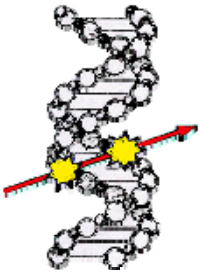
Open Source Radiation Safety Training

Module 3: Biological Effects

This module provides information about the following topics:

Mechanisms of Damage

Injury to living tissue results from the transfer of energy to atoms and molecules in the cellular structure. Ionizing radiation causes atoms and molecules to become ionized or excited. These excitations and ionizations can:



- Produce free radicals.
- Break chemical bonds.
- Produce new chemical bonds and cross-linkage between macromolecules.
- Damage molecules that regulate vital cell processes (e.g. DNA, RNA, proteins).

The cell can repair certain levels of cell damage. At low doses, such as that received every day from background radiation, cellular damage is rapidly repaired.

At higher levels, cell death results. At extremely high doses, cells cannot be replaced quickly enough, and tissues fail to function.

Return to the Top

Tissue Sensitivity

In general, the radiation sensitivity of a tissue is:

- proportional to the rate of proliferation of its cells
- inversely proportional to the degree of cell differentiation

For example, the following tissues and organs are listed from most radiosensitive to least radiosensitive:

Most Sensitive: Blood-forming organs
Reproductive organs
Skin
Bone and teeth
Muscle
Least sensitive: Nervous system

This also means that a developing embryo is most sensitive to radiation during the early stages of differentiation, and an embryo/fetus is more sensitive to radiation exposure in the **first** trimester than in later trimesters.

Return to the Top

Prompt and Delayed Effects

Radiation effects can be categorized by **when** they appear.

- **Prompt effects:** effects, including radiation sickness and radiation burns, seen immediately after large doses of radiation delivered over short periods of time.
- **Delayed effects:** effects such as cataract formation and cancer induction that may appear months or years after a radiation exposure

Return to the Top

Prompt Effects

High doses delivered to the whole body of healthy adults within short periods of time can produce effects such as blood component changes, fatigue, diarrhea, nausea and death. These effects will develop within hours, days or weeks, depending on the size of the dose. The larger the dose, the sooner a given effect will occur.

Effect	**Dose**
Blood count changes	50 rem
Vomiting (threshold)	100 rem

Mortality (threshold)	150 rem
$LD_{50/60}$* (with minimal supportive care)	320 – 360 rem
$LD_{50/60}$ (with supportive medical treatment)	480 – 540 rem
100% mortality (with best available treatment)	800 rem

(Adapted from NCRP Report No. 98 "Guidance on Radiation Received in Space Activities, NCRP, Bethesda, MD (1989))

* The $LD_{50/60}$ is that dose at which 50%of the exposed population will die within 60 days.

Go to to optional information to see how these dose levels compare with state dose limits and University investigational levels

Return to the Top

Partial Body Exposure

These acute effects apply only when the whole body is relatively uniformly irradiated. The effects can be significantly different when only portions of the body or an individual organ system are irradiated, such as might occur during the use of radiation for medical treatment. For example, a dose of 500 rem delivered uniformly to the whole body may cause death while a dose of 500 rem delivered to the skin will only cause hair loss and skin reddening.

Go to optional information about how specific organ systems respond to acute exposure

Return to the Top

Delayed Effects of Radiation Exposure

Cataracts

- Cataracts are induced when a dose exceeding approximately 200-300 rem is delivered to the lens of the eye. Radiation-induced cataracts may take many months to years to appear.

Cancer

- Studies of people exposed to high doses of radiation have shown that there is a risk of cancer induction associated with high doses.
- The specific types of cancers associated with radiation exposure include leukemia, multiple myeloma, breast cancer, lung cancer, and skin cancer.
- Radiation-induced cancers may take 10 - 15 years or more to appear.
- There **may** be a risk of cancer at low doses as well. The following frames discuss the risk of cancer at lower doses.

Return to the Top

The Process of Determining Cancer Risk

Why cancer risks at low doses are uncertain

It has been difficult to estimate cancer induction risks, because most of the radiation exposures that humans receive are very close to background levels. At low dose levels of millirems to tens of rems, the risk of radiation-induced cancers is so low, that **if** the risk exists, it is not readily distinguishable from normal levels of cancer occurrence. In addition, leukemia or solid tumors induced by radiation are indistinguishable from those that result from other causes.

Go to optional information about radiation-induced cancer risk studies

Return to the Top

Cancer Risk Estimates

Using the linear no-threshold risk model, the 1990 BEIR* V report provided the following estimate:

- The average lifetime risk of death from cancer following an acute dose equivalent to all body organs of 0.1 Sv (10 rem) is estimated to be 0.8%. This increase in lifetime risk is about 4% of the current baseline risk of death due to cancer in the United States. The current baseline risk of cancer induction in the United States is approximately **25%.**

Another way of stating this risk:

- A dose of **10 mrem** creates a risk of death from cancer of approximately **1 in 1,000,000.**

* The National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation
(the BEIR Committee)

Go to a more detailed excerpt from the BEIR V report

Return to the Top

Putting Risk into Perspective

One way of considering the level of a risk is to look at the number of "days lost" out of a population due to early death from a given cause, then distributing those days lost over the population to get an "average life expectancy lost" due to that cause. The following table provides an estimate of life expectancy lost due to several causes:

Health Risk	Estimated Life Expectancy Lost
Smoking 20 cigarettes a day	6 years
Overweight by 15%	2 years
Alcohol (US average)	1 year
all accidents	207 days
All natural hazards	7 days
Occupational dose of 300 mrem/year	15 days

Source: these estimates are taken from NRC Draft Guide DG-8012 and were adapted from B. L. Cohen and L. S. Lee, "Catalogue of Risks Extended and Updates," *Health Physics*, Vol. 61, September 1991.

You can also look at risk by considering the Relative Risk of a **1 in a million** chance of death from activities common to our society:

- Smoking 1.4 cigarettes in a lifetime (lung cancer)
- Eating 40 tablespoons of peanut butter (aflatoxin)
- Spending two days in New York City (air pollution)
- Driving 40 miles in a car (accident)
- Flying 2500 miles in a jet (accident)
- Canoeing for 6 minutes (drowning)
- Receiving a dose of 10 mrem of radiation (cancer)

(Adapted from DOE Radiation Worker Training based on work by B.L. Cohen, Sc.D.)

Return to the Top

Genetic Effects

There is no direct evidence of radiation-induced genetic effects in humans, even at high doses. Various analyses indicate that the rate of genetic disorders produced in humans is expected to be extremely low, on the order of a few disorders per million live born per rem of parental exposure.

Return to the Top

Prenatal Radiation Exposure

Rapidly proliferating and differentiating tissues are most sensitive to radiation damage. Consequently, radiation exposure can produce developmental problems, particularly in the developing brain, when an embryo/fetus is exposed prenatally.

The developmental conditions most commonly associated with prenatal

radiation exposure include low birth weight, microcephaly, mental retardation, and other neurological problems. These effects are related to the developmental stage at which the exposure occurs. The threshold dose for developmental effects is approximately **10 rems.**

The evidence that the developing embryo/fetus is more sensitive to radiation-induced cancer is inconclusive. But it is prudent to assume that there is some increased sensitivity.

Go to more detailed information about the Princeton University program to control prenatal radiation exposures (the Declared Pregnant Worker Program)

Return to the top

This is the end of the Biological Effects Module, which is the third of the four Radiation Basics modules. The next module is the Regulations Module.

Go to Module 4 (Government Regulations and the Radiation Safety Program)