOUND MODULE

This module presents:

- **sound**
- **the use of high-frequency sound (ultrasound) in surgery**
- **the use of high-frequency (ultrasonic) mechanical vibrations in surgery**

Background information

The term *ultrasonic* is used to describe many types of surgical procedures and instruments. However, this term can be misleading if it is interpreted to mean *ultrasound.*

When an object vibrates, it generates sound. The number of vibrations that occur each second is said to be the vibration's frequency. When an object vibrates very quickly (more than 20,000 times each second), the frequency of these vibrations is said to be *ultrasonic*. Sound generated at ultrasonic frequencies is called *ultrasound* and is above the range of sounds we can hear.

In surgical procedures that use ultrasound waves, the sound waves travel from an outside source into the patient's body. In these procedures, the sound waves are the surgical tool. Other techniques use tools that vibrate at an ultrasonic frequency. These tools must be in direct contact with the surgical site because their mechanical vibrations are what affect the tissue.

Explore It! activities in this module teach basic principles of sound. *Be the Surgeon* and *Real Stories / Real Surgery* activities in this module feature surgical procedures that capitalize on the energy of either ultrasound or ultrasonic mechanical vibration.

ULTRASOUND MODULE

Explore It!: SOUND IN THE ROUND

What You See / What You Do:
Visitors discover that sound results from vibrating objects and travels in waves at different frequencies. In this activity, a circular table houses a lighted tank of mineral oil. A metal ball at the center of the tank is connected to an external telegraph-like lever. Circular wave patterns form in the oil when visitors tap the lever and cause the ball to vibrate. Visitors change the vibration rate of the ball by changing their tapping rate. Text explains that the concentric wave patterns are analogous to sound waves being emitted from a vibrating object, and that the more vibrations there are per second, the higher the frequency of the sound.

What You Learn:
- Sound is generated by vibrating objects.
- The more vibrations per second, the higher the frequency of the sound.
- Sound travels in waves that have areas of high and low pressure.

National Science Education Content Standards:
- **Position and motion of objects (K-4)**
  - Sound is produced by vibrating objects.
  - The frequency (pitch) of the sound can be varied by changing the rate of vibration.

ULTRASOUND MODULE

Explore It!: VISIBLE VIBES

What You See / What You Do:
This activity allows visitors to create sounds with different frequencies and to see that sound carries energy through a medium. Visitors vary the frequency (pitch) of a sound by waving their hands near a sensor. The resulting sound is emitted from a speaker and travels through the air to a drumhead suspended above the speaker. The drumhead is covered with a layer of multi-colored plastic beads that vibrate due to the energy of the sound waves. Graphics and text show the range of frequencies for sounds that are audible to humans. Infrasound and ultrasound are described as being below and above this range, respectively. Accompanying text conveys that the energy in ultrasonic shock waves is used by doctors to break apart kidney stones.

What You Learn:
- Sound waves carry energy.
- Sound waves travel through a medium.
- Sound waves travel at different frequencies.
- Raising the frequency of a sound raises its pitch, while lowering the frequency of a sound lowers its pitch.
- The energy in ultrasonic (very high frequency) shock waves is used to break up kidney stones.

National Science Education Content Standards:
- **Position and motion of objects (K-4)**
  - The frequency (pitch) of a sound can be varied by changing the rate of vibration.
- **Transfer of energy (5-8)**
  - Energy is associated with sound.
- **Interactions of energy and matter (9-12)**
  - Waves have energy and can transfer energy when they interact with matter.

ULTRASOUND MODULE

Be The Surgeon: TISSUE TREMORS

What You See / What You Do:

Visitors push a start button that activates an introductory video of the electronic presenter. *Tissue Tremors* demonstrates how ultrasonic shock waves are used to break up kidney stones in a procedure called ultrasonic lithotripsy. On-screen animation illustrates the actual procedure, showing how an elliptical reflector focuses hundreds of ultrasonic shock waves at a kidney stone. Following the animation, the electronic presenter provides instructions for the activity.

The activity is like a pinball machine with a ball and a shooting mechanism, but it is housed in a table shaped like a partial ellipse. Visitors first assemble a three-dimensional puzzle of a kidney stone on a kidney-shaped platform. The kidney-shaped platform is fixed on top of a metal spring located at the far end of the table. Visitors aim the shooter in any direction and release the ball. Because the walls of the table form an ellipse, the ball always bounces off an inside wall to strike the spring, vibrating the kidney stone puzzle until it breaks apart. The electronic presenter explains that the ball represents the last shock wave needed to destroy the kidney stone.

In addition, real kidney stones are displayed to show their actual size.

What You Learn:

- Ultrasonic lithotripsy uses focused shock waves to destroy kidney stones.

National Science Education Content Standards:

- **Transfer of energy (5-8)**
  - Energy is associated with sound.

- **Interactions of energy and matter (9-12)**
  - Waves have energy and can transfer energy when they interact with matter.

ULTRASOUND MODULE

Real Stories / Real Surgery

What You See/What You Do:
This kiosk allows visitors to select and view short video clips of human interest stories and procedures.

Items presented in the videos are
- a brief explanation of the difference between using high-frequency sound (ultrasound) and using an instrument that is vibrating at an ultrasonic frequency
- interviews with patients who have undergone the following procedures:
  - extracorporeal shock wave lithotripsy (ESWL) to break up kidney stones
  - ultrasound-assisted lipoplasty to remove unwanted fat
  - phacoemulsification to remove a cataract
- interviews with medical professionals
- some associated risks and benefits

What You Learn:
- The difference between ultrasonic mechanical vibration and ultrasound, in addition to how both are used in surgery.
- Risks and benefits associated with the procedures.

National Science Education Content Standards:
- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

CRYOSURGERY MODULE

This module presents:

- **the effect of cold temperatures on cells**
- **how extremely cold temperatures are used to perform surgery**

Background information

Whereas the four other modules in this exhibit address the effects of various forms of energy acting on the body, this module focuses on the removal of thermal energy from living tissues. Traditionally, cryosurgery has been used to treat external tumors such as those on the skin, but recently some physicians have begun using it as a treatment for tumors that occur inside the body.

For internal tumors, liquid nitrogen is circulated through an instrument called a cryoprobe, which is placed in contact with the tumor. The temperature of the cryoprobe is approximately −196 °C (−321 °F). An ice ball forms as the tissue surrounding the cryoprobe freezes. The ice ball is allowed to extend just past the tumor and into healthy tissue to ensure that all of the diseased tissue is destroyed. This rapid freezing process causes ice crystals to form inside cells, damaging cell membranes and intracellular structures and resulting in cell death. Ice may also form outside of cells, removing available water and causing dehydration of the cells.

After the ice ball has formed, the tissue is slowly warmed. This thawing process causes even more cells to die, often due to a lack of oxygen since damaged blood vessels can no longer function. Doctors repeat these "freeze-thaw cycles" during cryosurgery to maximize the efficacy of the procedure.

The activities in this module explain the cellular effects of cryosurgery and demonstrate how cryosurgery is used to destroy cancerous tumors in the body.

CRYOSURGERY MODULE

Explore It!: FAST FREEZE

What You See / What You Do:

This is a full-body experience that conveys the concept of the freeze-thaw cycles used in cryosurgery. This component is a small room that is approximately 55ºF inside. Signage notifies visitors that they are undergoing a "freezing" process as they walk into the room.

Inside the room, visitors watch a short video clip featuring the electronic presenter, who compares the modest temperature change experienced by the visitor to the extreme temperature change that occurs during cryosurgery. Computer-animated graphics provide a simplified explanation of how ice crystals form inside cells during cryosurgery, causing the cell membranes to rupture and the cells to die. The electronic presenter provides narration for the animation and explains that multiple cycles of freezing and thawing are often used to maximize damage to the diseased tissue. As visitors exit, signage declares that they are entering the slow "thawing" phase. A thermometer graphic compares the temperature of the *Fast Freeze* room to standard room temperature, and normal body temperature to tissue temperature during cryosurgery.

What You Learn:

- Cells in the body contain water.
- Cryosurgery uses extremely cold temperatures to freeze water in cells, which ruptures cell membranes and causes cells to die.
- Cryosurgery uses cycles of freezing and thawing to maximize the amount of diseased tissue that is destroyed.

National Science Education Content Standards:

- **Properties of objects and materials (K-4)**
  - Materials can exist in different states — solid, liquid, and gas. Water can be changed from one state to another by heating or cooling.

- **Transfer of energy (5-8)**
  - Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

- **Structure and function in living systems (5-8)**
  - Cells carry on the many functions needed to sustain life.

CRYOSURGERY MODULE

Be The Surgeon: COOL SURGERY

What You See / What You Do:
This is a virtual reality simulation of cryosurgery that allows visitors to freeze tumors in a large, 3D computer-animated liver. Visitors control an animated cryoprobe in real-time by using a simulated cryoprobe that is tethered to the activity table. Visitors try to position the animated cryoprobe in one of the tumors so they can freeze and destroy the tumor tissue. Visitors press a button to begin the freezing process, which results in the formation of an ice ball. Animation indicates when the tissue is freezing and subsequently thawing. Visitors may repeat the procedure three more times in an attempt to destroy all of the tumor tissue. On-screen text gives feedback regarding the success of the procedure, providing the percentages of both tumor tissue and healthy tissue that were destroyed.

What You Learn:
- Cryosurgery uses cycles of freezing and thawing to destroy cells in diseased tissue.
- One application of cryosurgery is to destroy tumors in the liver.

National Science Education Content Standards:
- **Properties of objects and materials (K-4)**
  - Materials can exist in different states — solid, liquid, and gas. Water can be changed from one state to another by heating or cooling.
  - The position of an object can be described by locating it relative to another object or the background.

- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

- **Transfer of energy (5-8)**
  - Energy is associated with heat.
  - Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.

COOL SURGERY (CONTINUED)

- **Structure and function in living systems (5-8)**
  - Cells carry on the many functions needed to sustain life.
  - Specialized cells perform specialized functions in multicellular organisms. Groups of specialized cells cooperate to form a tissue. 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.

- **Understandings about science and technology (5-8)**
  - Technological designs have constraints. Some constraints are unavoidable; other constraints limit choices in the design, for example environmental protection, human safety, and aesthetics.
  - Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance. Risk is part of living in a highly technological world.
  - Technological solutions have intended benefits and unintended consequences. Some consequences can be predicted, others cannot.

- **Risks and Benefits (5-8)**
  - Individuals can use a systematic approach to thinking critically about risks and benefits.

- **Understandings about science and technology (9-12)**
  - Technological design is driven by the need to meet human needs and solve human problems.

CRYOSURGERY MODULE

Real Stories / Real Surgery

What You See/What You Do:

This kiosk allows visitors to select and view short video clips of human interest stories and cryosurgery procedures.

Items presented in the videos are
- cryosurgery to remove cancerous tumors of the liver
  [Note: This is an *open* procedure. Minimal views of an upper abdominal cavity are shown.]
- cryosurgery to treat prostate cancer
  [Note: Uses video of O.R. set-up and computer animation of male reproductive anatomy (representative views).]
- interviews with patients and medical professionals
- some associated risks and benefits

What You Learn:

- Current applications of cryosurgery.
- Risks and benefits associated with cryosurgery.

National Science Education Content Standards:

- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid new problems.

ZAPCAM

What You See / What You Do:
This cabin simulator seats up to 18 people and features a four-minute ride experience for visitors. Prior to riding the simulator, visitors view a five-minute program that introduces the five surgical technologies featured in the exhibit and establishes the premise of the ride. Visitors are told that ZapCam is a tiny, remote-controlled camera that will take them into a patient's body to record video of surgery in progress. This provides visitors with an exciting, immersive experience in which they witness interactions of the human body with featured surgical procedures from vantage points inside the body. This gives visitors a unique perspective not possible at other components and helps them grasp some challenging concepts while embarking on a fun adventure.

Graphics panels adjacent to the queuing line for ZapCam chronicle advances in surgical techniques and instrumentation through notable periods of history. This will complement the focus on contemporary surgical technologies in the exhibit and the futuristic premise of the simulator ride.

> Note: A small room close to ZapCam is provided for visitors who cannot or do not wish to ride the simulator. These visitors progress through the queuing line and view the pre-show with other visitors; however, they watch the ZapCam program on a large screen in this room.

What You Learn:
- The complete ZapCam experience reinforces the five technologies presented in the exhibit, drawing them together in one component. It creates a shared experience for visitors, addressing social needs while providing a common knowledge base.

National Science Education Content Standards:
- **The characteristics of organisms (K-4)**
  - Each plant or animal has different structures that serve different functions in growth, survival and reproduction.

- **Understandings about science and technology (K-4)**
  - People have always had problems and invented tools and techniques to solve problems. Trying to determine the effects of solutions helps people avoid some new problems.

ZAPCAM (CONTINUED)

- **Science as a human endeavor (K-4)**
  - Science and technology have been practiced by people for a long time.
  - Many people choose science as a career and devote their entire lives to studying it.

- **Transfer of energy (5-8)**
  - Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

- **Science and technology in society (5-8)**
  - Science and technology have advanced through contributions of many people, in different cultures, at different times in history.

- **History of science (5-8)**
  - Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

- **Interactions of energy and matter (9-12)**
  - Waves have energy and can transfer energy when they interact with matter.

- **Understandings about science and technology (9-12)**
  - Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research.
  - Technological design is driven by the need to meet human needs and solve human problems.

- **Historical perspectives (9-12)**
  - In history, diverse cultures have contributed scientific knowledge and technologic inventions.

ZAP JR.

What You See / What You Do:
This is a defined area for families with children ages 5-8 years old that encourages exploration and learning through play. It is designed to initiate a familiarity with basic human anatomy and to encourage role-play. Ample seating is provided for both children and adults. The area is designed to accommodate approximately twenty-five children at once. Stanchion ribbons incorporated into the modular walls provide the option to enclose the area for individual school groups.

Basic anatomy activities

- fabric internal organs can be attached to aprons featuring the human body
- child-shaped mirrors with fun graphics of different body systems (skeletal, digestive, and circulatory) are along the walls
- puzzle pieces featuring parts of various organ systems can be mixed and matched on a large body-shaped magnetic puzzle

Role-playing activities

- props to encourage role-play
  - brightly colored, child-sized surgical scrub shirts and lab coats
  - toy medical instruments
  - light boxes and X-rays
  - child-sized examination table
  - pretend sink for “scrubbing up” prior to surgery

- child-sized images of medical professionals have mirrors above the shoulders so children see themselves wearing medical apparel

- simple graphic of a child with designated spots for children to place simulated stethoscopes to hear body sounds (a playful graphic of a physician listening to a child's chest accompanies this activity)

Operation® game
Children can pretend to perform surgery by playing an oversized version of Hasbro’s Operation® game. The game is approximately one foot in height, so children can crawl on it as they play.

What You Learn:

- Activities in Zap Jr. build on prior knowledge and previous experiences to increase the comfort levels of young visitors with the human body, medical professionals and procedures, as well as various healthcare settings.

ZAP JR. (CONTINUED)

National Science Education Content Standards:

- **Understandings about scientific inquiry (K-4)**
  - Simple instruments, such as magnifiers, thermometers, and rulers, provide more information than scientists obtain using only their senses.

- **The characteristics of organisms (K-4)**
  - Each plant or animal has different structures that serve different functions in growth, survival, and reproduction. For example, humans have distinct body structures for walking, holding, seeing and talking.

- **Personal health (K-4)**
  - Individuals have some responsibility for their own health. Students should engage in personal care — dental hygiene, cleanliness, and exercise — that will maintain and improve health. Understandings include how communicable diseases, such as colds, are transmitted and some of the body's defense mechanisms that prevent and overcome illness.

- **Science as a human endeavor (K-4)**
  - Many people choose science as a career and devote their entire lives to studying it. Many people derive great pleasure from doing science.

TEXT PANELS

(INSERT TEXT PANELS)

ELECTRONIC PRESENTER SCRIPTS

GAMMA KNIFE MODULE

***Be The Surgeon*: TARGETING**

Screen Saver: Animation of human head wearing the Gamma Knife helmet with gamma rays entering the head. Text reads: "Press Start Button".

Electronic Presenter Script

electronic presenter: You're going to do this activity after you've seen it once, so watch carefully. This is a simulated Gamma Knife. The Gamma Knife uses gamma rays to destroy harmful things in the brain, without making a cut. Gamma rays are like X-rays only stronger.

Holes in the helmet are opened and closed in a certain pattern to focus gamma rays on their target and not on healthy tissue. A medical physicist helps the doctor to choose the pattern.

The Gamma Knife operates on things in the brain that other kinds of surgery can't reach. Now, you try it. Try to hit this tumor to save this patient's hearing.

(Animated tumor blinks.)

Use the model helmet in front of you and push the buttons to open and close the holes in the pattern you want. You'll see the path on the screen.

(Animated gamma beams appear on screen.)

Plan carefully to miss these important structures: the facial nerve, which affects sensations in your face, the auditory nerve, which affects hearing, and the brain stem which affects walking.

(These structures in the transparent head blink as she names them.)

When you've finished planning, press the button marked Zap! to perform the virtual surgery and see how well you did. Good luck!

TARGETING (Electronic Presenter Script -Continued)

Outcome Responses

Since multiple outcomes are possible for this activity, four video clips provide feedback. Video clip number #1 plays when the surgery was performed correctly. Clips #2-4 will play (individually or in tandem) when the surgery has affected the respective structure(s).

electronic presenter:

(Clip1) Congratulations! You chose the right pattern and destroyed the tumor. You've saved the patient's hearing. Great job.

(Clip 2) You've hit the facial nerve which may numb the patient's face, but the tumor might still be controlled.

(Clip 3) You've hit the auditory nerve which may damage the patient's hearing, but the tumor might still be controlled.

(Clip 4) You've hit the brain stem, so the patient may have trouble walking, but the tumor might still be controlled.

LASER MODULE

Be The Surgeon: MATCH 'EM

Screen saver description: Animation of random, darting laser beams of different colors. Text on the screen reads "Press Start Button". Video begins with the electronic presenter dissolving onto the screen, dodging laser beams as she speaks.

Electronic Presenter Script

electronic presenter: These are different kinds of lasers. They're used to do different kinds of surgery. Whoa!
How do you choose?

(Laser beams disappear, and she removes her protective goggles.)

electronic presenter: (voice over) One way is wavelength. It affects the laser's color, how deep it goes, and what it does.

(As she says this, an animation of a sinusoidal wave is used to demonstrate wavelength. Text and brackets above the wave identify the wavelength, which varies as the animated wave shortens and elongates. As the wavelength changes, the color of the animated wave also changes. The electronic presenter then returns to the screen.)

electronic presenter: Select a laser in front of you, read the clue, and try to match it to the proper surgery. See how well you match 'em!

LASER MATCH 'EM (Electronic Presenter Script Continued)

When visitors select a laser, a clue regarding that type of laser appears on the screen. When visitors use the correct laser to perform a procedure, **animation** and **voice over** describe how that particular laser performs the procedure.

CO_2 LASER

clue: This laser produces a narrow beam used for cutting in this surgery.

correct response: Right! The CO_2 laser is used on vocal chords because it doesn't penetrate too deeply or produce too much heat. Heat can shrink your vocal chords and change the sound of your voice.

SHORT-PULSED LASER

clue: This type of laser doesn't leave a lot of scars and comes in different colors.

correct response: Good job! Different colored, short-pulsed lasers are absorbed by different colored ink. The laser doesn't remove the tattoo completely, it just fades it by breaking up the ink.

HOLMIUM-YAG LASER

clue: This laser creates shock waves like a jack hammer to break up harder tissue.

correct response: Congratulations! The holmium-YAG breaks up damaged knee cartilage without a lot of heat. Excess heat could damage bones or soft tissue and make it difficult to walk or play sports.

INCORRECT CHOICE

response: Try again!

ENDOSCOPE MODULE

Explore It!: PICTURE PERFECT

Screen saver description: An image of the electronic presenter that is made up of large pixels (dot segments). Text says "Press Start Button".

Electronic Presenter Script

electronic presenter: When you look at these images, consider this. Images are made up of little tiny dots called pixels, like pieces of a puzzle.
One fiber optic cable transmits one pixel.

(An animated bundle of fiber optic cables appears. A small image of the electronic presenter is at one end of the bundle. As the electronic presenter says the following line, her talking image is transmitted, via pixels, to the other end of the fiber optics bundle.)

electronic presenter: A bundle of fiber optics transmits a whole picture. Just like that!

(The bundle of fiber optics morphs into an endoscope.)

electronic presenter: (voice over) Endoscopes have bundles of fiber optic cables like the ones in front of you. Doctors use them to get pictures of the inside of your body.

(The electronic presenter appears again.)

electronic presenter: Slide the mystery image over each bundle of fiber optics. What do you notice?

ENDOSCOPE MODULE

***Be The Surgeon*: VIRTUAL O.R.**

Screen saver description: Video loop of medical professionals in an operating room. Text says "Press button to do surgery".

Electronic Presenter Script

Video begins with the electronic presenter in a hospital corridor outside a set of operating room (O.R.) doors.

electronic presenter: You're about to help a surgeon do an operation. The patient has severe heartburn and needs surgery. If you do it right, it won't be bloody, because you'll use a high frequency scalpel.

(She holds the actual scalpel and points to the blade as she says her next line.)

electronic presenter: Now, you can't see it with your eye, but the blade vibrates 55,000 times a second! So it cuts and stops bleeding at the same time. And that's good for the patient. They're waiting for you. Good luck!

(Video inside an O.R while an endoscopic procedure is underway. Camera moves to the female surgeon in the O.R. who is standing over the patient.)

surgeon: Hi. Thanks for assisting. Please stand here. Let me show you where we are.

(She looks at an O.R. monitor displaying an endoscopic view of the patient. Shot dissolves to an animated anatomical view. An on-screen arrow points to each organ as she speaks...)

surgeon: We've lifted up the left side of the liver to show you the upper stomach...the lower esophagus...the diaphragm...and the spleen.

The visitor's role in the surgery is to cut three different items. The surgeon provides instructions and a response for each cut.

1st Cut

instructions

surgeon: We need to free the stomach from everything it's attached to. We'll start here. Squeeze the handle in front of you to use the scalpel. Cut through the tissue along this line. But be careful. There's a blood vessel behind there. You need to cut that also.

Be sure to grasp the entire vessel all at once and hold it for a count of three so it won't bleed while you cut it.

response if successful

surgeon:
(voice over) That's very good. Now, we can see this side of the stomach and this side of the lower esophagus. Now, let's go to the other side of the stomach and cut through the blood vessels between the stomach and the spleen.

2nd Cut

instructions

surgeon:
(voice over) Now, cut these vessels one at a time. Remember to grasp the entire vessel all at once and hold it for a count of three so it won't bleed while you cut it.

response if successful

surgeon:
(voice over) Very good. Now, let's cut the tissue between the upper stomach and the diaphragm.

3rd Cut

instructions

surgeon:
(voice over) Start here. Cut through the tissue along this line. Be careful. There's a blood vessel behind there. You need to avoid it.

response if successful

surgeon: Very good. Now, we can see this side of the stomach and this side of the esophagus. The upper part of the stomach is now completely free. I'm wrapping the upper part of the stomach around the lower part of the esophagus, and I'll stitch it in place. Now, I'll close the small incisions.

VIRTUAL O.R. (Electronic Presenter Script -Continued)

Response to all unsuccessful cuts
(The surgeon's tools are seen on-screen as she speaks.)

surgeon:
(voice over)

You've nicked the vessel. Don't panic. I'm grasping this side of the vessel. You grab the entire blood vessel and hold it for a count of three. Very good. Bleeding's stopped. We'll do the same thing on the other side. Very good. We've fixed the problem. Let's move on.

Response when visitor tries to cut in non-designated area
(On-screen arrow points to appropriate location.)

surgeon:
(voice over)

Over here.

Conclusion
(Video shows surgeon removing the endoscope from the patient as she speaks.)

surgeon: Thanks, you did a great job.

ULTRASOUND MODULE

***Be The Surgeon*: TISSUE TREMORS**

Screen saver description: A pattern of concentric, circular waves cycle in and out. Text says “Press Start Button”.

Electronic Presenter Script

Video begins with the electronic presenter standing beside the Tissue Tremors activity table.

electronic presenter: This activity shows how ultrasonic waves are used to break up kidney stones. Here’s how it works and what *you* get to do.

(Animation of lithotripsy starts with a side view of a person lying in the lithotripsy tub of water. Shock waves travel from the emitter, bounce off the ellipsoidal reflector, and hit the kidney stone, breaking the stone into sand particles. Voice over is heard during animation.)

electronic presenter: Hundreds of ultrasonic shock waves travel through the water. Each wave bounces off an elliptical reflector and hits the kidney stone. These focused waves generate a *powerful* force…strong enough to blast a kidney stone into sand.

Now it’s your turn. Assemble the kidney stone puzzle on the platform.

(The electronic presenter is shown assembling the kidney stone puzzle.)

electronic presenter: The ball inside the table represents the *last* shock wave you'll need to break the stone.

(Shot of electronic presenter pivoting the ball shooter as speaks.)

electronic presenter: Shoot the ball in any direction. What happens?

CRYOSURGERY MODULE

***Explore It!*: FAST FREEZE**

There is **no screen saver** because the video is activated when a visitor enters the component.)

Electronic Presenter Script

As she is wiping frost off the screen, the electronic presenter (who is wearing a parka) appears. She shutters and speaks.

electronic presenter: Brrrr! I won't keep you. It's really cold in here! But that's nothing. The probe used in cryosurgery is over 300 degrees below 0 Fahrenheit! Watch how it destroys tumors in your body.

(Animation shows cells freezing and rupturing.)

electronic presenter: (voice over) Cells in your body contain water. The cold temperatures used in cryosurgery cause the water in the cells to turn to ice. This ice causes cells to rupture and die.

To destroy an entire tumor, doctors repeatedly freeze and thaw the cells.

(Electronic presenter returns to screen.)

electronic presenter: Now, go thaw yourselves!

CRYOSURGERY MODULE

***Be The Surgeon*: COOL SURGERY**

Screen saver description: Animated liver is rotating on the screen.

Electronic Presenter Script

The electronic presenter in this component is all voice over and provides activity instructions only. Instructional text and clips from the activity accompany the electronic presenter's voice over.

electronic presenter: (voice over) Freeze the tumors in the liver. Use the track ball to rotate the liver and see the tumors better.

electronic presenter: (voice over) Locate the tumor with the tip of the cryoprobe. The tip turns green inside the tumor.

(Accompanying shot of green cryoprobe in a tumor.)

electronic presenter: (voice over) *Press* and *hold* the Freeze button to control the size of the ice ball. Use up to four ice balls to destroy both tumors.

(Shot of ice ball forming.)

RESOURCES

WEB SITES

http://www.zapsurgery.org
The homepage for *Zap! Surgery Beyond the Cutting Edge.* Educators and science center staff can access a database that can be searched by key words and contains the information in this document. Customized versions of this document can be printed to serve individual needs. In addition, slide shows and audio (taken from the *Real Stories / Real Surgery* components) of actual surgical procedures will be featured. Links will be embedded in the slide shows to provide additional information regarding the procedures or the surgical technologies.

http://www.accessexcellence.org/
The National Health Museum's site for health and bioscience teachers and learners. Includes a Middle School Forum for teachers and students, in addition to a collection of hands-on classroom activities that can be searched by National Science Content Standard. A career center provides projects and resources that promote awareness of scientific careers and help dispel stereotypes of scientists.

http://www.innerbody.com/htm/body.html
Human anatomy on-line. Anatomy is presented in a non-threatening manner.

http://faculty.washington.edu/chudler/neurok.html
Neuroscience for Kids site provides activities on the brain and nervous system. The site is applicable to elementary and secondary teachers and students.

http://www.elekta.com/www/elekta_web.nsf/html/framemain?opendocument
An explanation of Gamma Knife radiosurgery provided by the manufacturer of the Gamma Knife.

http://www.biointeractive.org
Features interactive learning modules and virtual labs.

http://www.exploratorium.edu/spectra_from_space/gammaray_activity.html
An activity about gamma rays from The Exploratorium in San Francisco.

http://science-eduction.nih.gov/homepage.nsf
Office of Science Education (OSE) of the National Institutes of Health (NIH). Includes a link where you can order free "Women are Surgeons" videos and posters (supported by the Office of Research on Women's Health).

http://www.mdchoice.com/cyberpt.acls/acls.asp
Perform diagnostic tests and administer medications to your cyberpatient.

http://www.cs.iupui.edu/~pellison/colorworm/home.html
Entertaining activities and information associated with lasers. Designed for middle-school students.

LITERATURE

Allison, Linda. *Blood and Guts.* Covelo, CA: The Yolla Bolly Press, 1976.

Bruun, Ruth D. and Bruun, Bertel. *The Human Body*. New York: Random House, 1982.

Eisenkraft, Arthur. *Active Physics: Medicine*. Armonk, NY: It's About Time, Inc, 1998.

Hellman, Samuel and Vokes, Everett. Advancing Current Treatments for Cancer. *Scientific American*. September, 1996.

Hewitt, Paul G. *Conceptual Physics*. 7th ed. New York: Harper Collins College Publishers, 1993.

Macaulay, David. *The Way Things Work*. Boston: Houghton Mifflin Company, 1996.

Walker, Richard. *The Children's Atlas of the Human Body*. Brookfield, CT: The Millbrook Press, 1994.

SUPPLEMENTAL ACTIVITIES

ACTIVITIES RELATED TO GAMMA KNIFE MODULE

ACTIVITIES RELATED TO LASER MODULE

Note that many of these activities, which teach principles of light, also relate to the learning objectives of the Endoscope Module.

Lightapallooza

What's the point?

- Light can be reflected, refracted and transmitted.
- Reflection occurs when a light ray bounces off of a surface.
- Refraction occurs when a light ray bends while passing across a medium boundary.
- Transmittance is when light passes through a medium.
- White light consists of different colors of light with different wavelengths.
- White light diffuses with distance.
- Laser light is only one wavelength, therefore it has different reflecting, refracting, and transmitting properties than white light.
- Laser light does not diffuse as much as white light when traveling over a distance.

Materials:

- White light sources
- Laser light
- Prisms
- Mirrors
- Lenses

Procedure:

1. Shine a white light through a prism. Observe its refraction properties. Repeat with laser.
2. Shine a white light at a mirror(s) so that the light reflects and hits a target on the opposite side of the room **(see Figure 1)**. Repeat with laser.

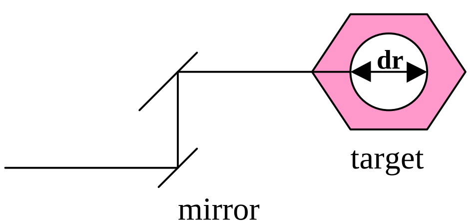


Figure 1

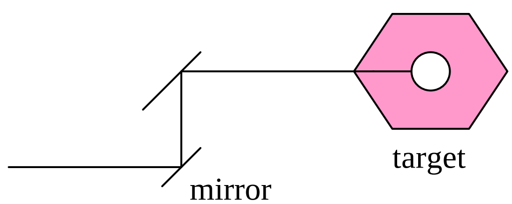


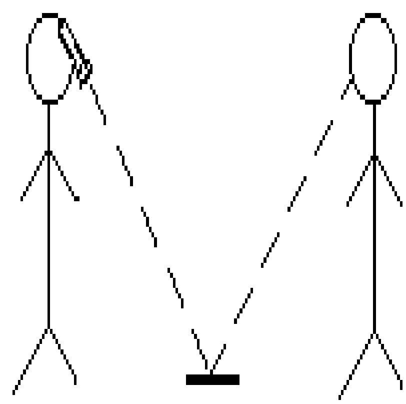
Figure 2

3. Measure the **diffusion radius** (**dr**) of light at the target **(Figure 1)**.
   Repeat with laser **(Figure 2)**.
4. Shine several white light sources at different lenses. Repeat with laser.
5. Observe and record the differences.

PROBLEM PRESENTATION / EXPLORATION

A. Flashlight Geometry

1. Needed for this exercise are two students of the same height, a flashlight, a flat mirror (15 cm x 15 cm), 2 meter sticks, and some masking tape.
2. Have two students stand facing one another 3-4 meters apart next to a blank wall. In between the students place a flat mirror (15 cm x 15 cm) on the floor.
3. With the lights dimmed have student #1 raise the flashlight to "nose-level" and aim it at the mirror. The flashlight bulb should be as close to his/her nose as possible.
4. Where will student #1 have to stand in order that he/she can aim it at the mirror on the floor and have the beam bounce up to student #2's nose?



5. Once this has successfully been done, measure how far each student is standing from the center of the mirror.
6. Repeat this activity with another student kneeling. Where would student #1 have to stand so that the flashlight beam hits student #3 in the nose?
7. Having studied the pattern involved in the first two cases, where would student #1 have to stand and where would the mirror have to be located to make the flashlight beam hit the intersection of the wall and ceiling? Is there more than one correct solution to this problem? [Yes]

B. **X** Marks the Spot

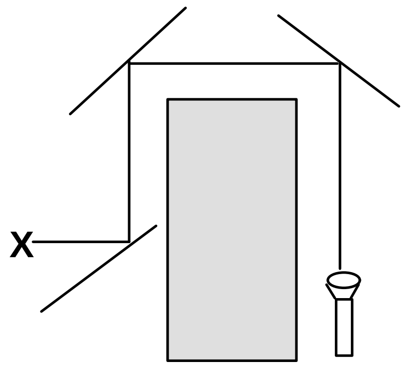
1. The CHALLENGE is to, with the help of three mirrors, shine a flashlight around an obstacle to hit the spot marked with an X.
2. The materials needed for this CHALLENGE are a penlight flashlight (obviously, if you have a **laser**, use it), three pocket mirrors (approximately 5 cm x 8 cm), clay or Play Doh®, a shoe box, and a card with a black X on it.
3. The rules are simple:
   a.) Have students draw a diagram of where they think the mirrors should be placed before they are given the mirrors and other equipment.
   b.) Arrange the three mirrors (all three must be used) in such a way that by aiming the flashlight a beam of light can be bounced around so that it will finally focus on a card with the X in the center. It would probably help to dim the lights in the room.
   c.) The X must be placed on the card and located on the opposite side

of the shoe box.

d.) The beam must be parallel to the table or floor on which the box is placed.

e.) The clay can be used to support the mirrors while they are being positioned.

f.) Compare the final solution(s) with the predicted diagrams. One of many possible ways to set this up is sketched in the diagram.



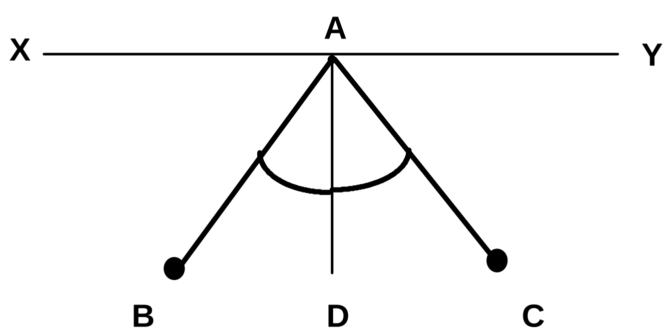
CLASS RESPONSE / CONCEPT INVENTION

A. Intuitive Angles

1. Find a volunteer who claims to be a good pool player for this demo.
2. On top of a lab table place a piece of wood approximately 5 cm by 10 cm by 100 cm. Arrange it so that the wide face is perpendicular to the table top.
3. In the middle of the board make a mark.
4. Place rubber ball approximately 100 cm from the mark and 65 cm from the board (Position B).
5. Challenge the "pool player" to roll another rubber ball in such a manner that it first hits the mark on the wood (Position A) and subsequently bounces off and hits the first rubber ball.
6. What positional relationship is operating in this effort? Refer to the drawing below.

B. Angle of Incidence and Angle of Reflection

1.



2. The line AD is referred to as the Normal line and is perpendicular to line XY.
3. Very likely the "pool player" will be able to articulate that angle BAD must equal angle CAD for a ball thrown from C to hit a ball resting at B.
4. We want to call angle CAD the ANGLE OF INCIDENCE, in other words the

angle initially made with the wall and the NORMAL. We want call angle BAD the ANGLE OF REFLECTION, or the angle made with the NORMAL when the ball reflected off the wall.

5. As the "pool player" intuitively knew, **the angle of incidence equals the angle of reflection**.

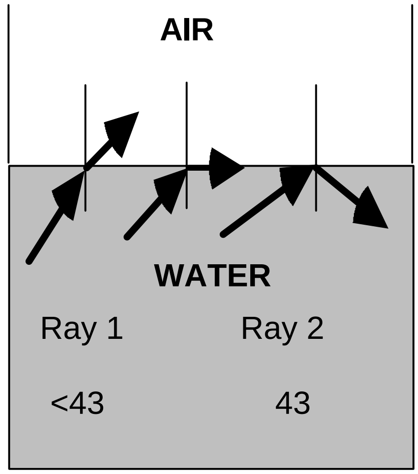
C. Finding the Angle of Incidence and Angle of Reflection for Visible Light

1. Place a sheet of paper with the long side facing you on the table. Draw a horizontal line across the page and label it XY.
2. Label the midpoint of XY A. Draw a dotted line perpendicular to XY through A. Label the other end of the dotted line D.
3. Draw a line from A to the left corner of the paper. Proceed down this line about 8 cm. from point A and mark a point B.
4. Place a mirror along line XY. Make sure that XY lines up with the back edge of the mirror. Make sure that the mirror remains perpendicular to the paper. You might use some blobs of clay to secure the mirror.
5. Take two pins, stick them on small pieces of clay, and place them on line AB. Make sure the pins remain vertical.
6. Lower your body to the level of the pins. Move your head left and right. Look at the pins toward the mirror, until the front pin covers the back pin and they look like one.
7. Place a pin to the right of the dotted line AD and move it around, until it looks as if it is lined up in the mirror and covers the other two pins. All pins should appear in a straight line. Keep your eyes near the level of the pins. After you line up the three pins, press the third pin down to mark the point. Label it C.
8. Draw a line from A going through point C.
9. Measure angles BAD and CAD. What positional relationship appears to be acting in this case? [The two angles are equal.]

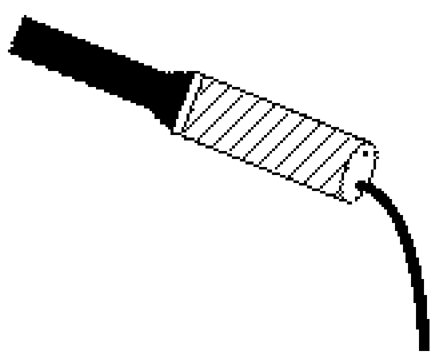
CONCEPT EXTENSION

A. Critical Angle

1. If you swim underwater and look up, you will see some objects above the water. To your surprise you also might see a reflection of an object from in front and underneath you.
2. Against a black background place a deep aquarium. Get a waterproof flashlight and submerge it. Shine the beam of light from the bottom of the aquarium up toward the top surface of the water. Notice what happens to the beam of light. Now change the angle of the beam shining on the underneath surface of the water. When the angle is about 43° from the normal, what happens? (see diagram below)



3. When the angle of incidence is greater than 43° with the normal, light is totally reflected at the boundary of the water and air. This special angle is called the **critical angle**. It differs for each two adjacent media that the light passes through. For the boundary of glass and air it is about 48°; for the boundary of a diamond and air it is about 24°. This is the principal utilized in **fiber optical instruments**.
4. Fill a straight glass tube with water. Seal one end with some type of kitchen plastic wrap. Shine a flashlight from one end and look at the other end of the tube. Does light travel down the tube so that you can see it coming out the other end? [Yes] This should be no great surprise since we know that light travels in straight lines. What would happen if you used a curved glass tube? Would you be able to see light coming out of the bottom of the curved tube. [No] Could you design a way to "pour" light so that light would undergo total reflection and finally come out the bottom end?
5. Obtain a tall skinny bottle (some types of olive jars will work). With a nail put a large hole at the edge in the metal lid. Put a smaller hole on the opposite edge. To the bottom of the jar attach a flashlight. Duct tape works well. Wrap some newspaper around the jar so that light doesn't escape out the sides. Fill the jar within about two centimeters of the top, then screw on the lid. Turn the flashlight on. Tilt the jar/flashlight apparatus so that water pours out the hole. If the water is poured out in a darkened room, the light will be contained (because of total reflection) in the curved stream of water. All light hitting the water/air boundary at greater than about 43° will be totally reflected internally over and over until it comes out the end of the stream of water. If you stick your finger into the stream of water, light will fall on it. This will happen if you put your finger in the water near where it comes out of the jar or in the curved part of the stream near the sink.



6. Are there other substances that allow light to travel a curved path by way of total reflection? [A curved piece of Lucite® will work.]

ACTIVITIES RELATED TO ENDOSCOPE MODULE

GOT SCOPES?

What's the Point?
- Endoscopic procedures are performed with specialized instruments through small openings in the body.
- Endoscopic procedures require skill to manipulate the instruments and to complete a task from a distance.

Materials:
- Empty plastic gallon milk jug (washed)
- X-ACTO knife
- Penlight
- Masking tape
- 2 telescoping graspers (sold in kitchen and hardware stores)
- Small objects with different characteristics (colors, shapes, sizes) to remove from the jug "body" [e.g. jellybeans, popcorn kernels (popped or unpopped), shoelaces].

Procedure:
1. Cut 3 holes in the sides of the milk jug as shown in **Figure 1**.
2. Place the penlight partway through hole A, tape in place.
3. Place graspers partway through holes B and C.

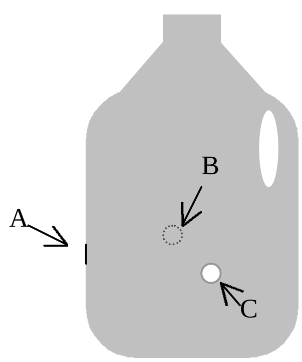


Figure 1

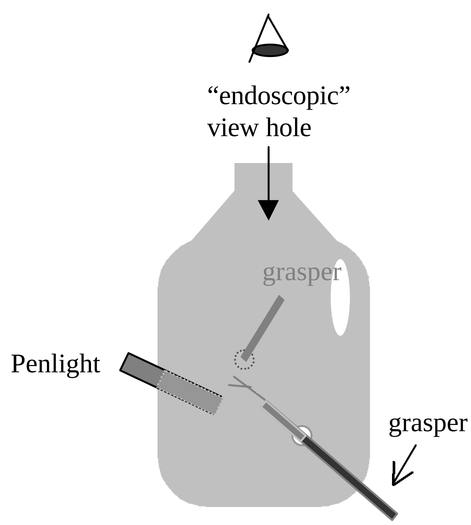
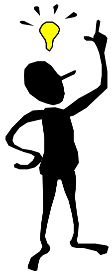


Figure 2

4. Pour small objects into milk jug.
5. Challenge your students to look into the "endoscope" at the top of the milk jug (**Figure 2**) and use the graspers to remove a specific object from the jug (e.g. remove the yellow jellybean).
6. Depending on the age and dexterity of the students, other challenges could include tying a knot in a shoelace, moving an object through a key ring, or building a tower using dice (all inside the milk jug using the graspers, while looking in from the top).



Fiber Optics Activity

Optical Fibers as 'light pipes'

Light travels in a straight line. But light sent through optical fibers can go around corners. You can model the effect of optical fibers in this experiment.

Materials

1. 2 clamps and stands
2. Solid glass rod about 50 to 60 centimeters long, with a bend in the middle
3. Sheet of cardboard (approximately 50 cm x 50 cm)
4. Flashlight
5. Piece of white paper (8.5 in. x 11 in.)

Procedure

1. Put the glass rod into the clamp on the stand.
2. Make a hole in the center of the sheet of cardboard and slide it over the end of the rod. The cardboard will act as a shield against light that isn't focused down the rod
3. Focus the flashlight on one end of the glass rod and clamp it into position. (The glass of the flashlight can be touching the glass rod.)
4. Hold a piece of white paper a short distance from the other end of the rod.
5. Observe the beam of light on the paper.

Questions

a. Given that light always travels in a straight line, would you expect the light from the flashlight to land?
b. Explain why the light follows the bend in the glass rod.
c. There is only a weak beam of light transmitted through the glass rod. Why?

Teachers notes

Preparation

Obtain a rod of glass of about 3 to 5 mm in diameter. Put a 30-40 degree bend in it by heating the middle of the rod with a Bunsen burner until the glass softens.

You can use a small flashlight with a diameter similar to the diameter of the glass rod.

If you use a larger flashlight, you may need to use black tape or paper around the space between the light and the rod to reduce the amount of light that is not focused on the glass rod.

A small halogen lamp could be used instead of a flashlight, but this will get too hot to allow you to wrap the intervening space with tape or paper.

The results are easiest to see if the room is very dark, so use a darkroom if one is available.

Try the following variations to focus more light down the rod:

- Remove the glass of the flashlight and put the rod as close as possible to the bulb.
- Use a lens to focus the light onto the end of the rod.

This experiment could be done in small groups if you have enough equipment.

Answers to questions

a. Normally the beam from the flashlight would land on a spot directly in front of the flashlight.
b. When light traveling through the glass rod meets the air-glass interface at a small enough grazing angle, the light is reflected back into the rod and none escapes.
c. Much of the light from the flashlight has been absorbed by the glass rod. All glass absorbs light. For example, when you look through a window pane, only about one half of the external light is visible through the pane. If the pane of glass were half a meter thick, much more light would be absorbed.

With new glasses that have been developed for optical fibers, light can travel more than 10 km before 90% of it is absorbed. This is a big improvement over ordinary glass. When light travels through ordinary glass 90% of the light has been absorbed after only about 20 meters.

Students may notice that the light travelling down the rod is colored. Glass does not absorb all the wavelengths of light equally (e.g., Pyrex glass absorbs blue and red wavelengths, transmitting yellow-colored light; ordinary soda glass transmits green light best.) Infrared light is used to send messages down optical fibers because glass absorbs least in the infrared part of the spectrum.

Even with ideal conditions, a fiber optics network requires an amplifier every 10 or 20 kilometers of optical fiber to boost the light signal, but this distance is being increased as glass technology improves.

ACTIVITIES RELATED TO ULTRASOUND MODULE

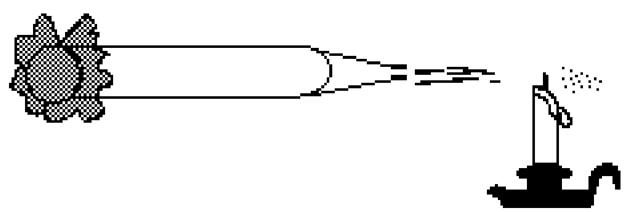
PROBLEM PRESENTATION / EXPLORATION

A. Can You "See" Sound?

1. If you were deaf, how could you see sound? You have all seen receivers in a stereo system that have meters that indicate the various sounds that are being produced by the speakers. In this case as the tape, record, or CD is activated, a current is sent to the meters at the same time it is sent to the speakers. In this way you can "see" the sound as well as hear it.
2. Let's build a non-electronic device to observe sound. You will need an oatmeal box or coffee can. Remove both the top and bottom of the box or can. Stretch a balloon or rubber sheet over one end of the box/can and secure with a rubber band or string. Be sure the balloon is stretched tight.
3. Attach a small mirror to the center of the surface of the balloon with some glue. Place the device on its side on a table. After darkening the room shine a flashlight at about a 45° angle with the flat surface of the balloon. Direct the reflection at a white wall or movie projection screen.
4. Have a student yell into the open end of the tube and watch the reflection. Can you explain what you see? Try different degrees of loudness.

B. Can You Put Out a Fire With Sound?

1. Obtain a mailing tube or large cardboard tube having a diameter of seven to ten centimeters. Both ends should be open. To one end stretch a balloon or rubber sheet and secure it with a rubber band or string.
2. Make a paper cone and fasten it to the other end of the mailing tube. The hole at the bottom of the cone should be between 0.5 and 1 cm in diameter.



3.. Light a candle and place it in front of the mailing tube/cone device. Secure the candle so that it will not tip over. Now clap your hands near the stretched balloon. Notice what happens Whistle or play a small radio near the stretched balloon. Finally flick your finger at the balloon surface. The flame should go out. Explain what happened in each of these cases.

C. Can You Hear a Bell in a Bottle?

1. Obtain a large Florence flask and equip it with a solid rubber stopper. Find a small hand bell (jingle bell) that will fit through the mouth of the flask. Push a thumbtack into the bottom of the rubber stopper. Finally, attach the bell with a short piece of iron wire to the thumbtack so that when the rubber stopper is lowered into the flask the bell will hang at about the center of the flask.
2. Shake the flask. Can you hear the bell? [Yes]
3. After removing the stopper, pour about 20 mL of water into the flask and heat it to boiling. Let it boil for at least one minute.
4. Immediately insert the stopper with the bell into the flask. (Use a towel or other protection from the steam and hot glass.)
5. After letting the flask cool off for a minute shake it again. Can you hear the bell now? [Not very well.]

D. How Fast Does Sound Travel?

1. Take the class outside and face a large vertical brick wall.

2. Starting about 10 meters in front of the wall bang two sticks together and slowly walk backwards away from the wall.
3. As soon as an echo of the banging sticks is heard by someone, move forward or backward, a step at a time, until the whole class hears the echo.
4. Measure the perpendicular distance from the position where the echo was heard to the wall.
5. The minimum time interval that the human ear can detect between two claps of the stick is 0.1 second. When this interval between the clap and the echo is shorter than 0.1 second, no echo is heard. This is why no echo was heard when standing only 10 meters in front of the wall. The time it took the echo to come back at this distance must be 0.1 second.
6. Can you find out from the information collected how fast the sound was traveling through the air? [The echo should be heard at about 17 m in front of the wall. This would mean that the sound traveled to the wall and back (2 x 17m) in 0.1 second. This means that the speed of sound is about 34m/0.1 second or about 340 m/second.]

CLASS RESPONSE / CONCEPT INVENTION

A. What Causes Sound?
   1. Every sound starts with energy being imparted to an object. This sets up a vibration in the object. Vibrating your vocal chords when you speak, or beating on a drum, or blowing into a trumpet are examples. The first EXPLORATION activity illustrates the idea of vibration. The energy was supplied by clapping your hands which caused the air molecules to vibrate which in turn caused the balloon to vibrate which caused the mirror to move back and forth so that you could visibly see the sound.
   2. Notice how important the air was in this process. Could the energy disturbance (the hand clapping) have reached the balloon without the air providing a means of transferring the energy disturbance? [No] In addition to having an energy disturbance there must be a medium through which the disturbance can travel.
   3. Notice what happened in the bell in the flask case. Shaking the bell was the energy disturbance. This then caused the air in the flask to vibrate and was transmitted to the glass, to the air on the outside of the flask, and to our ears. But in the case where the water was boiled, the air was forced out of the flask and replaced by water vapor. Upon the cooling of the water vapor the water molecules suddenly condensed into liquid water leaving most of the volume void of molecules. Shaking the bell now produced only a faint sound. The same energy disturbance occurred, but there was very little medium through which it could be transmitted to reach our ears. If a perfect vacuum could be produced, no sound would be heard.

B. How Would the Nature of the Medium Affect Sound?
   1. Does sound travel better through gases, liquids, or solids?
   2. Have you ever put your ear down to a railroad track and heard the train coming from miles down the track? Have you ever been swimming under water and heard somebody hit two rocks together? How does that compare with sticking your head out of the water and having the two rocks banged together above the water?
   3. Position an ordinary coat hanger upside down (hook end pointing down). Tie a piece of string to each end (the curved parts making up the corners of the hanger "triangle.") Wind the string two or three times around the end of your first finger on each hand. Now stick these fingers in your ears. Either swing the hanger into a stationary, solid object or have someone else hit the coat hanger with a pencil. How does the sound you hear differ from hitting a normal coat hanger with a pencil?

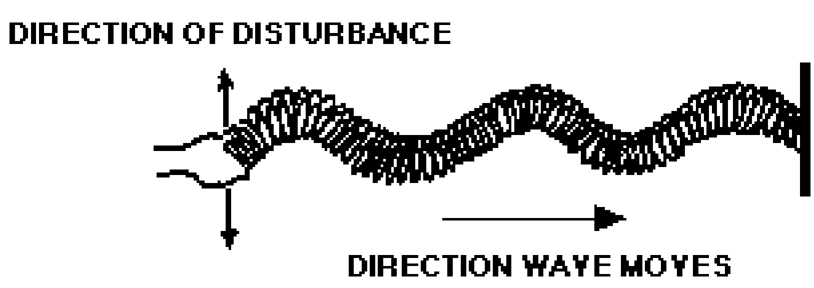
4. The original vibration was set up by hitting the hanger with the pencil. This caused the hanger to vibrate which caused the string to vibrate, which was transmitted through your fingers to your ears. The resulting sound was a gong-like one, much richer and louder than the vibrations that normally travel
through the air to your ears.
5. The idea of sound being a disturbance from one molecule to another can be illustrated by the following demonstration. Line up four students side by side and shoulder to shoulder. Place a chalkboard eraser on the head of the last student. Each student should gently push against his or her neighbor, thereby showing the transmission of the movement along the line. The eraser falling from the head of the end student is evidence that the disturbance that began on the opposite end of the line has reached the one wearing the eraser. Did the first student push on the end student wearing the eraser? No. This is a very simple analogy of how an energy disturbance is transmitted through a medium.

C. How Would the Speed of Sound Be Affected Through Different Media?

1. Line up dominoes at evenly spaced intervals (approximately 2 cm apart stretching out over a 100 cm length. Push over the first one and watch this disturbance transmitted to the next domino, and to the next, etc. Measure the amount of time it takes until the last domino topples. Lets say this setup represents sound being transmitted through a solid. Now line up the dominoes at evenly spaced intervals (approximately 4 cm apart.) stretching out over a 100 cm length Push the first domino and predict whether the time required for the last domino to topple will be greater or smaller than in the first case. [Longer] This might represent a liquid where the molecules are farther apart. Setting up both the solid and liquid situations and applying the disturbance at the same time may more graphically illustrate the comparison. Sound travels slower through substances where the particles making up the medium are farther apart. **The general rule is that the speed of sound is directly proportional to the density of the medium**.

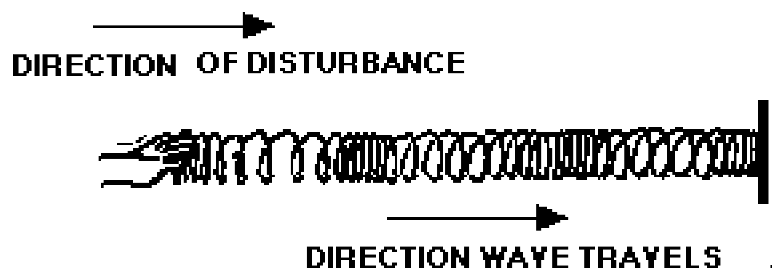
D. Transverse and Longitudinal Waves

1. A wave can be classified by the direction in which it disturbs the medium. A bobber on the end of your fishing line will float calmly on the lake until a fish pulls it down. In response the bobber will bounce up and down vertically, but the water waves generated will move horizontally out from the original disturbance. A **Transverse Wave** is a disturbance that moves the medium at right angles to the direction in which the wave travels. As the disturbance moves horizontally outward the medium is disturbed for an instant in a vertical plane.

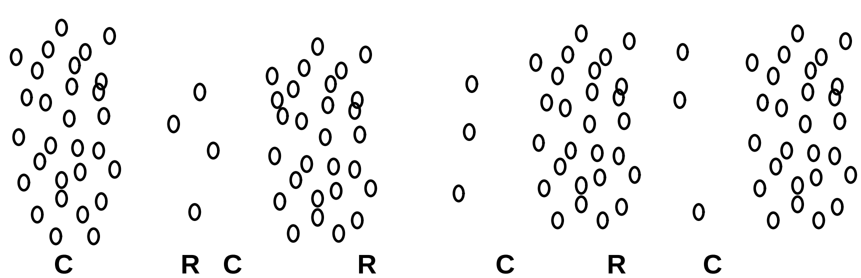


2. Place a large Slinky® on a smooth level surface. Have a partner hold the opposite end firmly. Stretch the spring until the coils are no more than 1 cm apart.

3. Suddenly move your end of the spring sideways about 20 cm, then quickly return it to its original position. A pulse should travel along it length and reach your partner. Compare the direction that the medium (Slinky®) moved compared to the direction of the pulse. This is an example of a transverse wave. If you rhythmically move your hand back and forth you will see a continual waveform traveling down the spring.
4. Bring the Slinky® back to its initial starting position. Reach a short distance down the spring and gather the coils toward you. Quickly release them. Observe the direction in which the pulse move and the direction in which the coils of the medium move. Is this a transverse wave? [No]
5. In this case the spring did not move at right angles to the direction of the disturbance. It bunches up in some areas and spreads out in others. The spring moves back and forth rather than up and down. When the disturbance moves the medium back and forth parallel to the direction in which the wave travels we have a **Longitudinal Wave**. Sometimes these are called compressional waves.



6. By which type of waves does sound travel? [Longitudinal]
7. Sound is produced by the vibration (rapid back-and-fort motion) of an object which then pushes again and again on the surrounding medium. An example of a longitudinal wave traveling through air can be seen when you quickly push a door to your room inward. The door pushes against the air molecules next to the door, these molecules bump into other air molecules, etc. until the curtain hanging in your open window will swing out the window. Pulling the door shut will cause a rarefaction of the air next to where the door started and air molecules will rush into this near the door. The air molecules in the room will successively move toward the door and finally the curtains will be pulled toward the door.
8. Consider what happens when the tines of a tuning fork are struck with a rubber mallet. A series of **compressions** and **rarefactions** is set up and moves through the air. The air molecules move together and spread apart with respect to the frequency of the tines moving back and forth



E. Frequency, Wavelength, and Speed

1. The distance from one compression to the next compression in a sound

wave is called its **wavelength**. Therefore, the diagram above shows a portion of the wave three wavelengths long.

2. If you stand at a fixed spot and count how many wavelengths of the sound reach you, you will determine the **frequency** of the sound.
3. If the wavelength above measures 4 cm and the portion of the wave pattern above represents a total of 1.0 seconds, the frequency would be 3 cycle/second. (When dealing with sound we use the term Hertz, so the frequency of this wave would be 3 Hertz.)

Make A Sound Cannon

To understand how air pressure can make something move and vibrate, use an empty Quaker Oats box.

1. Cut a hole about an inch in diameter in the center of the lid.

2. Put the lid back on the box (securely) and point the hole at the flame of a lit candle.

3. Flick the bottom of the box with your finger. As you do, you will hear a sound and see the candle flame move and flicker.

The sound, initiated when your finger hits the box, is a result of the disturbance in the air. You can see the effect of the disturbance on the candle flame. If you flick the box softly, the flame will move just a little. If you flick the box very hard, the flame will go out. The ear drum responds similarly to changes in air pressure.

Hearing and Listening. The Exploratorium, 1976.

ACTIVITIES RELATED TO CRYOSURGERY MODULE

DON'T CRYO OVER SPLIT GRAPES

What's the point?

- Cells in the body contain water.
- Cryosurgery uses extremely cold temperatures to freeze water in cells, which damages cell membranes and causes cells to die.
- Cryosurgery uses cycles of freezing and thawing to maximize the amount of diseased tissue that is destroyed.
- You will use a grape to represent the effect of cryosurgery on a cell. When the grape (which represents a cell) is quickly frozen, the skin of the grape (which represents the cell membrane) ruptures.

Materials:

- Ethyl Alcohol (~ 1-2 cups)
- Dry ice (~ 3-4 ice cube sized chunks)
- Glass jar (16 oz)
- Tongs
- Protective High/Low-Temperature Gloves
- Grapes – one bunch

Procedure:

1. Pour ethyl alcohol into glass jar. Using the protective gloves and tongs, put dry ice into the jar so that the jar's contents bubbles. Throughout the experiment, continue adding small amounts (ice cube size) dry ice to maintain bubbling contents.
2. Using the tongs, place a grape into the jar.
3. After 2 minutes (time may vary), remove the grape.
4. The outer skin of the grape should crack open.