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# Genetic Effects and Birth Defects from Radiation Exposure

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People exposed to the release of radioactive materials from Hanford have many questions and concerns about radiation's effects on their personal and family health. One concern is whether radiation from Hanford caused [genetic effects](#) or birth defects.

This report discusses [genes](#), [mutations](#) and birth defects, and how radiation can harm a cell. Then it reviews studies on the effects of parental radiation exposure before pregnancy and the effects of radiation exposure before birth. Next, it presents results from new laboratory research. Lastly, this report discusses the information in relation to Hanford's releases.

Other HHIN publications may be referred to for information about other aspects of exposure to Hanford's radioactive releases. [An Overview of Hanford and Radiation Health Effects](#) summarizes the potential health effects of radiation from Hanford. [Radioactivity in the Body](#) discusses how the body handles internal radiation exposure. The [Health Bulletin](#) contains a map of the area for which representative dose estimates are now available from the [Hanford Environmental Dose Reconstruction Project](#). The Health Bulletin also has a list of factors that affect the dose of radiation a person receives.

### The Basics of Genetic Effects and Birth Defects

Characteristics such as eye, hair or skin color that make each person unique are called genetic traits. These traits are based on information contained in the [genes](#) of the deoxyribonucleic acid ([DNA](#)), which are inherited at the time of birth. Genes are part of the 23 pairs of [chromosomes](#) found in human cells.

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Changes in the genes of DNA can arise spontaneously (naturally) or as a result of exposure to radiation or to chemical and physical agents. Such changes are known as mutations. When these changes result from radiation exposure they are called radiation-induced mutations.

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There are two types of mutations: germline and somatic. A germline mutation, or inheritable genetic effect, occurs when the DNA of a reproductive cell (sperm or egg) is damaged. Radiation-induced germline mutations may cause health problems which include miscarriages, stillbirths, congenital defects, premature death (death in the first year of life), chromosomal abnormalities and cancer in later life.

A somatic mutation, which is not inheritable, occurs when the DNA of a non-reproductive cell is damaged. Radiation-induced somatic mutations may also cause health problems but affect only the exposed individual [see the HHIN publication [An Overview of Hanford and Radiation Health Effects](#)].

Health problems present at birth are known as birth defects. These can arise spontaneously, through impairment of normal developmental processes by radiation or by other toxic exposures. A birth defect caused by a germline mutation from a mother or father's exposure before conception is an inherited or genetic effect.

Other birth defects may occur if a child was exposed to radiation during the mother's pregnancy. These birth defects include a reduction in height, severe mental retardation, small head size and impaired brain development, the latter of which may indirectly reduce an individual's intelligence quotient (IQ) and school performance.

## How Radiation Can Harm a Cell

When a radioactive particle or wave hits a cell in the [body](#), one of four things can happen:

- It may pass through the cell without doing damage.
- It may damage the cell, but the cell may be able to repair the damage before it produces new cells.
- It may damage the cell in such a way that the damage is passed on when new cells are formed.

It may kill the cell.

## Studies of Genetic Effects and Birth Defects from Exposure to Radiation

This section summarizes the results of [studies](#) on [genetic effects](#) and birth defects related to radiation exposure. Most research of radiation and genetic effects and birth defects involves exposure to [external radiation](#), such as X-rays. In contrast, nearly all of the [dose](#) from Hanford came from [internal exposure](#). That is, people were exposed to this radiation through the food and water they consumed and the air they breathed.

When reviewing studies of [external exposure](#), it is important to understand that the study results may not apply to people exposed to internal radiation. Also, an internal exposure from a radioactive substance may give a dose mainly to one organ, such as iodine-131 gives to the [thyroid](#). The genetic effects from internal radiation exposure may be different than those caused by external radiation exposure.

## Radiation Exposure of Either Parent before Pregnancy

### *Children of Hanford Workers*

Studies by Lowell E. Sever, an epidemiologist with Battelle's Seattle Research Center, and others reported an association between [neural tube defects](#) and the radiation [dose](#) fathers received before their children were conceived. This effect was observed in children whose parents received low doses (10 [rem](#) or less) of external [whole-body](#) radiation while working.

Hanford. These results were not supported by studies of children born to Japanese atomic bomb survivors who received higher doses of radiation.

Other research suggests there is reason to believe that radiation exposure before pregnancy can increase the frequency of birth defects. Further studies are underway. One [study](#) being done around the Hanford Site is investigating the relationship between parents' exposure to radiation and [leukemia](#) in their children.

### *Children Born in the Hanford Area*

Sever and others also conducted a study of birth defects in Washington's Benton and Franklin counties near Hanford. The researchers examined the number of cases of certain birth defects between 1968 and 1980. There were more [neural tube defects](#) than expected when the county rates were compared with rates from Washington, Oregon and Idaho. Cleft lip was reported less often in Benton and Franklin counties than in the three-state area.

Using information from a study of Hanford workers, the researchers concluded that the increase in neural tube defects was not explained by parental employment at Hanford or by [occupational exposure](#) to radiation. The researchers also concluded it was unlikely that exposure of the general public to radiation from Hanford operations caused the increase in neural tube defects. This conclusion was based on a [dose](#) estimate of slightly more than 1 [rem](#) for the years 1974-1980.

This Hanford study includes only a few of the years which fall within the Hanford Health Information Network's Congressional mandate to focus on 1944-1972 - the years of the largest releases. In addition, the study's dose estimate for the public only included the years 1974-1980, during which there were limited Hanford operations. Also, the study was conducted prior to any dose estimates being available from the [Hanford Environmental Dose Reconstruction Project](#).<sup>1</sup>

### *Japanese Atomic Bomb Survivors*

William J. Schull (Director and Ashbel Smith Professor, Graduate School of Biomedical Sciences, University of Texas Health Science Center), Masanori Otake (Department of Statistics, Radiation Effects Research Foundation - RERF, Hiroshima, Japan) and other scientists have reported on genetic studies of children whose parents were exposed to the Hiroshima and Nagasaki atomic bombs. The studies found essentially no difference between the rate of inherited birth defects in children whose parents were exposed to radiation and in those whose parents were not exposed. These researchers, however, believe that [genetic damage](#) did occur because of the radiation exposure. Animal research and laboratory experiments suggest that inherited genetic effects from radiation exposure should occur in humans. It is possible that current research methods may not be able to detect the genetic effect in humans.

### *Cancer Survivors*

John J. Mulvihill (epidemiologist in genetics at the National Cancer Institute) and J. Byrne (Department of Internal Medicine at Loma Linda University in California) studied cancer survivors who received radiation treatment or chemotherapy (drug treatment). They investigated whether the offspring of the cancer survivors had higher rates of genetic disease than children of parents without cancer. People in the study group were diagnosed with cancer before the age of 20 and had survived for more than five years. The researchers compared the study group to a group of people without cancer.

The rates of genetic diseases were the same in both the cancer survivors group and the non-cancer group. This indicated that there was not a higher rate of genetic disease in children of cancer survivors who had undergone radiation therapy or chemotherapy or both.

### *Leukemia in Children Born to Radiation Exposed Fathers*

In 1990, Martin J. Gardner (Environmental Epidemiology Unit at the University of Southampton, England) and colleagues published the results of a study of [leukemia](#) and lymphoma among young people born and living near the

Sellafield nuclear power plant in West Cumbria, United Kingdom. The researchers concluded that leukemia in children was linked to their fathers' exposure to external [whole-body radiation](#) before conception of the child.

For children whose fathers worked at the nuclear facility, the rate of childhood leukemia was twice as high as normal. There was also an eight-fold increase of leukemia in children whose fathers received a life-time dose greater than 10 [rem](#) or a [dose](#) greater than 1 rem within the six months before the children's conception. Leukemia, however, was also found more often than expected in children whose fathers were farmers or worked in the steel or chemical industries.

Interpretation of this finding includes consideration of the very small number of fathers whose children had leukemia. Out of the 46 fathers who worked at Sellafield, four had children with leukemia. In comparison, out of the 276 fathers who did not work at Sellafield, but were part of this study, only three had children with leukemia.

Several scientists attempted to reproduce the results of Gardner's study. A study by P.A. McKinney (Information and Statistics Division, Scottish Common Services, Edinburgh, Scotland) indicated a 2.5-fold increase in leukemia in children whose fathers had radiation doses similar to those in the Gardner study. A study by J.D. Urquhart (Principal Research Officer, Information Services Division, Scottish Health Services, Edinburgh, Scotland) found that there was a 42 percent reduction in leukemia in children of exposed fathers compared with unexposed fathers.

Other scientists have developed different explanations about the results of Gardner's study. H.J. Evans (Human Genetics Unit, Western General Hospital, Edinburgh, Scotland) found that most of the children had a genetic disorder that caused acute lymphatic leukemia and that this disorder was not related to a father's radiation exposure. L.J. Kinlen (Department of Public Health and Primary Care, University of Oxford, England) suggested that the increase in leukemia was due to a virus and found increased childhood leukemia in children born in other towns.

A number of scientists have concluded that Gardner's finding is not consistent with data from other research. Although Sir Richard Doll and Sarah C. Darby (both with the Imperial Cancer Research Fund, Radcliffe Infirmary, Oxford, England) believe that Gardner's finding is biologically plausible, they disagree with Gardner's conclusion. They argue that the conclusion is not supported by what is currently known about radiation genetics, or the inherited nature of childhood leukemias, or studies of the children of atomic bomb survivors or nuclear facility workers. Doll and Darby conclude that the association between a father's radiation exposure and leukemia is a chance finding.

Tom Sorahan (Cancer Epidemiology Research Unit, Department of Public Health and Epidemiology, University of Birmingham, England) and Penelope J. Roberts (Medical Physics and Medical Engineering Department, Southampton General Hospital, England) evaluated the relationship between childhood leukemia and a father's radiation exposure before his child's conception. Using data already collected for the Oxford Survey of Childhood Cancer, these researchers estimated a father's radiation dose based on his reported occupation. The researchers found little support for the idea that a father's exposure to external whole-body radiation in the six months before a child's conception is a risk factor for childhood cancer. The study suggested, however, that a father's [internal exposure](#) to [radionuclides](#) was connected with childhood cancer risk more often than was exposure to external whole-body radiation.

### **Effects of Radiation Exposure before Birth**

Research suggests there is a relationship between [X-ray](#) exposure before birth and development of childhood cancer. A large study by Alice M. Stewart (Senior Research Fellow, Department of Public Health and Epidemiology, University of Birmingham, England) and one by Brian MacMahon (Professor Emeritus, School of Public Health, Harvard University) each found an association between medical X-ray exposure before birth and childhood cancer. These findings indicate that the most sensitive period of exposure for developing [leukemia](#) is about the seventh month of pregnancy. The most sensitive period of exposure for developing all cancers, except leukemia, is the first six months of pregnancy.

Studies of children born to mothers who received [whole-body radiation doses](#) of between 50 and 100 [rad](#) following the Japanese atomic bombing showed that the children had an increased risk for small brain size and mental retardation. This was especially true for those women who were eight to 15 weeks pregnant at the time of exposure. Compared with non-exposed children, children exposed to whole-body radiation doses during this period before birth had lower intelligence test scores and performed less well in school. Atomic bomb survivor studies also suggest that children exposed to radiation before birth have cancer rates equal to or higher than children who were exposed from ages one to nine.

### Laboratory Experiments and Genetic Effects

Laboratory experiments suggest that plutonium-238 may produce [genetic damage](#) in cells. Munira A. Kadhim (MRC Radiobiology Unit, Chilton, England) reported that [alpha](#) particles from plutonium-238 produced a high frequency of [chromosome](#) damage in descendants of cells grown in the laboratory. Research by Hatsumi Nagasawa and John B. Little (both are with the Department of Cancer Biology, Harvard School of Public Health) indicates that alpha particles from plutonium-238 can cause genetic damage in the chromosomes of a cell for [doses](#) as small as 0.03 [rem](#) (30 mrem).

These findings from laboratory studies suggest that plutonium-238 can possibly induce [genetic effects](#) in humans from small doses of radiation. Two factors need to be considered when interpreting these findings: (1) genetic damage is constantly being repaired by the cells themselves, and (2) laboratory experiments with cells cannot be used to predict exactly what might occur in cells inside the human body.

E. Janet Tawn (Medical Department, British Nuclear Fuels, Sellafield, England) and colleagues studied the chromosomes of white blood cells in plutonium workers. An increase in chromosomal aberrations, or changes, were found. This suggests a relationship between plutonium exposure and genetic effects.

Scientists do not agree on the significance of some chromosomal aberrations. One perspective is found in a report issued by a National Academy of Sciences committee that studied the biological effects of ionizing radiation (known as [BEIR V](#)). The scientists commented that the implications, if any, of an increase in chromosomal aberrations in white blood cells are not clear. Another perspective is offered by John Gofman (Professor Emeritus of Molecular and Cellular Biology, University of California, Berkeley). He argues that if aberrations increase in white blood cells, they also increase in other cells, including reproductive cells. Gofman's opinion is that many birth defects of unknown origin result from chromosomal damage induced by radiation.

Animal studies, mainly using mice, have detected genetic effects from radiation exposure that have not been detected in human studies. This may suggest that humans are less sensitive to radiation than mice. Since genetic [mutations](#) from radiation are found in all animal species studied, it is expected that they do occur in humans.

### Summary of Studies

Animal research and laboratory experiments suggest that inherited [genetic effects](#) of radiation exposure should occur in humans. However, studies of the offspring of the Japanese atomic bomb survivors have not detected inherited genetic effects. Some studies suggest that exposure of a father to radiation before conception of a child may cause [leukemia](#) in that child, while others suggest this exposure does not cause leukemia as an inherited genetic effect. A child's exposure to radiation before birth is linked to problems such as childhood leukemia, mental retardation, small head size and lower IQ.

Again, it is important to understand that results from studies of external exposure may not apply to people exposed to internal radiation.

### Genetic Effects, Birth Defects and Hanford

In comparison to the [doses](#) of most groups studied for [genetic effects](#) and birth defects, the Hanford dose estimates are generally considered low. This does not rule out the possibility that genetic effects and birth defects could be

caused by a dose from Hanford.

Some people exposed to Hanford's releases may have received doses equal to or higher than doses in the large study by Stewart. This study linked [X-ray](#) exposure before birth to [leukemia](#) in children. However, the effects of exposure to X-rays may not predict the effects of exposure to the substances released from Hanford.

In April 1994, the [Hanford Environmental Dose Reconstruction Project](#) released draft dose estimates for representative individuals. According to these estimates, even people who received the highest exposures were in the low-dose category for [whole-body](#) exposure (below 50 [rad](#)).

The Dose Reconstruction Project developed dose estimates for [six radioactive](#) substances released into the air: iodine-131, plutonium-239, ruthenium-103, ruthenium-106, strontium-90 and cerium-144. Iodine-131, which concentrates in the [thyroid](#) gland, accounts for most of the dose to most people from the air [pathway](#). The highest estimated dose to the thyroid was 870 rad. This was for a child who lived in Ringold, WA, from 1944 to 1951 and drank milk from a cow fed on fresh pasture. This is equivalent to an estimated whole-body dose of 26.1 rem EDE (Effective Dose Equivalent).<sup>2</sup> A typical adult had a cumulative estimated whole-body dose from exposure to all six air pathway substances of 1 [rem EDE](#) from 1944 to 1972.

For releases into the [Columbia River](#), the Dose Reconstruction Project made dose estimates for five radioactive substances: zinc-65, phosphorus-32, neptunium-239, sodium-24, and arsenic-76. The highest estimated cumulative dose to an adult's red bone marrow was 2.8 rem EDE, and to the lower large intestine was 4.8 rem EDE. The highest estimated cumulative whole-body dose for an adult was 1.4 rem EDE.

## downwinder perspective

*Many callers to the Hanford Health Information Lines have questions and concerns about whether exposure to radiation from Hanford caused or may cause [genetic effects](#) and birth defects. Some [downwinders](#) have health problems and believe that they are, or might be, related to Hanford. The following personal perspective is offered to help readers understand these experiences and concerns.*

"My mother worked at Hanford. I know she worked in a research building (or on an experimental project) and that she was contaminated with plutonium. My mother was three months pregnant when she left her Hanford job. She was fired because she was pregnant with me. It says so in her medical records. As far as I know, the delivery was hard and she didn't have any other children after me. My mother died at 44. I have high blood pressure and an enlarged [thyroid](#). When I was 18 years old, I had my gall bladder removed.

I don't think it affected me as far as birth defects, but it's always in the back of my mind. And I wonder if my health problems are related to all of this. She [my mother] worked there, she was exposed to plutonium. Would this be happening to me now if she hadn't? What about my children?

I worry about my children. I don't know how this will affect them. I understand that it could take years for you to know if anything is wrong. This is very scary. Some things you read say that we were exposed to a certain amount of radiation and that it is nothing to worry about. And then you hear something else that says any amount is harmful. I don't think anyone really knows if Hanford's radiation will affect future generations. But I can't help but worry."

\* This perspective was contributed by a woman whose mother worked at Hanford and who now has children of her own. She was born in 1952 and lived in Richland until 1954. Name withheld by request.

## Conclusion

As with other health effects from radiation, it is assumed that any exposure to radiation carries some risk of genetic effects and birth defects. There are many questions which require additional study. The answers to these questions

can be used to determine the magnitude of the risk for genetic effects and birth defects.

## Selected References

Gardner, M.J., M.P. Snee, A.J. Hall, et al. "Results of Case-control Study of Leukaemia and Lymphoma Among Young People near Sellafield Nuclear Plant in West Cumbria." *British Medical Journal*. 1990.

Gofman, John W. "Radiation-inducible Chromosome Injuries: Some Recent Evidence on Health Consequences - Major Consequences." Committee for Nuclear Responsibility. Spring 1992.

Otake, M., W.J. Schull. "Radiation-related Small Head Sizes Among Prenatally Exposed A-bomb Survivors." *International Journal of Radiation Biology*. 1993.

Otake, M., W.J. Schull, J. Neel. "Congenital Malformations, Stillbirths, and Early Mortality Among Children of the Atomic Bomb Survivors: A Reanalysis." Radiation Effects Research Foundation (RERF) Technical Report 13-89 [RERF TR 13-89]. Hiroshima: RERF, 1989.

Sever, Lowell E., Ethel S. Gilbert, Nancy A. Hessol, and James M. McIntyre. "A Case-Control Study of Congenital Malformations and Occupational Exposure to Low-Level Ionizing Radiation." *American Journal of Epidemiology*. 1988.

Sever, Lowell E., Nancy A. Hessol, Ethel S. Gilbert, and James M. McIntyre. "The Prevalence at Birth of Congenital Malformations in Communities Near the Hanford Site." *American Journal of Epidemiology*. 1988.

Schull, W.J. "Critical Assessment of Genetic Effects of Ionizing Radiation on Pre- and Post-Natal Development." *Issues and Review in Teratology*. 1984.

## NOTES

**1** - The Hanford Environmental Dose Reconstruction (HEDR) Project was established to estimate what radiation dose people living near Hanford some time between 1944 and 1992 might have received from releases of radioactive materials. The Technical Steering Panel, which directed the study, completed its role in 1995. The federal Centers for Disease Control and Prevention (CDC) is now working with the HEDR Task Completion Working Group to continue public participation and to assure completion of the remaining HEDR activities. When using information from the Dose Reconstruction Project and other studies, readers should keep in mind that research results depend on a number of factors, such as the information available, and the methods and type of analysis used.

**2** - The Hanford Environmental Dose Reconstruction Project has used the tissue weighting factors from ICRP Publication No. 26 (1977).

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