Basic Guide to Radiation and Health Sciences

放影研 RERF Radiation Effects Research Foundation

Introduction

Today, more than 100 years after the discovery of X-rays, radiation is used widely in various fields, including medicine. Consequently, it is important now to understand radiation's properties, its effects on health, and how health can be protected from radiation effects.

With the support of the many A-bomb survivors exposed in Hiroshima and Nagasaki, the Radiation Effects Research Foundation has studied for more than 65 years A-bomb radiation effects on human health. This booklet has been prepared to explain, based on the results of our studies to date, the relationship between radiation and health in an easily understandable manner. Efforts have been made to avoid difficult scientific terms when possible, albeit at the risk of compromising some scientific accuracy. Please do not hesitate to comment on any points that merit our attention. Our goal is to continually improve this booklet through feedback from our readers.

Radiation Effects Research Foundation

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What is Radiation?

Radiation Research: A Leading Scientific Field in the 20th Century

Dr. Roentgen received the first Nobel Prize in Physics

In 1895, Dr. Roentgen discovered mysterious rays that had light-like properties and could travel through matter, and he named these X-rays. Dr. Roentgen soon used X-rays to take a photograph of his wife's hand. X-rays brought about a vast improvement in medical diagnosis. For this achievement, Dr. Roentgen was awarded the first Nobel Prize in Physics in 1901. This knowledge of the existence of X-rays has provided great insight into radiation.


Dr. Wilhelm Roentgen


X-ray photo of Mrs. Roentgen's hand taken by her husband

The 20th century—the century of physics

In the scientific community, the 20th century is often called the "century of physics." And radiation research was at the forefront of this field. Following Dr. Roentgen, Dr. Becquerel found that a mineral called uranium emitted radiation. Such emission of radiation from matter is called "radioactivity."

In addition, Drs. Pierre and Marie Curie succeeded in extracting radioactive elements from mineral ores and named them polonium and radium. Dr. Becquerel and both Curies received the Nobel Prizes in Physics in 1903.


Dr. Marie Curie

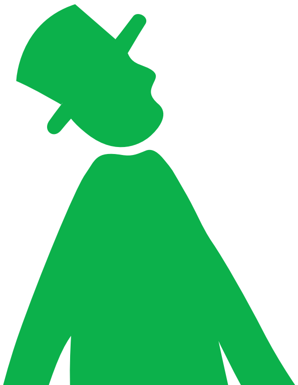

Dr. Henri Becquerel

Research of radiation and atoms led to discovery of atomic energy

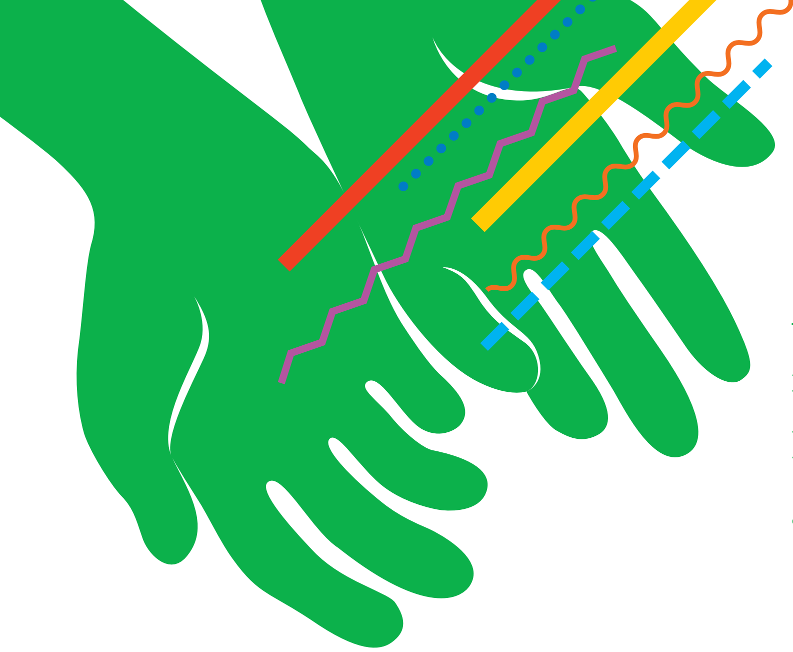
Advances in science in the 20th century, starting with the discovery of radiation, were not limited to physics. In 1911, Dr. Marie Curie again received the Nobel Prize, this time in chemistry for research that included study of the nature of radium. Dr. Ernest Rutherford, who received the Nobel Prize in Chemistry in 1908, conducted research on the mechanism of radiation emission due to the natural decay of atoms composing matter. Dr. Frederic Soddy found that atoms change to other atoms with different masses and emit radiation when they decay, and that atoms have radioactive radioisotopes of different masses. For his work, Dr. Soddy received the Nobel Prize in Chemistry in 1921.

Research on atoms, the building blocks of matter, thus advanced based on radiation research, leading to the discovery of a new form of energy: atomic power. Atomic power means energy produced by reactions (fission and fusion) of nuclei, located in the center of atoms, and is also called nuclear energy. The theory of relativity, established by Dr. Einstein, a leading scientist of the 20th century, provided the theoretical basis for the discovery of atomic power. Dr. Einstein regarded mass and energy as equivalent and interchangeable, and showed the possibility that enormous energy could be produced by nuclear reactions accompanied by a reduction of mass.

Though not visible to our eyes,
radiation is all around us.
Radiation's discovery gave birth
to a new field of science.



Nobel Prizes are awarded in six fields: physics, chemistry, physiology or medicine, literature, peace, and economics. Nobel Prizes for research on the health effects of radiation are awarded in the field of physiology or medicine. One such Nobel laureate is Dr. Hermann Muller (recipient in 1946), who found that X-irradiation increased gene mutations in experiments with fruit flies.

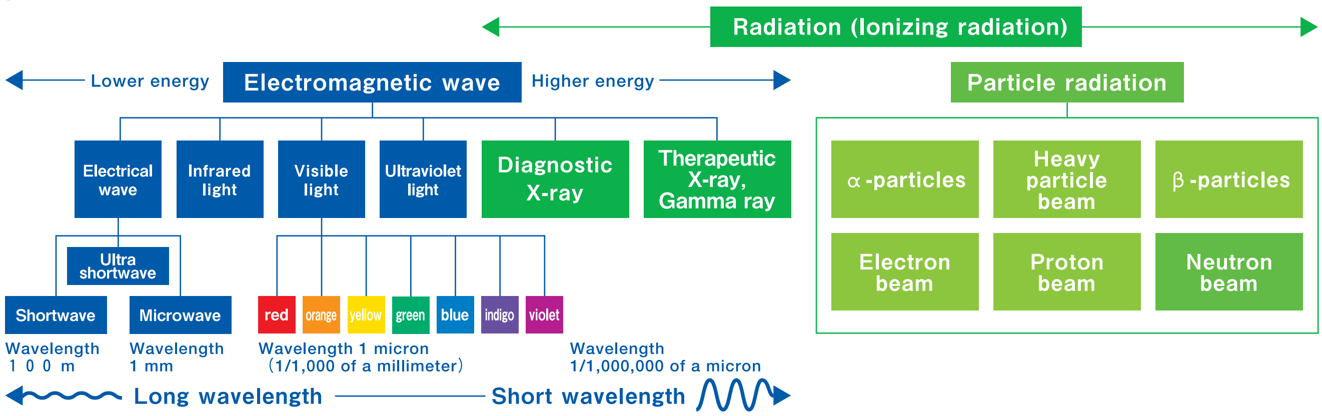


Although it has no color or shape, radiation is not of a single type. How many kinds of radiation are there?

Types and Properties of Radiation

Radiation types

Radiation can be classified into electromagnetic radiation, which has characteristics similar to those of light, and particle radiation, which is generated by the movement of particles. X-rays and gamma rays (γ-rays) are electromagnetic radiation, whereas alpha particles (α-particles), beta particles (β-particles), and neutrons are particle radiation.

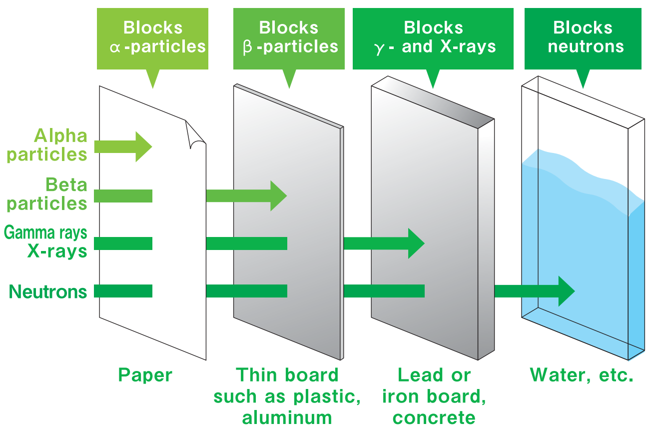


Radiation penetrates matter

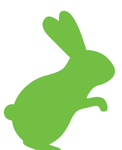
One of radiation's properties is its ability to penetrate various substances. This power of penetration varies depending on the type of radiation and on the radiation's energy.

In handling X-rays and gamma (γ) rays, shielding with very dense materials, such as lead or concrete, is used on equipment for the prevention of radiation leaks. To block release of neutrons from nuclear reactors, water is generally used for shielding.

Alpha (α) particles are produced following the splitting of large, unstable atomic nuclei such as those of uranium and plutonium. Each α-particle consists of two protons and two neutrons, components that form the atomic nuclei. This large particle can be blocked with a single sheet of paper. Beta (β) particles are another type of particle radiation consisting of one electron. A one-centimeter-thick plastic board can sufficiently block β-particles, even though impeding this radiation is not as easy as with α-particles.



Radiation dose to which an A-bomb survivor in Hiroshima or Nagasaki was exposed differs depending on whether he/she was shielded in a house or was outside, and on distance from the hypocenter. Radiation Effects Research Foundation (RERF) surveys detailed exposure conditions of each individual at the time of the bombing and thereby calculates radiation dose specific to each major organ.



Radiation in Nature and Everyday Life

Radiation in nature

Radiation is generated from such natural sources as the cosmos and the inside of the earth. Our body—bones in particular—also emits radiation. Therefore, we can never completely avoid radiation. Because cosmic radiation is attenuated as it passes through earth's atmosphere, cosmic radiation dose at ground level is one-fifth of that at the summit of Mt. Fuji. Also, air travel results in exposure to slightly higher doses of cosmic radiation. Total annual natural radiation dose for people living on Earth can be estimated at about 2 mSv on average, though it varies by geographical area.

Radiation exposure from health examinations

A primary source of radiation exposure in daily life is health examinations using radiation. Let's consider one truckload as representing the annual average of total natural radiation dose (about 2 mSv). Radiation dose from 40 chest X-ray examinations corresponds to roughly one truckload. Certain special X-ray examinations, such as stomach X-ray and CT (computed tomography) examinations involving multiple images, can correspond to three truckloads and four truckloads per examination, respectively. These examinations are for disease diagnosis. Therefore, when they are considered necessary by a physician, rather than refusing to undergo the examinations simply out of fear of radiation, soliciting opinions from the physician would be wise. Ionizing radiation is not used in ultrasonographic and MRI (magnetic resonance imaging) examinations.

Radiation dose per one X-ray examination (approximate)

General X-ray exam (chest)	=	About 0.03 truckloads
Natural radiation (annual average)	=	1 truckload
General X-ray exam (upper GI)	=	3 truckloads
X-ray CT exam (chest)	=	4 truckloads

Radiation in everyday life

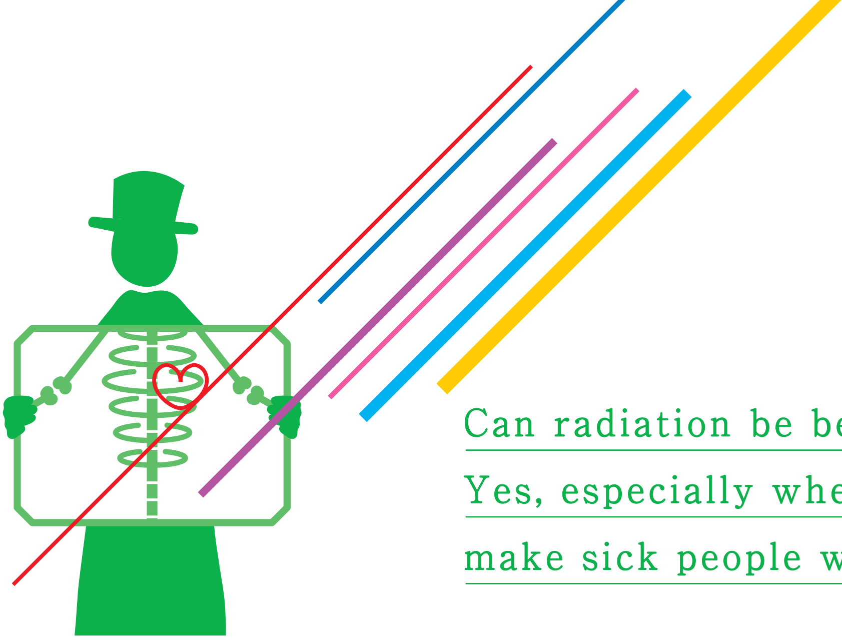
The special properties of radiation are used in various ways in our daily life. Radiation's ability to destroy cells and cause mutations is used in anti-bacterial sterilization, pest control, and selective breeding of plants. Its property of penetrating substances is used in measuring material thickness and testing for product defects. Furthermore, nuclear power generation uses energy produced from nuclear fission, which creates radiation.

Radiation dose units

Gray (Gy)	=	Unit of dose absorbed by matter exposed to radiation
Sievert (Sv)	=	Hypothetical unit of magnitude used to represent effects of different types and doses of radiation on humans
Millisievert (mSv)	=	0.001 Sv

Radiation comes from both the ground and the air. It is important to learn about radiation, even though we cannot see it.

Radiation has multiple uses in our daily lives. RERF's radiation research results have proved useful in establishing safety standards for protecting people from radiation.



Can radiation be beneficial to people?

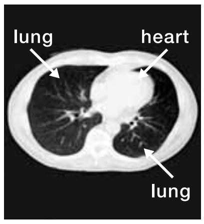
Yes, especially when it can be used to make sick people well again.

Radiation Actively Used in Medical Care

Using X-rays to look inside the body

X-rays can be used to see inside the human body utilizing their ability to penetrate matter. The amount of X-rays that penetrate depends on the density of materials (such as amount of air or water). Black-and-white images based on this property are produced to visualize tumors, inflammation, and other disorders. Computed tomography (CT) is a technology for taking 360° images and reproducing realistic cross-sectional images of the body. CT examinations have drastically advanced diagnosis of tumors and vascular disease.

Radiograph
(Frontal view of chest)

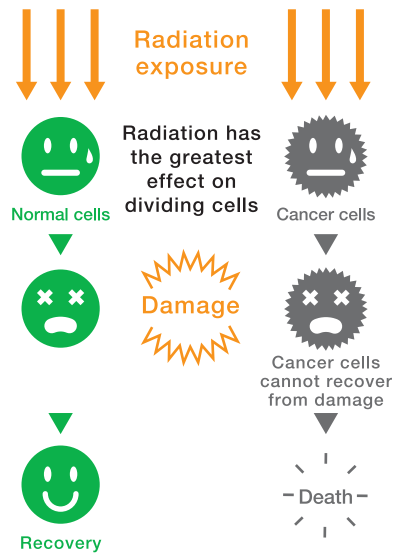


CT image
(Cross section of chest)

Disease diagnosis using radioactive agents

When administered in the body, radioactive agents are absorbed by specific organs or tissues, depending on their chemical characteristics. Disease diagnosis can be made by detecting the radiation released from such agents. Positron emission tomography (PET), a technology recently attracting attention for cancer diagnosis, utilizes cancer's property of proliferation in this way. Patients are administered internally a sugar compound containing a radioactive atom, a large amount of which is absorbed by cancer cells, and which then allows cancer to be identified by localizing the points of radiation emission.

Radiation therapy of cancer



Actively dividing cancer cells perish rapidly

Eliminating cancer cells with radiation

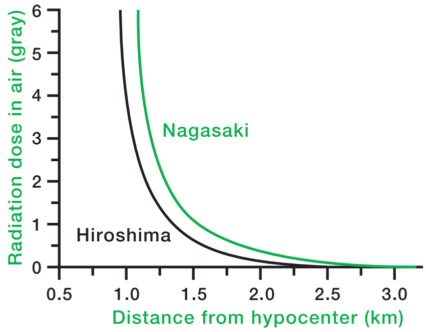
Cancer cells are susceptible to radiation effects because they undergo active cell division. Radiation therapy is therefore used to eliminate cancer cells by exposing them to radiation from outside the body or inserting radioactive substances into the body. Along with surgery and chemotherapy using anti-cancer agents, radiation therapy is a commonly utilized cancer treatment. Traditionally, high-energy X-rays, electrons, and gamma rays have been used to treat cancer. Recently, however, attention is focused on treatment using protons, heavy particles, and other types of radiation that selectively release their energy at the cancer site and are less detrimental to normal cells.

The "new type of weapon" dropped on Hiroshima that claimed so many lives was confirmed to be an atomic bomb because unused X-ray film stored in tightly sealed containers at the Hiroshima Red Cross Hospital was found to have changed its color due to radiation exposure.

Atomic Bombs and Radiation

Destructive energy of atomic bombs

The atomic bomb dropped on Hiroshima used uranium and is estimated to have released energy equivalent to 16,000 tons of conventional TNT (trinitrotoluene) explosive. The explosive energy of later hydrogen bombs was at least 1,000 times higher. The bomb dropped on Nagasaki used plutonium and is said to have generated energy equivalent to 21,000 tons of TNT. The bombs exploded at altitudes of 600 m and 500 m, respectively. About 50%, 35%, and 15% of the total energy was released as blast, heat, and radiation, respectively, and the greater the distance from the hypocenters, the more dissipated the energy became in its respective forms.



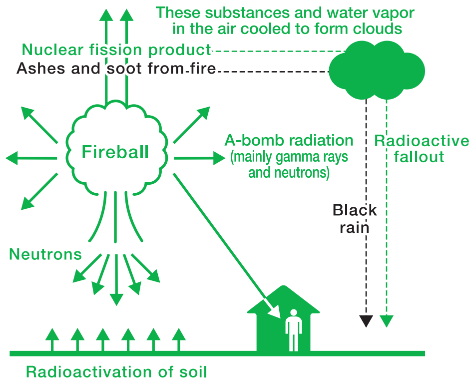
Relationship between radiation dose (total of neutrons and gamma rays released directly from each A-bomb) and distance from the hypocenter without any shielding. In average Japanese houses, radiation doses were about half of the values in this figure.

Number of deaths due to the atomic bombs

Damage to people in Hiroshima and Nagasaki caused by these bombs was due to the above-mentioned blast, heat, and radiation. Near the hypocenters, many died because of the intense heat of several thousand degrees or from being trapped under the crushed houses or blown away by the strong blast. Fires also broke out, with many people unable to escape dying in the flames. Although the number of deaths is unclear, estimates of casualties by the end of 1945 indicate that, of Hiroshima's total population of 360,000, 140,000 died and 80,000 were injured, and of Nagasaki's total of 250,000, 70,000 people died and 80,000 were injured. The threat from invisible radiation caused great anxiety among the exposed, because radiation health effects were unknown then and it was the first time in human history that so many people had been exposed.

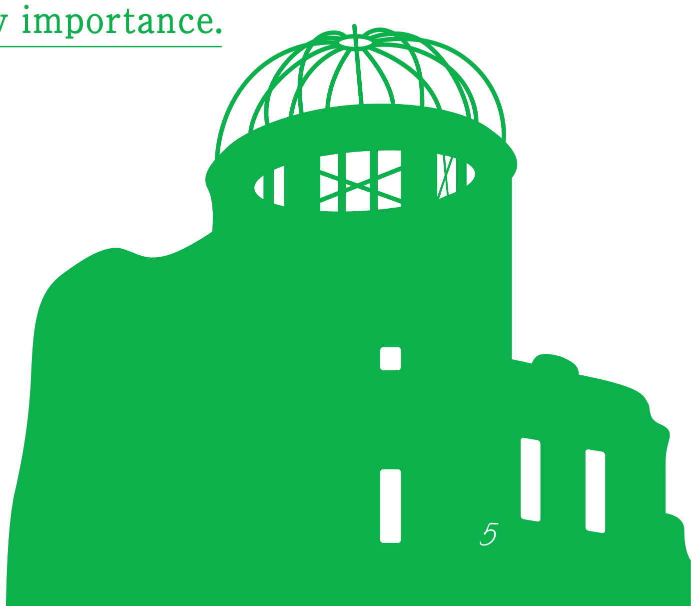
Radiation doses to which people were exposed

To determine radiation effects on health, it is necessary to analyze relationships between radiation doses to which A-bomb survivors were exposed and disease incidence and mortality. In studies of A-bomb survivors, the radiation dose to each A-bomb survivor was estimated based on such detailed information as his or her distance from the hypocenter and the presence of structures that shielded him or her from radiation. In addition, information on his or her orientation and posture at the time of exposure has been collected for estimation of doses to which respective organs in the body were exposed. Such organ doses are used in organ-specific cancer risk analyses.



People were exposed to not only radiation released directly from the bombs but also radiation from radioactive fallout contained in black rain and from neutron activation in soils. Estimation of radiation doses from such sources requires each individual's actual record of activities, such as his or her location and time spent in that location after the bombing.

Radiation can also be used with disastrous results.
People's peaceful coexistence is therefore
of primary importance.



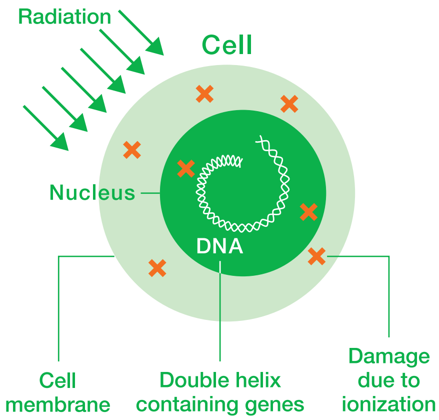
RERF studies health effects of A-bomb radiation in Hiroshima and Nagasaki. Study results are used for maintenance of the health and welfare of A-bomb survivors. Such information is also used by the United Nations, other international organizations, and governments as the most fundamental source of information on radiation risks in order to improve the health and safety of people around the world.

Health Effects from Radiation

Effects of Radiation on the Human Body

Radiation affects cells in the body

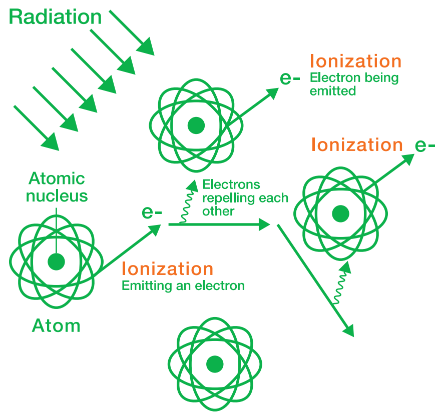
Human tissue viewed through a microscope can be seen to be comprised of small cells. Proteins and other compounds, which are formed by atoms, the building blocks of all substances, constitute such cells. When the human body is exposed to radiation, the molecules, the bonds between atoms, are damaged. This damage can cause cell death and changes (mutations) to genes, the blueprint for cells, leading to transformation into cells with different characteristics. Gene mutations are considered to be one of the causes for future development of cancer cells.



Injuries caused by radiation are at the molecular level

Effects are caused by emitted electrons

Atoms constitute all substances and have a nucleus at their center, with negatively charged electrons orbiting the nucleus. The atomic nucleus contains positively charged protons. Because the number of protons equals that of electrons, an atom has no net electrical charge. When radiation hits an atom, however, electrons are released from the atom. This produces free negatively charged electrons and an atom that is positively charged due to the loss of electrons. This process is called "ionization." Electrons emitted in this way can further ionize surrounding atoms. Radiation ionizes atoms constituting the human body, and damages cells and genes, which may cause various diseases. Radiation that ionizes other substances is formally termed "ionizing radiation," but more often just called "radiation."



Radiation induces atoms to release electrons

Tissues and organs undergoing active cell division are susceptible to radiation effects

Radiation damages cells and genes, and may prevent normal function of body tissues and organs to cause various diseases. Cells undergoing active cell division to produce new cells are especially susceptible to radiation effects. Therefore, cells that generate skin, cells forming the mucous membrane of the digestive tract, and cells in bone marrow for blood production are all affected greatly.

At RERF, blood and other biosamples donated by A-bomb survivors in Hiroshima and Nagasaki are used for studying mechanisms of radiation damage to cells and genes, and of diseases such as cancer.

Epidemiological Research Reveals Health Effects from Radiation

Epidemiological studies

Epidemiological studies are designed to examine individual health status, analyze the accumulated information at the group level, and reveal disease causes. This field has contributed greatly to the health and medical care of humankind by serving to overcome epidemics in the past and more recently by generating results in revealing causes of pollution-related, occupational, and lifestyle diseases, as well as judging effects of inoculations and health examinations.

Methods of epidemiological investigation

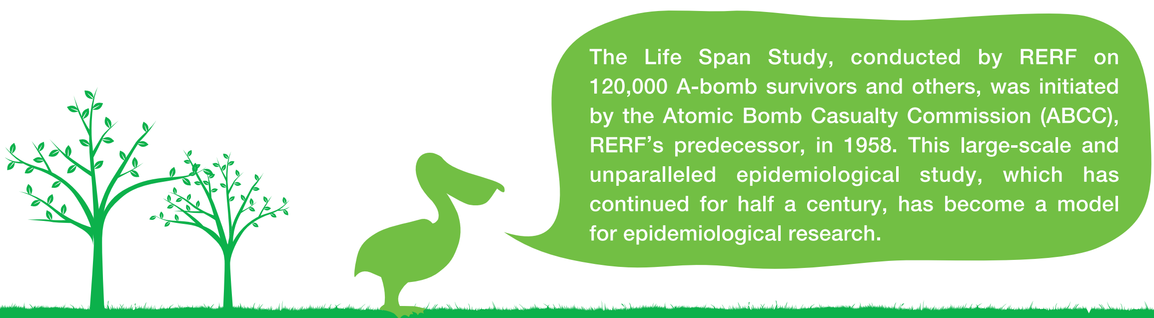
The first step of an epidemiological investigation is to ascertain how a certain disease is caused in human populations. It is important to investigate not only those affected by the disease but also the entire group, including healthy individuals. The incidence (frequency) of a certain disease can be calculated by dividing all affected individuals, comprising the numerator, by the entire population, the denominator.

With regard to several possible factors behind a specific disease, the relationship between the amount of exposure to these factors and frequency of the disease is examined to ensure that causes of the disease are identified. If greater exposure to a factor is observed to cause a higher incidence, a good possibility exists that the factor is a cause of the disease. The criteria shown below are also used to identify disease causes in a comprehensive manner.

Criteria for estimation of disease causes based on epidemiological studies

Even if greater exposure to a factor is observed to cause higher incidence of a certain disease, the observation may be the result of chance. Other hidden factors may also be interacting with that factor. In other words, causation cannot be determined based simply on an observed association alone. However, the factor is likely to be an actual cause when the five criteria indicated below hold true. The explanations in the parentheses indicate how each of the criteria applies to the relationship between cancer and radiation in RERF studies.

1. **Timing**
   The factor was present before development of the disease. (RERF studies meet this criterion because increased development of cancer and other diseases after radiation exposure in 1945 is investigated in those exposed.)
2. **Consistency**
   The same associations are also observed in other populations. (The relationship between radiation and cancer meets this criterion because the same trend has been observed in other populations, such as people undergoing radiotherapy.)
3. **Strength**
   There is strong association between higher exposure to the factor and a higher ratio of people affected by the disease. (Results of RERF studies meet this criterion because cancer frequency increases with increased radiation dose, being about 1.5 times higher at a radiation exposure of 1 Gy compared to the frequency in unexposed.)
4. **Specificity**
   A 1:1 ratio exists between the factor and the disease. (Radiation is related to cancer but is also known to cause other diseases, such as cataracts. At the same time, cancer is related not only to radiation but also to smoking and alcohol intake. Thus, the 1:1 ratio does not exist between radiation and cancer but this does not negate the causal relationship between them.)
5. **Coherence**
   The relationship does not contradict generally accepted medical and biological theories and knowledge. (The relationship between radiation and cancer has been confirmed in animal experiments, and its mechanisms are becoming clear. Thus, the relationship meets this criterion.)

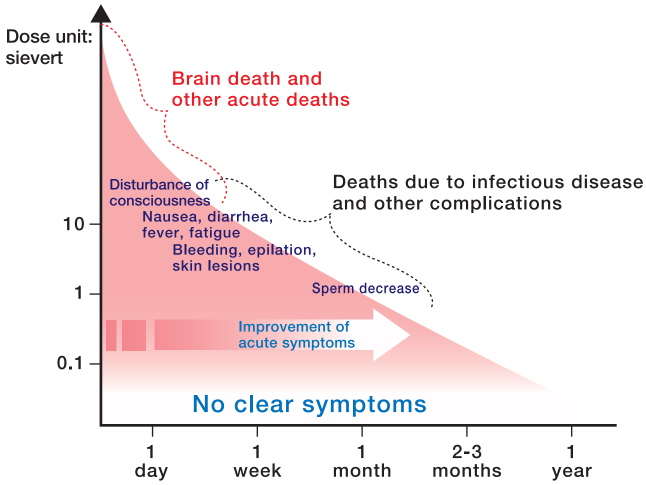


Early Effects from Radiation

Following the radiation exposure, various health effects occur, depending on dose. Even with the same total radiation dose, effects of one-time exposure are different from those exposures divided into multiple doses. Here, we will explain early effects (within about one year) of one-time exposure (either whole-body or partial-body).

Early effects in whole-body exposure

When the entire body is exposed to radiation, various symptoms appear over time. In the figure at right, the vertical axis represents radiation dose, and the horizontal axis represents time since exposure. The higher the radiation dose, the more serious the symptoms become. When exposed to more than 5 Sv of radiation, death can occur within one week. Such serious consequences are due to radiation damage to cells in essential organs and result in loss of the functions of such organs. When bone marrow is damaged, the production of blood cells is interrupted and a shortage of blood cells can occur. Then, hemorrhage can occur. Infections can occur, as well, due to decreased immunological competence. Damage to digestive tract mucous membranes causes diarrhea, while damage to skin triggers dermatitis and epilation (loss of hair). If cell functions recover, such symptoms can gradually improve.



Early effects in partial-body exposure

Symptoms that appear after partial-body exposure to radiation vary, depending on not only radiation dose but also the functions of the exposed tissues and organs. For example, if skin is exposed to high-dose radiation, not only the skin surface, but also the cells that produce new skin, can be damaged, leading to deep ulcers (open sores) that do not heal easily. Because tissues and organs in which active cell division takes place are more susceptible to radiation effects, skin, the mucous membrane of the digestive tract, and blood-producing bone marrow are all susceptible to damage.

Health disturbances due to A-bombs

Health disturbances due to the A-bombs are not limited to radiation effects. Injuries from the blast and burns due to heat and subsequent fires were the main early injuries caused by the A-bombs. Such damage was investigated in detail by Japanese survey teams immediately after the bombings and later by the U.S.-Japan Joint Commission.

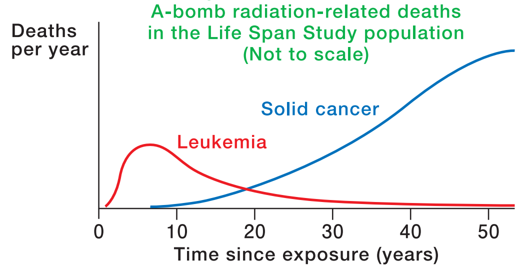
After investigations of early effects of the atomic bombs, considering that long-term studies were essential to investigate late effects, the Atomic Bomb Casualty Commission (ABCC) was established in March 1947. In 1975, the present-day Radiation Effects Research Foundation (RERF) took over the long-term systematic studies begun by ABCC.

Long-term Effects of Radiation Findings from RERF Studies

Cancer incidence and mortality among A-bomb survivors

RERF studies have found that cancer incidence (rate of cancer in the population) and mortality (rate of death in the population) are higher among people exposed to radiation than among those who were not exposed. RERF's Life Span Study estimates that, among A-bomb survivors, leukemia mortality started to increase two to three years after exposure, reached a peak after five to ten years, and decreased thereafter. Mortality from solid cancers (all cancers except leukemia) started to appear about 10 years after exposure and has increased with the aging of A-bomb survivors.

Changes over time in number of A-bomb radiation-related deaths in the Life Span Study population (Not to scale)



Relationship between solid cancers and radiation dose

For radiation doses of at least 100–200 millisieverts (mSv), the degree of cancer increase (relative risk) is directly proportional to the dose: the risk is estimated to be about 1.5 times greater at 1,000 mSv, around 1.25 times greater at 500 mSv, and perhaps about 1.05 times greater at 100 mSv. For doses of less than 100–200 mSv, the relationship between the relative risk of cancer and dose is uncertain because, especially for that dose range, cancer risks from radiation can be difficult to detect due to the effects of different risk factors, such as smoking and other lifestyle habits.

Estimates of the lifetime risk of mortality (the probability of eventually dying from a particular cause) from solid cancers following radiation exposure indicate that, whereas the lifetime cancer mortality risk for unexposed people is about 20% (roughly 20% of people die from cancer), the risk for those exposed to 100 mSv at age 30 is around 21%, an increase of approximately one percentage point (see table at right).

Radiation risk in the Life Span Study population (Lifetime risk)

Age at exposure	Sex	Lifetime excess risk (%)	Lifetime risk without exposure (%)
10	Males	2.1%	30%
	Females	2.2%	20%
30	Males	0.9%	25%
	Females	1.1%	19%
50	Males	0.3%	20%
	Females	0.4%	16%

Diseases other than cancer

RERF studies of A-bomb survivors show that, in addition to cancer, the rates of cataract (a disease marked by clouding of the eye lens), thyroid nodules (non-invasive masses arising in the thyroid gland), and hyperparathyroidism (excessive functioning of the parathyroid gland) are higher among persons exposed to radiation than among those who were not exposed. Brain development (in the case of exposure during 8–25 weeks after conception) and physical growth were also affected among persons exposed *in utero* (in the mother's womb prior to birth), especially those whose mothers were so heavily exposed as to experience acute symptoms of radiation sickness.

Further elucidation of radiation effects anticipated in the future

The mechanisms of cancer development related to radiation exposure continue to be an important research topic. In addition, detailed studies are now under way regarding the effects of radiation on various non-cancer diseases. For example, increased rates of heart disease and chronic liver disease, elevated cholesterol levels and blood pressure, and certain immunological function abnormalities have been observed. However, researchers have only recently begun to observe these diseases owing in part to improved diagnostic methods and clearer scientific hypotheses that have emerged over the course of the RERF studies, and therefore further long-term research is needed to clarify any possible associations.

To confirm whether or not cancer increased due to radiation exposure, it is necessary to examine how much higher cancer rates are among exposed people than the unexposed. Since 1957 in Hiroshima and 1958 in Nagasaki, local medical institutes have cooperated in collecting information on how many people have contracted what kinds of cancer. These activities comprise the work of cancer registries.

Radiation and Heredity

Radiation exposure sometimes damages genes, which are the blueprint for cells. What if radiation hits the reproductive cells of men or women? Could it cause diseases or disorders in children yet to be born?

Studies of genetic effects in A-bomb survivors

One of the most serious concerns of A-bomb survivors was whether exposure to A-bomb radiation would increase the incidence of diseases and disorders among their children. Fortunately, no increase in abnormalities in children of the A-bomb survivors due to parental radiation exposure has been observed in any of the studies conducted to date. However careful follow-up will be continued in the future.

Large-scale studies of the children of A-bomb survivors, conducted to investigate this issue, are shown below.

Study	Population size	Period of study
1 Abnormalities at birth	77,000 persons	1948 — 1954
2 Chromosome aberrations	16,000 persons	1967 — 1985
3 Blood protein abnormalities	24,000 persons	1975 — 1985
4 Cancer and mortality	77,000 persons	1946 — present
5 Lifestyle diseases	12,000 persons	2002 — present

An offspring of the A-bombed Chinese parasol tree

The offspring of an A-bombed Chinese parasol tree, planted to commemorate the 30th anniversary of RERF, symbolizes the wishes of RERF and A-bomb survivors for the good health of the children of the survivors.

Protection from Radiation Health Effects

What rules enable humans to coexist with radiation?

Radiation Risk Assessment and Safety Standards

International assessment of radiation risks

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) collects and analyzes data regarding radiation effects on the environment and on human health from United Nations members and other countries and compiles reports on radiation-risk assessment. Many countries and international organizations use such reports as the basis for investigations into radiation protection and safety. Scientists from 21 countries, including the United States, the United Kingdom, Sweden, and Japan, currently take part in UNSCEAR activities.

The Committee on the Biological Effects of Ionizing Radiation (BEIR) of the U.S. National Academy of Sciences also compiles radiation-risk assessments and publishes related periodical reports.

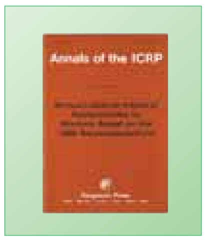
UNSCEAR report

BEIR report

Radiation safety standards of countries

Based on radiation risks indicated in UNSCEAR reports and other documents, the International Commission on Radiological Protection (ICRP) considers fundamental principles on radiation protection and specific views concerning regulatory measures such as dose limits, and publishes its recommendations. These reports are regarded by countries throughout the world as an important basis for establishment of radiation safety standards.

Based on ICRP recommendations, Japan has incorporated standards for protection of human health into the Law Concerning Prevention of Radiation Hazards, as shown in the table at right. Current radiation dose limits are the result of revisions to standards made in 2000 based on the 1990 ICRP recommendations. In addition, Japan's Industrial Health and Safety Law as well as medical and pharmaceutical laws have been established to set safety standards for workplaces, medical care, and drug production.



1990 ICRP recommendations

Radiation dose limits set by the Japanese government

For workers handling radioisotopes	For the general public
100 mSv/5 years 50 mSv/year	1 mSv/year

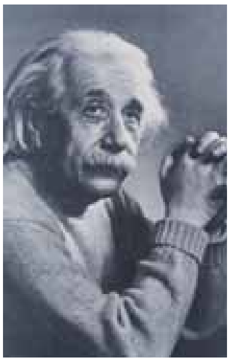
International regulations concerning safety standards in countries

With regard to radiation safety standards established by countries, international organizations such as the International Atomic Energy Agency (IAEA), the World Health Organization (WHO), and the International Labour Organization (ILO) conclude treaties that present consistent views internationally. They also draw up international policy measures such as those for immediate notification following nuclear power accidents and support to be provided in emergencies. Member countries of such international organizations have a legal obligation to observe the treaties after completing official procedures to formally accept them.

Results of epidemiological studies conducted by RERF are considered by the global community to be the most reliable source of such information because of the large number of study subjects, accuracy of estimated radiation doses, and completeness of follow-up studies. These results are cited in reports published by such organizations as UNSCEAR, BEIR, and ICRP, and serve as important data for the establishment of radiation protection standards around the world.

Path to World Peace

Scientists for peace


Dr. Albert Einstein

All humanity agrees that the first atomic-bomb tragedies in human history experienced by Hiroshima and Nagasaki must never be repeated. This sentiment has driven many scientists to engage in activities toward creation of a peaceful world without nuclear war. Such activities continue today.

Dr. Einstein, a German theoretical physicist who had sought asylum in the U.S. because of oppression from Germany's Nazi government, sent a letter to the U.S. president in 1939, notifying him of the Nazis' attempts to develop powerful weapons using uranium and encouraging research in this field in the United States. After the war, chagrined that atomic bombs had actually been used, he signed the Russell-Einstein Manifesto, which urged governments of the world to find peaceful means for settling disputes, with the aim of avoiding annihilation of the human race by nuclear weapons. Among the other nine scientists who signed the manifesto were Drs. Pauling and Rotblat, both of whom were later awarded the Nobel Peace Prize. Also included were Dr. Hideki Yukawa, a Japanese physicist, and Dr. Muller, who discovered the relationship between X-rays and genetic mutations. In support of this manifesto, the Pugwash Conferences on Science and World Affairs, an international forum of scientists who call for the elimination of all nuclear weapons and armed conflicts, was established in 1957.

Scientists who were awarded the Nobel Peace Prize


Dr. Linus Pauling


Dr. Joseph Rotblat

Dr. Pauling pointed out the possibility that above-ground nuclear testing could pose public health risks in the form of radioactive fallout, and presented the United Nations with a petition signed by more than 10,000 scientists calling for a ban on nuclear-weapons testing. He received the Nobel Peace Prize in 1962 for his efforts, which led to signing of the Partial Test Ban Treaty (PTBT) in 1963 by the U.S., the U.K., and the USSR.

The International Physicians for the Prevention of Nuclear War (IPPNW), which was awarded the Nobel Peace Prize in 1985, campaigned for prevention of nuclear war during the Cold War period, as a shared mission among member physicians in both the East and West.

In 1995, together with its president Dr. Rotblat, the Pugwash Conferences, a forum for scientists to engage in discussions as individuals unrestrained by their positions, won the Nobel Peace Prize for its contributions to and large impact on nuclear disarmament policymaking. Dr. Rotblat, in his Nobel Peace Prize acceptance speech, called for harmony between science and humanity.

A-bomb-exposed radiologist's prayer for peace

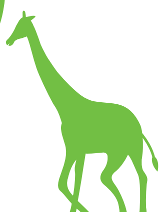

Dr. Takashi Nagai, confined to bed, with his family

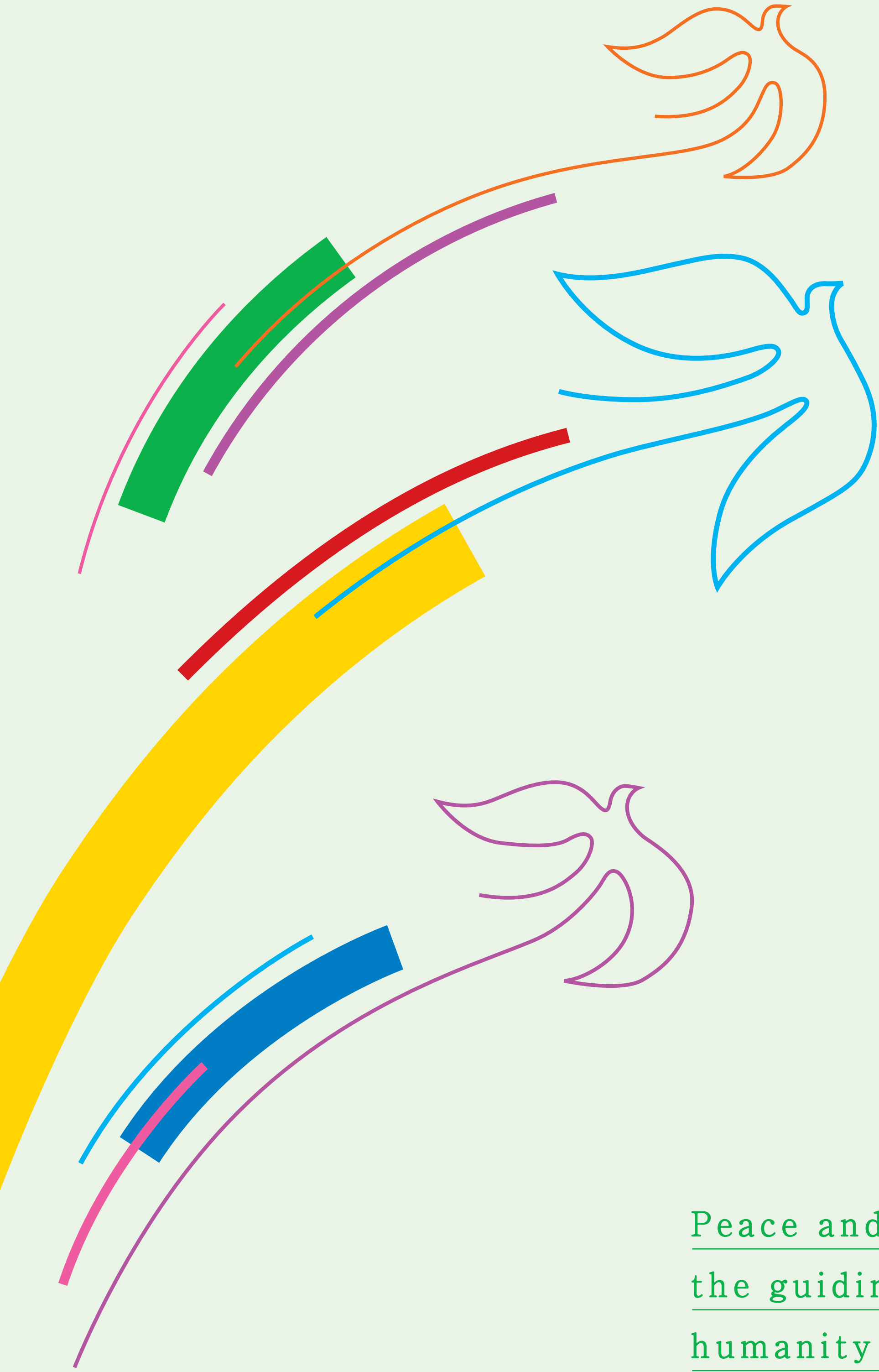
Dr. Nagai, a radiologist, was exposed to the atomic bombing at the Nagasaki Medical College close to the hypocenter in that city. Despite having lost his wife and suffering injuries and serious illness himself, he never ceased the work of treating other survivors. All his research materials were incinerated in the bombing. Yet, this did not deprive him of his spirit of scientific inquiry.

"The totally new disease that has emerged before our very eyes. The disease for which we have been chosen as the most appropriate witnesses and observers in the history of medical science. Atomic bomb disease! I shall study this new disease!" (From his book "Leaving These Children Behind") Later, as his condition worsened and he was confined to his bed, he continued his research, believing, "Fortunately, the very disease I want to study lies within my body." (From the same book)

The last chapter of another of his books, "The Bells of Nagasaki," represents his prayer for peace: "Men and women of the world, never again plan war! With this atomic bomb, war can only mean suicide for the human race. We pray that Uragami may be the last atomic wilderness in the history of the world."

RERF conducts medical research and studies for peaceful purposes, with a view to protecting the world's people from radiation effects. We hope that our efforts can prove useful in the attainment of health and wellbeing for not only those exposed to the A-bombs but for all people throughout the world.





Peace and science can be
the guiding lights to lead
humanity into the future.

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First edition: July 2008
Second edition: March 2014