Radiation Hazards and Safeguards

Ionizing radiation can be dangerous to living things precisely because it *is* ionizing—it strips electrons from atoms. An ionized molecule can then chemically react with other molecules to form new compounds. These ionized molecules and new compounds can alter the vital processes and functions inside a living thing.

Ionizing radiation can damage any living tissue in the human body. The body tries to repair the damage, but the natural repair process may fail if the damage is too severe or widespread.

Hazards to People

The effects of radiation on human health fall into two general categories: *chronic* and *acute.*

Chronic Health Effects

Exposure to low levels of radiation over a long time can cause *chronic* effects, which are unpredictable. Because radiation affects different people differently, some effects of exposure occur randomly and do not always depend on the size of a dose. All that can be said for sure is that the greater a person's radiation exposure, the more likely that person is to develop health problems like cancer.

Cancer is the uncontrolled growth of cells. Normally, natural processes control the rate at which cells grow and replace themselves. Ionizing radiation can disrupt the natural controls, allowing runaway cell growth. This is why ionizing radiation's ability to strip away electrons and break chemical bonds in atoms and molecules makes it such a potent *carcinogen* (cancer producer).

Radiation also can make changes in DNA, the "blueprints" that cells follow as they repair and copy themselves. Changes in DNA are called *mutations.* Generally (but not always), mutations are harmful, and they may be passed on to new cells that are made when the damaged cell divides.

What is the cancer risk from radiation? Health physicists estimate that, if each person in a group of 10,000 people is exposed to 1 rem of ionizing radiation, in small doses over a lifetime, we would expect five or six more people to die of cancer than would otherwise. In this group of 10,000 people, we can expect about 2,000 to die of cancer from all causes other than radiation. The lifetime exposure to 1 rem of radiation, therefore, would increase the number of cancer deaths to about 2,005 or 2,006.

Compare this to the lifetime odds of dying from other causes, such as

- A fall—1 in 246
- An auto accident—1 in 247
- A pedestrian accident—1 in 608
- Drowning—1 in 1,126
- Fire and smoke—1 in 1,116
- A plane crash—1 in 4,023
- Any injury (all types)—1 in 23

—From the U.S. Environmental Protection Agency and the National Safety Council

Acute Health Effects

An *acute* exposure—that is, getting a big dose of radiation in a short time—produces *acute* effects because they can be predicted with certainty (determined) from what has happened in the past to people exposed to bursts of intense radiation.

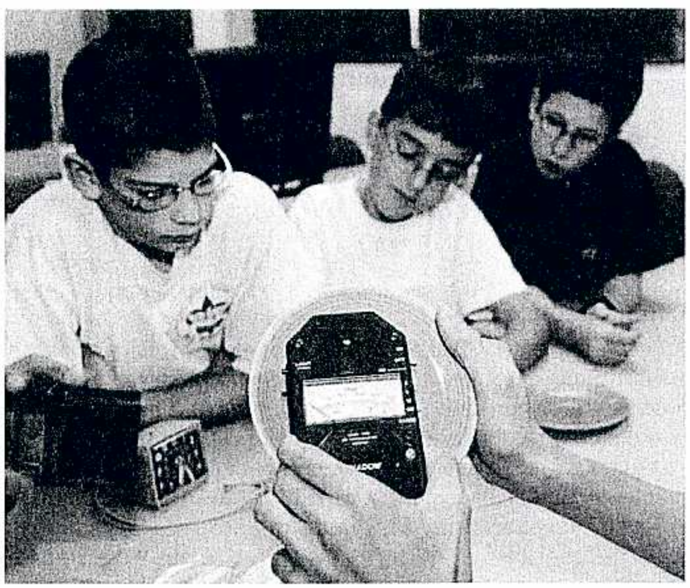
Unlike cancer, which can take years to show up, health problems from acute exposure usually appear quickly. Acute effects include burns and *radiation sickness.*

One measure of radiation exposure is known as a *rem*.

Radiation sickness (also called radiation poisoning) can be fatal. The symptoms include nausea, vomiting, weakness, hair loss, skin burns, and bleeding (hemorrhage). A person who receives a lethal dose of radiation may die within hours or days, depending on the size of the dose. Common treatments for radiation sickness include blood transfusions and using antibiotics to fight infection. In some cases, a bone marrow transplant can be lifesaving.

Exposure (rem)	Health Effects
25	Changes in the blood
100	Radiation sickness
200	Radiation sickness with worse symptoms in less time
400	Death probable within two months*
600	Death probable within one to two weeks*

*One-half of any group of people exposed to a single quick dose of 400 rem likely will die within 60 days. A single quick dose of 600 rem or more usually causes death within a week, although people have survived doses up to 800 rem.



Radiation Units

Radiation is measured in several different units. The *roentgen* (R) is for measuring the ionizing ability of X-rays or gamma rays in air. The unit was named for Wilhelm Conrad Roentgen, who discovered X-rays.

Different kinds of ionizing radiations have different effects on humans. The *rem* (*r*oentgen *e*quivalent, *m*an) measures the intensity of the radiation, the type of the radiation, and its effect on the body. The rem is used for health and safety purposes, describing the biological effect of radiation on people. One rem is approximately the dose from any radiation corresponding to exposure to one roentgen of gamma radiation.

If one rem is divided into 1,000 equal parts, each part is one *millirem* (mrem).

The International System unit (see the chart) for measuring the biological danger of radiation is the *sievert* (Sv). One sievert equals 100 rem.

To describe the quantity of radiation physically absorbed by some material, the unit used is the *rad* (*r*adiation *a*bsorbed *d*ose). The International System unit for absorbed dose is the *gray* (Gy). One gray equals 100 rad.

Converting Radiation Units

Just as the meter may be used instead of the foot, or the liter instead of the quart, another set of radiation units may be used, called the International System (SI). This table shows how to convert one system to the other.

Multiply this	by this	to get this
SI Units		**Common Units**
coulomb per kilogram (C/kg)	3876	roentgen
becquerel (Bq)	0.000000000027	curie
sievert (Sv)	100	rem
gray (Gy)	100	rad
Common Units		**SI Units**
roentgen (R)	0.000258	coulomb per kilogram
curie (Ci)	37,000,000,000	becquerel
rem	0.01	sievert
rad	0.01	gray

Radiation Hazards to Wildlife

Although we know much about the dangers of radiation to humans, its effects on wildlife are less understood. Scientists have tended to assume that as long as people were protected, animals and plants would be, too.

But that idea is changing, and more research is now being done to learn how best to safeguard wildlife. Many researchers are focusing on how wild plants and animals have been affected by the radioactivity released from the exploded nuclear reactor at Chernobyl. For example, some researchers are finding that worms in a nearby lake are changing their behavior in ways that may help protect them from radiation damage.

The Chernobyl Nuclear Accident

In April 1986, operators at the Chernobyl power plant in Ukraine, in southeastern Europe, were conducting a test of a nuclear reactor, in which several safety systems and processes were bypassed. Conditions to conduct the test were not as planned, but they proceeded anyway, and the reactor exploded, releasing a cloud of radiation. Killed at once were 31 people, mostly firefighters responding to the emergency. About 200 people suffered acute radiation poisoning. High radiation levels within 20 miles of the plant forced the evacuation of some 150,000 people.

For millions of people exposed to radioactive fallout from Chernobyl, the long-term health effects are uncertain. At least 2,000 children and young adults in the most severely contaminated areas got cancer of the thyroid. Other forms of cancer also may be on the rise.

The explosion spread radioactive contamination across a large area, particularly in Belarus, Russia, and Ukraine. Some land is so contaminated that it can no longer be farmed. In grazing animals such as cattle and goats, radioactivity has built up in the meat and milk.

> Unlike most nuclear reactors in the West, the Chernobyl reactor had no enclosure to prevent radioactive materials from escaping.

Wildlife in the forests also is contaminated from feeding on radioactive lichens and berries. Predators such as wolves and foxes are more contaminated than the grazing animals they eat, because the radioactivity from their prey concentrates in their bodies.

Radiation Hazards to the Environment

The environment is as big as the planet (bigger, when you include the atmosphere extending more than 60 miles overhead), so for requirement 6 you may want to focus on a specific environmental issue such as radioactive waste. Radioactive wastes produced by nuclear reactors, research, and medical laboratories pose a potentially serious environmental problem.

The safe and permanent disposal of radioactive waste is both difficult and expensive. The United States government has been working on a plan to isolate radioactive waste in an underground storage site at Yucca Mountain in Nevada.

A storage site for nuclear waste must be in an area without earthquakes or weaknesses in the ground. The site must be dry so that containers of waste will not rust or corrode and leak into underground water supplies. The site must be built and protected so that future generations do not accidentally dig into it and release radioactivity.

Many types of radiation detectors are in use. Your counselor can probably discuss some of the other types with you.

Radiation Detectors

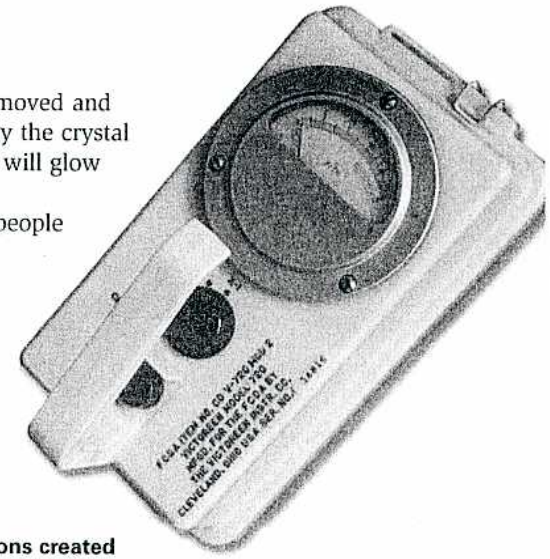
Using our normal senses, people cannot detect radiation. You cannot hear, smell, see, taste, or feel it. So how do we know it's there? How do we protect ourselves from it?

Many types of radiation detectors are in use. You have learned that radiation makes changes in photographic film and will create ions in matter through which it passes. One way to detect radiation, therefore, is to wrap pieces of film in dark paper and put them in holders or badges that people wear on their clothes. When radiation passes through the dark paper and hits the film beneath, it darkens the film. The darker the film, the more radiation the person has received.

Another example is an easy-to-carry radiation monitor called the *thermoluminescent dosimeter* (TLD). This monitor contains a small crystal of a substance (like lithium fluoride) that absorbs energy when hit by radiation. When the crystal is removed and heated, it will glow. The more energy the crystal received from radiation, the more it will glow when heated.

***Dosimeters*—devices such as film badges, TLD badges, or pocket ionization chambers—measure the doses of radiation a person has received.**

A radiation detector that most people have heard of is the *Geiger counter.* Basically, this instrument counts radiation as it passes through a gas-filled tube and makes ions in the gas. If the instrument has a speaker, you hear a click each time a radiation passes through. The more clicks, the more radiation is being detected.



A Geiger counter clicks as it counts ions created when radiation passes through the instrument's gas-filled tube. Faster clicks mean higher radiation.

Use a Radiation Survey Meter

Most emergency response groups, such as fire departments and ambulances, have radiation detectors that you might be able to use for this activity. You also could check with nearby colleges, physics labs, or even high schools.

Different types of radiation survey meters are used to detect different types and energies of radiation.

- **Ionization (ion) chambers.** Used mainly to determine the exposure rate from gamma ray and X-ray emitters, ion chambers are particularly useful for measuring machine-produced X-rays.
- **Geiger-Müller (GM) detectors.** Easy-to-use, portable GM detectors (familiar to most people as Geiger counters) are good for many types of radiation surveys. They are most efficient for detecting high-energy beta emitters such as phosphorus-32, but they can be used to measure low-energy beta emitters such as carbon-14.
- **Scintillation detectors.** Scintillation detectors are used to detect gamma radiation and they are much more sensitive to gamma and X-rays than are GM detectors. They may have an audible output like GM detectors.

For a radiation source, you might use an old radium-dial watch or a radioactive lantern mantle. A good Geiger counter can detect the radiation in potash, in very low-sodium salt, or in any high-potassium fertilizer. You will *not* be able to detect the radiation from a smoke detector.

Your counselor or other qualified adult will show you how to properly use a radiation survey meter. When monitoring for low-energy beta emitters with a GM survey meter, you must pass the detector slowly across and very close to the surface you are checking.

Radioactive material spread about or deposited on skin, clothing, or any place in the environment where it should not be is *contamination*. A person contaminated with radioactive material will receive radiation exposure until the material is removed. Radiation survey meters are used to detect contamination so that it can be removed or kept ALARA.

Natural Background Radiation

To give you some perspective on the hazards from radiation, remember that sunlight—the most essential radiation of all—also can be harmful in big doses. Too much sunlight can cause burns and skin cancer, just as an overexposure to ionizing radiation can.

And also like sunlight, ionizing radiation is a natural part of our environment. Radiation exists all around us in nature. Soil, rocks, air, food, water, and even your body contain radioactive substances. Radioactive carbon-14 is in all the food we eat. *Cosmic rays* fall on us from space. Most Americans get about 300 millirem (mrem) each year from natural radiation sources.

Cosmic Rays. The sun and other stars give off radiation that we call cosmic rays. The average exposure in the United States from this source is 30 mrem per year. Air protects us from most cosmic rays. The higher the elevation at which you live, the closer you are to space and the more cosmic radiation you receive. People in Denver, a city that is almost the highest point in the United States, may get 50 mrem each year.

Test for Radon Indoors

Radon is a naturally occurring radioactive gas. It is produced by the radioactive decay of radium, an element found in soil and rocks in all parts of the United States.

Colorless and odorless, radon gas may seep indoors unnoticed from the soil and rocks beneath buildings. It can enter homes through drains or cracks in the foundation. In some areas that have a lot of radon in the ground, the gas may build up indoors to unhealthy levels.

As radon decays, it gives off radiation in the form of alpha particles that can damage cells in the body, leading to cancer. By some estimates, radon causes about 20,000 deaths from lung cancer each year in the United States. The average U.S. radiation exposure from radon gas in the air is 200 mrem (a figure that can vary greatly, depending on actual levels of radon in the ground where you live and the construction/ventilation properties of the building).

Test kits are available for people to check the radon levels in their homes. The Environmental Protection Agency recommends taking action to reduce radon if the radioactivity from this gas is more than 4 picocuries per liter of air (4 pCi/L). The EPA estimates that 6 percent of U.S. homes exceed 4 pCi/L.

A picocurie is one-trillionth of a curie.

It is fairly simple to test the radon level in your home. First call the National Radon Hotline at 800-SOS-RADON (800-767-7236) to request a brochure. To order a test kit, call the Air Quality Helpline at 800-557-2366, or use the printable coupons at *http://www.nsc.org/ehc/radon/coupon.htm*. Kit prices start at about $10.

With your parent or guardian, decide whether to use the long-term or short-term test method. Short-term tests remain in your home for two to 90 days, depending on the device. Long-term tests take longer—

more than 90 days—but are more likely to tell you your home's year-round average radon level. (Radon levels can vary from day to day and season to season.)

Carefully follow the instructions that come with the kit. Keep the test in place for as long as the instructions say, but for at least 48 hours. Then, mail the kit to the laboratory specified. You should receive the results in a few weeks.

If your testing shows high levels of radioactivity from radon, your parent may wish to call the Radon Fix-It Helpline (toll-free 800-644-6999) for information on reducing radon. Fixing radon problems is not necessarily expensive. Sealing cracks and other openings in the foundation or coating the basement floor and walls with a flexible sealant may stop some radon leaks. The radon might be sucked from below the house and vented outdoors. Ventilating the inside of a home also helps lower the radon level. The air outdoors usually has radioactivity from radon of less than 0.5 pCi/L.

Would it surprise you to know that your home may be radioactive? If your house is constructed from brick, concrete, stone, or adobe, it gives you an exposure of about 7 mrem a year.

Exposures From Manufactured Radiation

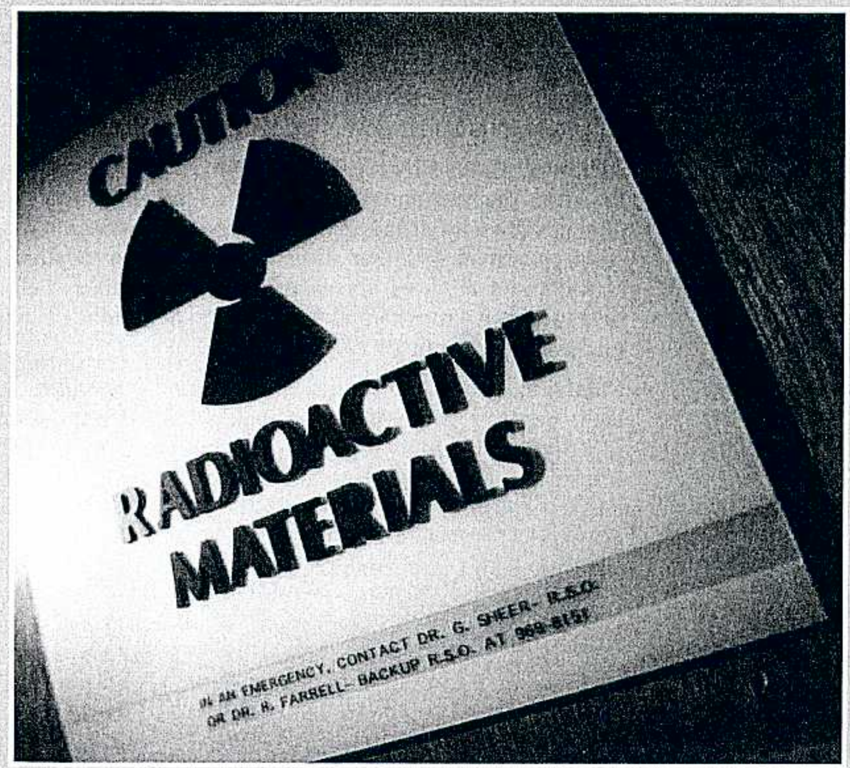
In daily life, people also can get radiation (60 mrem a year, on average) from sources other than those found in nature. Luminous (tritium-dial) wristwatches and some gas lantern mantles emit small amounts. If you've gone through luggage inspection at an airport, you have received a tiny dose of X-radiation. If you live within 50 miles of a nuclear power plant, you get perhaps 0.01 mrem per year. The figure is triple (0.03 mrem—still very small) if you live within 50 miles of a coal-fired power plant, because burning coal releases small amounts of uranium into the air.

Many people are exposed to radiation for medical purposes, such as getting thyroid scans (14 mrem) or dental, chest, and other kinds of X-rays (7 mrem on average). Wearing a plutonium-powered heart pacemaker can expose a person to 100 mrem a year. The benefit of a pacemaker to steady the heartbeat or an X-ray to check for broken bones is much greater than the limited risk from these small radiation exposures. Even so, you should not get X-rays you don't need.

Since the first use of nuclear weapons in 1945, atomic bombs have been tested all around the world. Nuclear explosions spread radioactive dust called *fallout*. Although there has been no testing in the air for many years, some of this fallout is still around, but we absorb less than 1 mrem every year from this source.

Hazard Symbol

To make sure people know when they are somewhere they might be exposed to high levels of radiation, a distinctive symbol is used to mark the area. The radiation warning symbol is a three-bladed disk in magenta (light purple) on a yellow background. The sign is displayed at laboratories or factory areas where radioactive materials are being used, and in storage areas for radioactive substances.



Radiation Dose Limits and ALARA

The United States has laws to limit people's unnecessary exposure to radiation. Radiation workers may be exposed to no more than 5,000 mrem annually. Health physicists generally agree that an average person who does not work with radioactive materials should not be exposed to more than about 100 mrem per year beyond the 360 mrem (average) background radiation we all receive. That means an ordinary person's exposure normally should not exceed about 500 mrem per year from all sources.

Limiting unnecessary exposure is the idea behind ALARA (as low as reasonably achievable). It is not possible to avoid all radiation exposure, but people can take steps to keep their exposure as low as it reasonably can be.

Three essential steps involve *time, distance,* and *shielding.*

- **Time.** The shorter the time a person is exposed, the less radiation that person will receive. Imagine you are in a laboratory working with a radiation source that gives off 1 rem per hour. If you work with it for one hour, you get 1 rem; for two hours, 2 rem; three hours, 3 rem; and so on. How do you keep the dose down? By keeping the *time* down.
- **Distance.** The farther a person is from a source of radiation, the lower the radiation dose. Radiation levels decrease dramatically with distance. A radiation source that is strong close up is weaker farther away. Alpha radiation (emitted by radon, for instance) travels only a short distance in air. Beta radiation (from carbon-14, among other emitters) may travel several feet in air.
- **Shielding.** Earlier you learned that a piece of paper can stop alpha particles. Aluminum will block beta particles. Gamma rays and X-rays are blocked by a lead or concrete shield. Placing a radioactive source behind a massive object or other effective shield provides a barrier to radiation. In X-ray rooms, operators stand behind a barrier to avoid getting radiation exposure with every patient.

It's impossible to say exactly what level of radiation is safe or dangerous for a person. While 5 rem (5,000 mrem) each year is used as a maximum limit for radiation workers, any unnecessary exposure should be avoided.

Calculate Your Approximate Annual Radiation Dose*

		Your Annual Dose
Approximate Natural Background Radiation:		
Cosmic rays		____ mrem
If you live at sea level	26 mrem	
1,000 feet	28	
2,000 feet	31	
3,000 feet	35	
4,000 feet	41	
5,000 feet	47	
6,000 feet	52	
7,000 feet	66	
8,000 feet	79	
9,000 feet	96	
Food and water (U.S. average)		40
Air (from radon, U.S. average)		200
Soil		____
Colorado Plateau (around Denver)	63	
Atlantic or Gulf Coast	16	
Elsewhere in the United States	30	
Manufactured Sources:		
Medical X-rays/nuclear medicine		____
Arm, leg, hand, or foot X-ray	1	
Dental X-ray	1	
Chest X-ray	6	
Pelvis/hip X-ray	65	
Skull/neck X-ray	20	
Upper GI X-ray	245	
CT scan/MRI (head and body)	110	
Nuclear medicine (e.g., thyroid scan)	14	
Home (7 mrem from brick, concrete, stone, or adobe)		____
Luminous wristwatch (0.06 mrem if you regularly wear one)		____
Gas lantern mantle (0.2 mrem if you use the radioactive kind)		____
Jet travel (0.5 mrem per hour in the air)		____
Weapons test fallout		1
Total		____ mrem

How does your approximate annual dose compare to the U.S. average of about 360 mrem per year? It's not unusual for a person to receive far more than the average dose in a year's time (mainly from medical procedures the person may undergo). International standards allow exposure to as much as 5,000 mrem a year for people working with and around radioactive materials.

*Adapted from "Estimate Your Personal Annual Radiation Dose," ©2000, American Nuclear Society, *http://www.ans.org/pi/resources/dosechart/docs/dosechart.pdf*

Nuclear Science Careers

Nuclear science and technology offer a huge variety of careers, ranging from power generation and environmental protection to medical diagnosis and treatment. Only a few of the possible careers can be described or mentioned here.

> To learn more, talk with your counselor and with the people you have met while completing the requirements for the Nuclear Science merit badge. People who work in this field will be your best sources for information. Ask them how they got interested in the field, how they trained for it, what education and experience are required, what they like (and dislike) about their work, and whether they would recommend it as a career (and why or why not).

Professionals in any nuclear science or technology career need good communication skills. It is important to be able to explain your ideas and your research to other people, whether they are in your field or work in other fields, or are members of the general public.

Basic Training

Preparing for any career in this field starts now, with taking as many science and math courses as you can: biology, chemistry, physics, algebra, and geometry. In college, you probably will major in physics, chemistry, or nuclear engineering.

To enter the field as a scientist or engineer, you will need at least a four-year bachelor's degree. Some positions require a master's degree or doctorate.

Nuclear technologists and technicians also need math and science. Entry-level technologist jobs generally require at least two years of college or extensive technical education.

Careers in Scientific Research

Nuclear scientists study the structure, properties, and interactions of atomic nuclei and how the elements were formed in the cosmos. Experimental nuclear scientists create and analyze experiments, while nuclear theorists interpret results from experiments and predict new phenomena. The ultimate goal is to understand the building blocks of nature and the physical laws they obey.

To become a nuclear scientist, most people earn a doctorate in physics or chemistry. The path to this degree takes many years of study and research. As college students majoring in physics or chemistry, they may take one or two specialized nuclear science courses and participate with a nuclear science research group.

Then, after graduation from college, they enter a doctoral program, taking courses for the first year or two, then beginning full-time research. Almost all nuclear science graduate students are paid to go to school through fellowships, teaching assistantships, research assistantships, or a combination of these. After obtaining a doctoral degree, many work as a post-doctoral fellow.

Nuclear scientists may choose from several careers.

- Some join a university or college, where they teach courses, guide students, and do research.
- Some conduct full-time research at a national laboratory.
- Some assist with the operations of an accelerator to help those doing experiments.

Some nuclear scientists have been leaders in developing new techniques in the treatment and diagnosis of disease; others help develop new solutions to problems in energy, or homeland or national security.

Careers in Nuclear Medicine

Every day, tens of thousands of patients in hospitals and clinics have some kind of nuclear medicine procedure. Physicians rely on X-rays and other imaging methods to diagnose medical problems without the need for invasive surgery. Radiation is used to treat leukemia and other types of cancer. Medical equipment is sterilized with radiation. Radioisotopes are used in developing more than 80 percent of all new drugs.

- Nuclear medicine technologists (NMTs) run tests on patients. They may prepare radioactive tracers; position patients for imaging; operate the nuclear instruments; collect, prepare, and analyze blood samples and other biological specimens; and prepare the information for the physician's use in making a diagnosis. NMTs must have a solid background in anatomy, physiology, math, chemistry, physics, laboratory technique, and radiation safety.
- X-ray technicians (also called radiologic technologists) prepare patients for X-rays and do X-ray imaging. Most work in hospitals, clinics, medical offices, and dental offices.
- Health physicists assure the safe use of radiation. Their job is to protect people and the environment from its harmful effects while applying the beneficial uses of radiation.

Careers in Nuclear Energy

Nuclear energy can help to meet the growing demand for electricity worldwide while not emitting the large amounts of greenhouse gases produced by power plants that burn fossil fuels. Nuclear energy also powers ships, submarines, and satellites, and provides electricity for some spacecraft and space laboratories.

- Engineers design power plants and supervise their operations. They also work in nuclear fuel manufacturing.
- Reactor operators run the controls at commercial power plants that produce electricity.
- Nuclear energy technologists work in uranium mining and processing.
- Radiation protection technicians at nuclear power plants implement radiation control procedures to protect workers, the public, the environment, and the power plants.

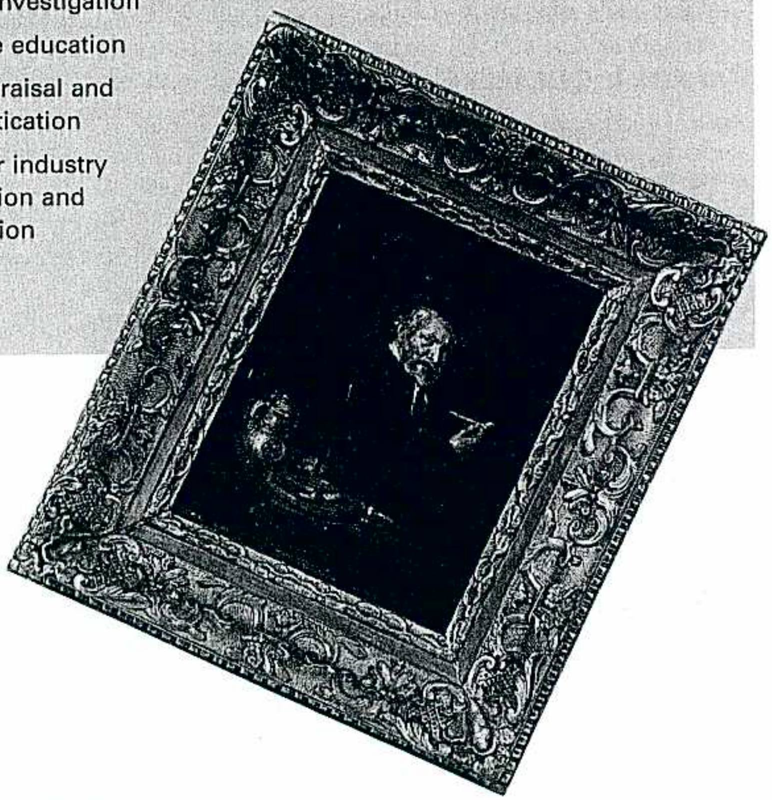
Careers in Agriculture and Food Technology

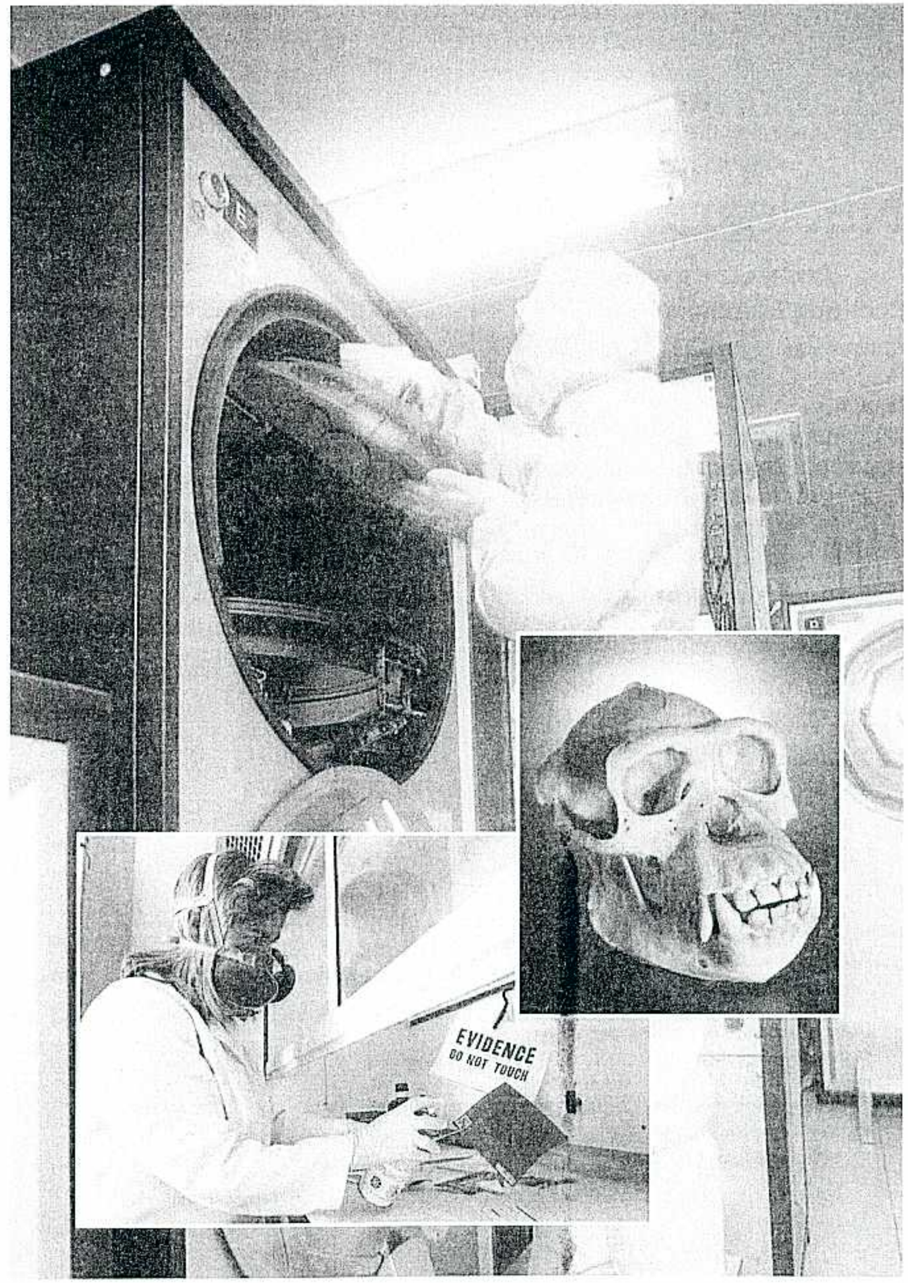
A growing world population needs more food. Radiation helps people develop plants that yield bigger crops, control pests without toxic chemicals, and make foods safer.

- Operators at irradiation facilities use radiation to destroy harmful microorganisms like salmonella and E. coli.
- Biologists experiment to develop new varieties of hardier, more disease-resistant crops.
- Research assistants help scientists and food engineers collect and analyze data.

Other Nuclear-Related Career Choices

- Archaeology and paleontology
- Crime investigation
- Science education
- Art appraisal and authentication
- Nuclear industry regulation and inspection





Nuclear Science Resources

Scouting Materials

Archaeology, Astronomy, Chemistry, Dentistry, Electricity, Emergency Preparedness, Energy, Engineering, Environmental Science, Geology, Medicine, Plant Science, and *Space Exploration* merit badge pamphlets

Books

Contemporary Physics Education Project. *Nuclear Science—A Guide to the Nuclear Science Wall Chart, 3rd ed.* CPEP, 2003.

Enslow Publishers, ed. *Enrico Fermi: Trailblazer in Nuclear Physics.* Enslow, 2004.

Fox, Karen. *Chain Reaction: Pioneers of Nuclear Science.* Scholastic Library Association, 1998.

Gallant, Roy A. *The Ever-Changing Atom.* Marshall Cavendish, 2000.

Goldstein, Natalie. *How Do We Know the Nature of the Atom?* Rosen Publishing Group, 2001.

Hamilton, Janet. *Lise Meitner: Pioneer of Nuclear Fission.* Enslow Publishers, 1997.

Mander, Lelia, ed. *Nuclear Energy.* Gareth Stevens, 2003.

Richardson, Hazel. *How to Split the Atom.* Scholastic Library Publishing, 2001.

Stwertka, Albert. *The World of Atoms and Quarks.* 21st Century, 1997.

Organizations and Web Sites

ABCs of Nuclear Science
Web site: *http://www.lbl.gov/abc*

American Nuclear Society
555 N. Kensington Ave.
La Grange Park, IL 60526
Telephone: 708-352-6611
Fax: 708-352-0499
Web site: *http://www.ans.org*

American Physical Society
One Physics Ellipse
College Park, MD 20740-3844
Telephone: 301-209-3200
Fax: 301-209-0865
Web site: *http://www.aps.org*

For more information about or to order Scouting-related resources, see *http://www.scoutstuff.org*—with your parent's permission, of course.

EPA Radiation Protection Students' and Teachers' Pages
Web site: *http://www.epa.gov/radiation/students/index.html*

Health Physics Society
1313 Dolley Madison Blvd., Suite 402
McLean, VA 22101
Telephone: 703-790-1745
Web site: *http://hps.org*

International Atomic Energy Agency
United Nations Liaison Office
1 United Nations Plaza,
Room DC-1-1155
New York, NY 10017
Telephone: 212-963-6010
Web site: *http://www.iaea.org*

Lawrence Berkeley National Laboratory
Web site: *http://www.lbl.gov/abc*

NEI Science Club
Nuclear Energy Institute
1776 I Street NW, Suite 400
Washington, DC 20006-3708
Telephone: 202-739-8000
Web site: *http://www.nei.org/scienceclub/index.html*

Nuclear Medicine on the Net
Web site: *http://www.nucmednet.com/frameset.htm*

The Particle Adventure
Web site: *http://particleadventure.org*

U.S. Department of Energy's Office of Nuclear Energy, Science, and Technology
1000 Independence Ave. SW
Washington, DC 20585
Toll-free telephone: 800-342-5363
Web site: *http://www.ne.doe.gov/home/public1.html*

U.S. Nuclear Regulatory Commission
Office of Public Affairs
Washington, DC 20555
Toll-free telephone: 800-368-5642
Web site: *http://www.nrc.gov*

Acknowledgments

For expert assistance in updating the requirements and revising the text of the *Nuclear Science* (formerly *Atomic Energy*) merit badge pamphlet, the Boy Scouts of America gratefully acknowledges

- Howard Matis, Ph.D., Eagle Scout and staff physicist, Nuclear Science Division, Lawrence Berkeley National Laboratory
- Dennis E. Showers, Ph.D., Eagle Scout and director, Center for Science, Mathematics and Technology Education, and associate professor, Science Education, State University of New York (SUNY) at Geneseo; author of the former *Atomic Energy* merit badge pamphlet
- Jolie Cizewski, Ph.D., professor and vice dean, Physics Department, Rutgers University
- Lynn Yarris, science writer, Lawrence Berkeley National Laboratory
- The American Nuclear Society, in particular Sharon Kerrick and the Outreach Department