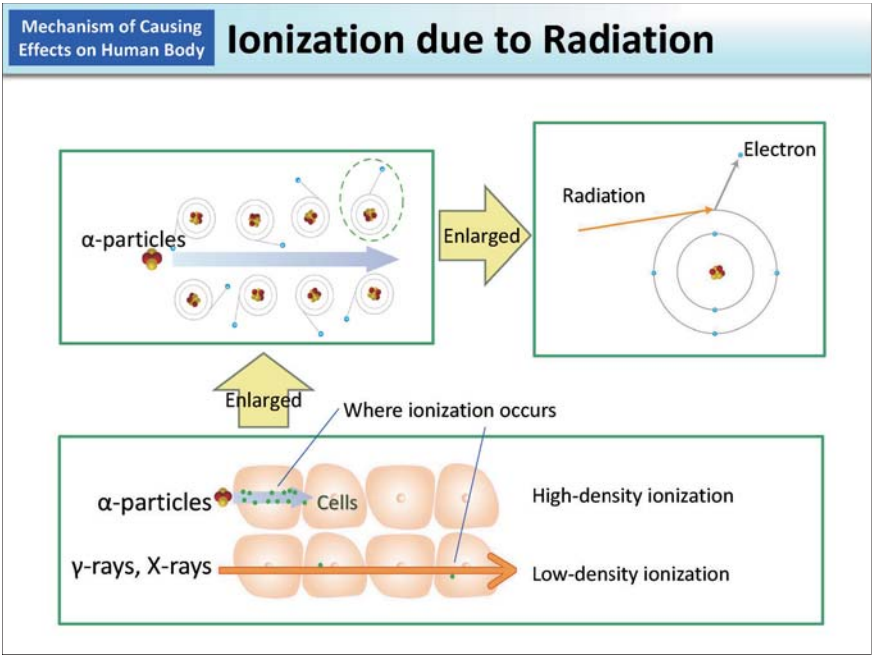
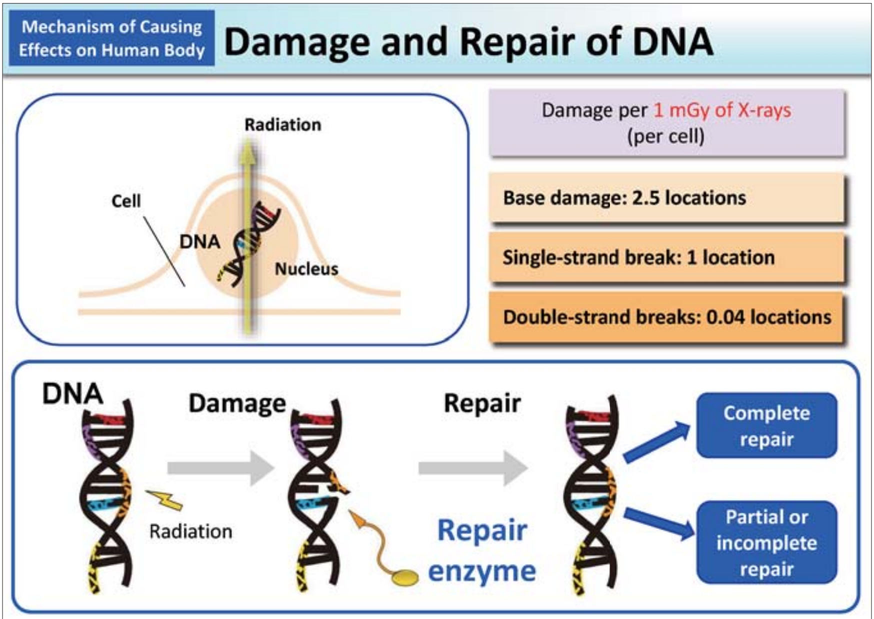


Radiation provides energy to substances along its pathway. Electrons of substances along the pathway are ejected with the given energy. This is ionization.

The density of energy provided by radiation differs by the type of radiation. Compared with β-particles and γ-rays, α-particles provide energy more intensively to substances in an extremely small area. Due to such difference in the ionization density, damage to cells differs even with the same absorbed dose.

(Related to p.18 of Vol. 1, "Ionization of Radiation - Property of Ionizing Radiation")

Included in this reference material on March 31, 2013
Updated on March 31, 2019



Source: Morgan, Annual Meeting of the National Committee on Radiation Protection and Measurements (NCRP) (44th, 2008)

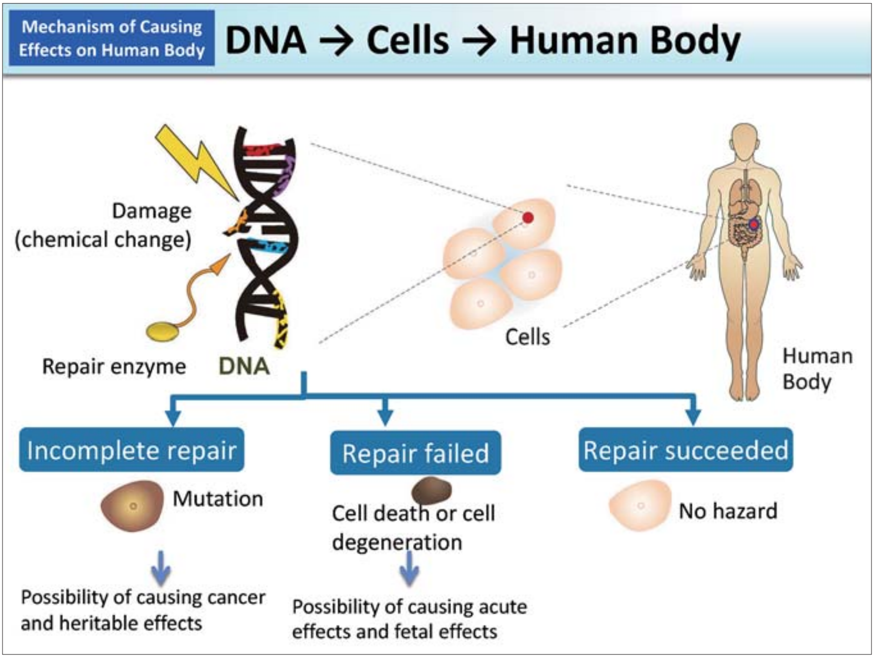
Cells have DNA, the blueprint of life. DNA consists of two chains of sugar, phosphate and four different bases. As the genetic information is incorporated in the arrangement of these bases, bases are combined firmly to mutually act as a template in order to maintain the arrangement. When DNA is irradiated, it may be partially damaged depending on the amount of radiation.

1 mGy of X-rays is thought to cause a single-strand break at one location per cell on average. A double-strand break occurs less at 0.04 locations. Therefore, when 100 cells are evenly exposed to 1 mGy of X-rays, double-strand breaks occur in four cells.

DNA is damaged not only by radiation but also by carcinogens in foods, tobacco, chemical substances in the environment and reactive oxygen, etc. It is said that DNA is damaged at 10,000 to 1,000,000 locations per cell every day.

Cells have functions to repair damaged DNA. Damaged DNA is repaired by the action of repair enzymes. There are cases where DNA is completely repaired and partially or incompletely repaired (p.89 of Vol. 1, "DNA→Cells→Human Body").

Included in this reference material on March 31, 2013
Updated on March 31, 2019



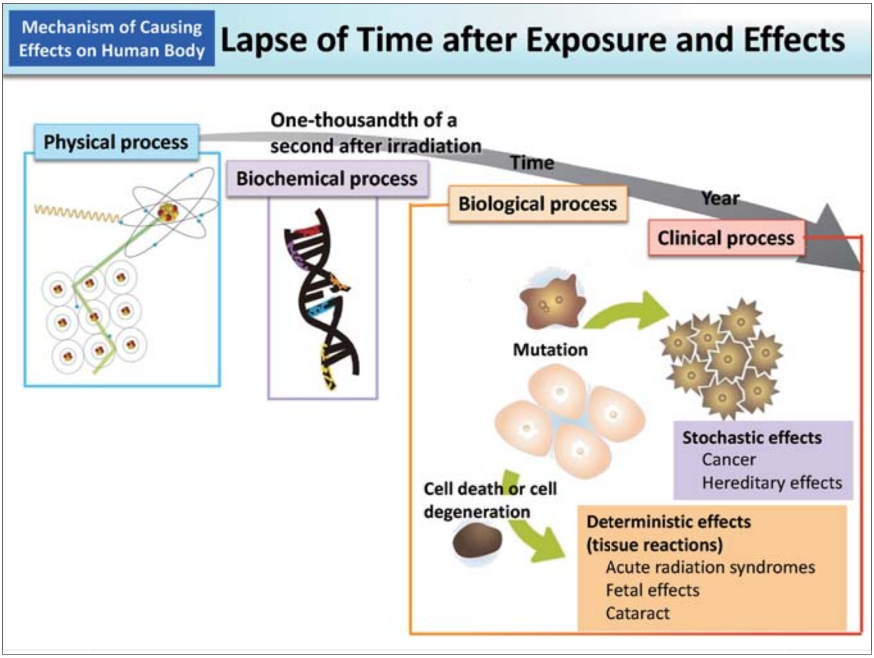
Looking closely into the irradiated portion, radiation may directly or indirectly damage the DNA sequences of a gene. These damaged DNA sequences are repaired by a pre-existing system in the body.

Minor damage is successfully repaired and restored. However, when many parts are damaged, they cannot be fully repaired and cells themselves die. Even when some cells die, if other cells can replace them, dysfunction does not occur in organs and tissues. However, when a large number of cells die or degenerate, there is the possibility that deterministic effects (tissue reactions) will appear, such as hair loss, cataract, skin injury or other acute disorders, as well as fetal disorders (p.90 of Vol. 1, “Lapse of Time after Exposure and Effects,” and p.91 of Vol. 1, “Cell Deaths and Deterministic Effects (Tissue Reactions)”).

When a cell in which DNA was not completely repaired survives, the cell gene may mutate and cause a stochastic effect such as cancer or heritable effect.

DNA is damaged not only by radiation but also by carcinogens in foods, tobacco, chemical substances in the environment and reactive oxygen, etc. It is said that DNA is damaged at 10,000 to 1,000,000 locations per cell every day. Damage due to low-dose exposures is significantly rare compared with metabolic DNA damage. However, radiation provides energy locally and causes complicated damage affecting multiple parts in DNA strands. Approx. 85% of radiation effects are caused by reactive oxygen, etc. created by radiation and approx. 15% is direct damage by radiation.

Included in this reference material on March 31, 2013
Updated on March 31, 2021



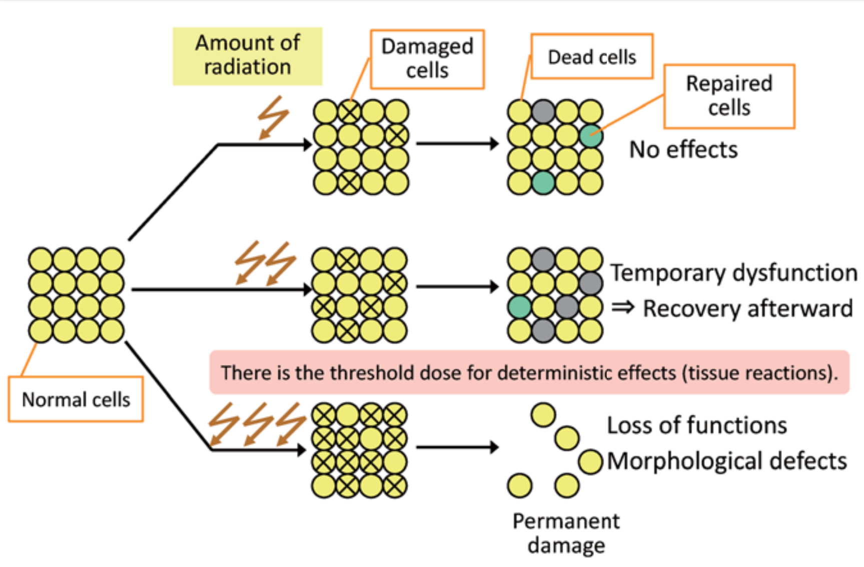
In as short a time as one-thousandth of a second after irradiation, DNA breaks and base damage occur. In a second after irradiation, DNA repair starts, and if repair fails, cell deaths and mutation occur within an hour to one day. It takes some time until such reaction at the cell level develops into clinical symptoms at an individual level. This period is called the incubation period.

Effects due to which symptoms appear within several weeks are called acute (early) effects, while effects that develop symptoms after a relatively long period of time are called late effects. In particular, it takes several years to decades until a person develops cancer. (Related to p.113 of Vol. 1, "Mechanism of Carcinogenesis")

Included in this reference material on March 31, 2013
Updated on March 31, 2021

Mechanism of Causing Effects on Human Body

Cell Deaths and Deterministic Effects (Tissue Reactions)



Even if some cells die due to exposure to a small amount of radiation, if tissues and organs can fully function with the remaining cells, clinical symptoms do not appear.

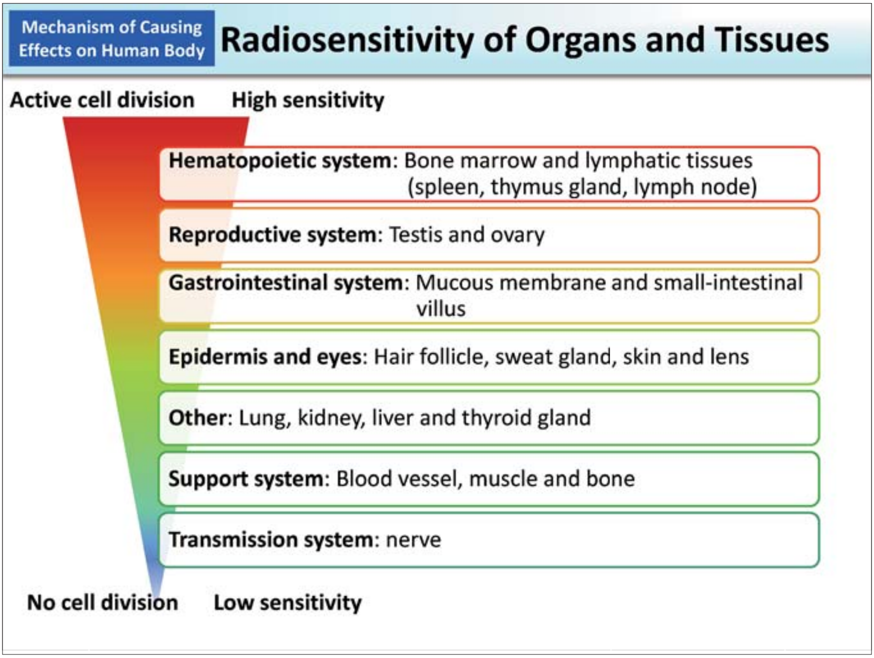
When the amount of radiation increases and a larger number of cells die, relevant tissues and organs suffer temporary dysfunction and some clinical symptoms may appear. However, such symptoms improve when normal cells proliferate and increase in number.

When cells in tissues or organs are damaged severely due to a large amount of radiation, this may lead to permanent cell damage or morphological defects.

In this manner, for deterministic effects (tissue reactions) due to cell deaths, there is a certain exposure dose above which symptoms appear and under which no symptoms appear. Such dose is called the threshold dose (p.97 of Vol. 1, "Threshold Values for Various Effects").

(Related to p.86 of Vol. 1, "Deterministic Effects (Tissue Reactions) and Stochastic Effects")

Included in this reference material on March 31, 2013
Updated on March 31, 2021

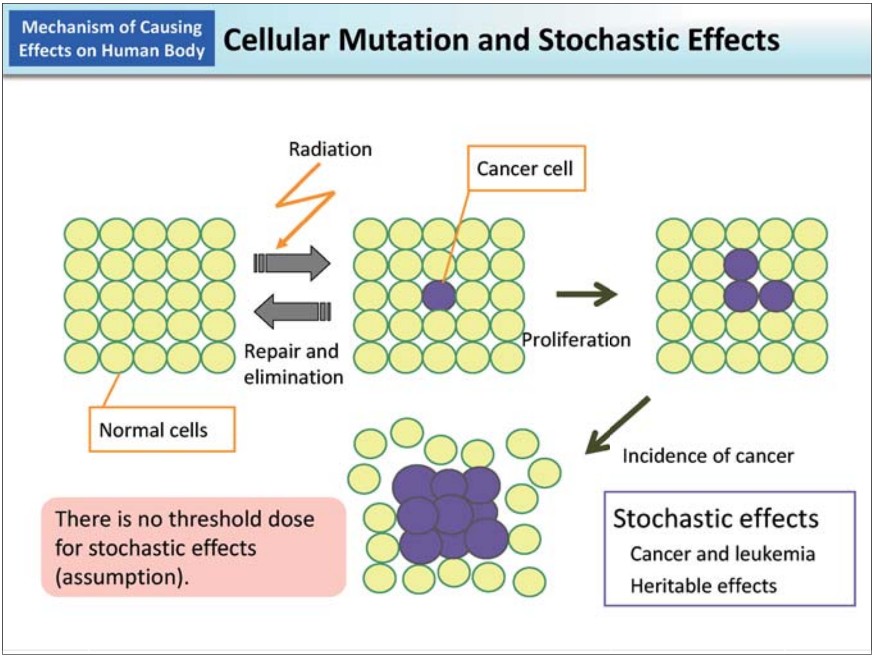


Actively dividing cells that are less differentiated tend to show higher radiosensitivity. For example, hematopoietic stem cells in bone marrow are differentiated into various blood cells, while dividing actively. Immature (undifferentiated) hematopoietic cells that have divided (proliferated) from stem cells are highly sensitive to radiation and die due to a small amount of radiation more easily than differentiated cells.

As a result, the supply of blood cells is suspended and the number of various types of cells in blood decreases. In addition, the epithelium of the digestive tract is constantly metabolized and is also highly sensitive to radiation.

On the other hand, nerve tissues and muscle tissues, which no longer undergo cell division at the adult stage, are known to be resistant to radiation.

Included in this reference material on March 31, 2013



Risks of effects of cellular mutation are considered to increase even if mutation occurs in a single cell.

Mutated cells are mostly repaired or eliminated but some survive and if their descendant cells are additionally mutated or the level of gene expression changes, the possibility of developing cancer cells increases. Proliferation of cancer cells leads to clinically diagnosed cancer (diagnosed by a doctor based on physical symptoms). Cells become cancerous as multiple mutated genes have accumulated without being repaired. Therefore, when assessing cancer-promoting effects, all doses that a person has received so far need to be taken into account.

Included in this reference material on March 31, 2013
Updated on March 31, 2019