

“Radiation exposure” refers to the situation where the body is exposed to radiation. There are two types of radiation exposure, “internal exposure” and “external exposure.”

External exposure means to receive radiation that comes from radioactive materials existing on the ground or in the air, or attached to clothes or the surface of the body (p.25 of Vol. 1, “External Exposure and Skin”).

Conversely, internal exposure is caused (i) when a person has a meal and takes in radioactive materials in the food or drink (ingestion); (ii) when a person breathes in radioactive materials in the air (inhalation); (iii) when radioactive materials are absorbed through the skin (percutaneous absorption); (iv) when radioactive materials enter the body from a wound (wound contamination); and (v) when radiopharmaceuticals containing radioactive materials are administered for the purpose of medical treatment. Once radioactive materials enter the body, the body will continue to be exposed to radiation until the radioactive materials are excreted in the urine or feces or as the radioactivity weakens over time (p.26 of Vol. 1, “Internal Exposure”).

The difference between internal exposure and external exposure lies in whether the source that emits radiation is inside or outside the body. The body is equally exposed to radiation in both cases (p.24 of Vol. 1, “Various Forms of Exposure”).

The terms “internal exposure” and “external exposure” are used irrespective of types of radiation, i.e., naturally occurring radiation, accident-derived radiation or medical radiation (p.63 of Vol. 1, “Exposure Dose from Natural and Artificial Radiation”).

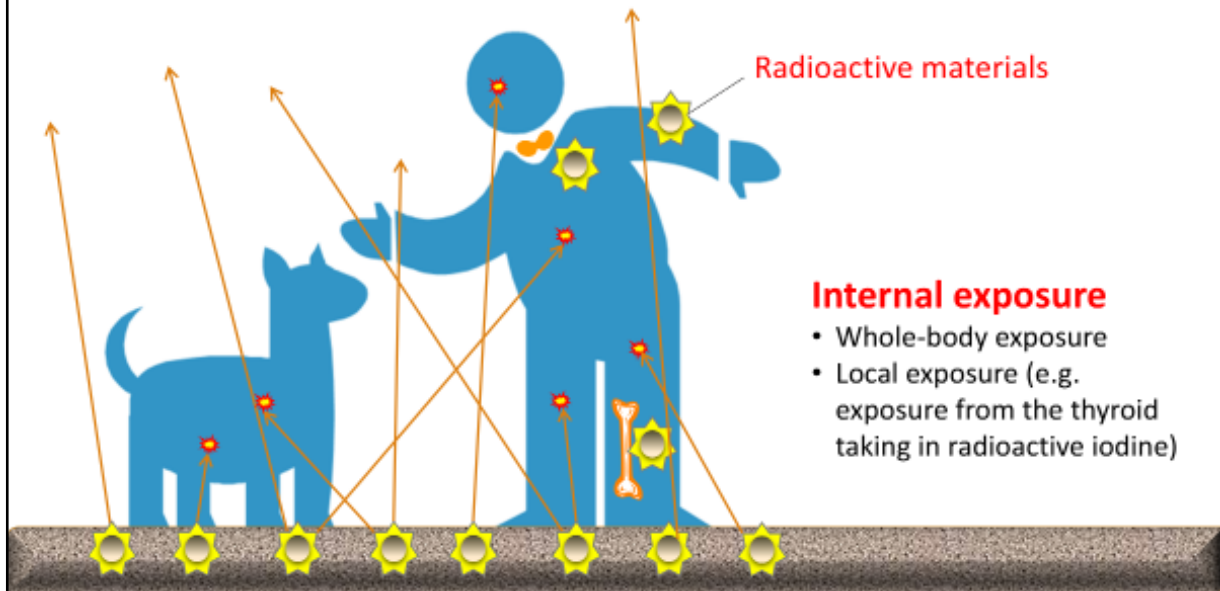
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## Various Forms of Exposure

### External exposure

- Whole-body exposure
- Local exposure (e.g. exposure by X-ray examination or local body surface contamination)



To what extent the body will be affected by radiation exposure depends on the location and the extent of the exposure.

Whole-body exposure refers to exposure of the entire body to radiation, while local exposure refers to exposure of a part of the body to radiation.

In whole-body exposure, all the organs and tissues may be affected by the radiation, while in local exposure, the effects are, in principle, confined to the exposed organs and tissues. If any organ of the immune system or endocrine system is included in the part exposed, distant organs or tissues could be indirectly affected, but the main concern is basically with the effects on the exposed organs and tissues.

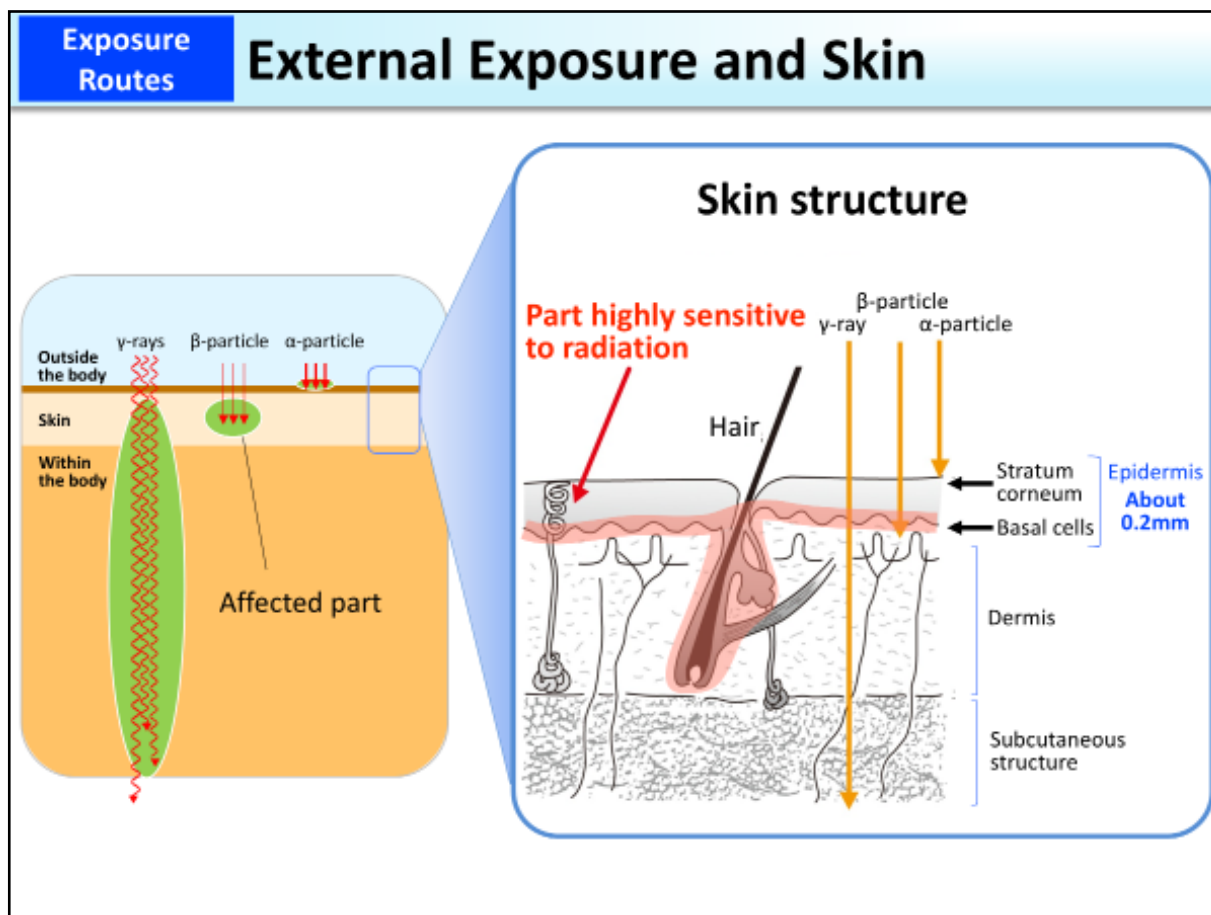
Organs differ in sensitivity to radiation. In local exposure, therefore, the extent of the effects varies greatly depending on whether the exposed part includes organs that are highly sensitive to radiation.

In internal exposure, organs and tissues where radioactive materials are likely to accumulate will receive high doses of radiation. If such organs and tissues that are prone to accumulation have high sensitivities to radiation, they are more likely to be affected by the radiation. In Belarus and Ukraine, after the Chernobyl NPS Accident, there was an increase in the number of thyroid cancer cases among children. It was due both to the tendency of radioactive iodine to accumulate in the thyroid and children's thyroids having a higher sensitivity to radiation than adults'.

(Related to p.4 of Vol. 1, "Types of Exposure")

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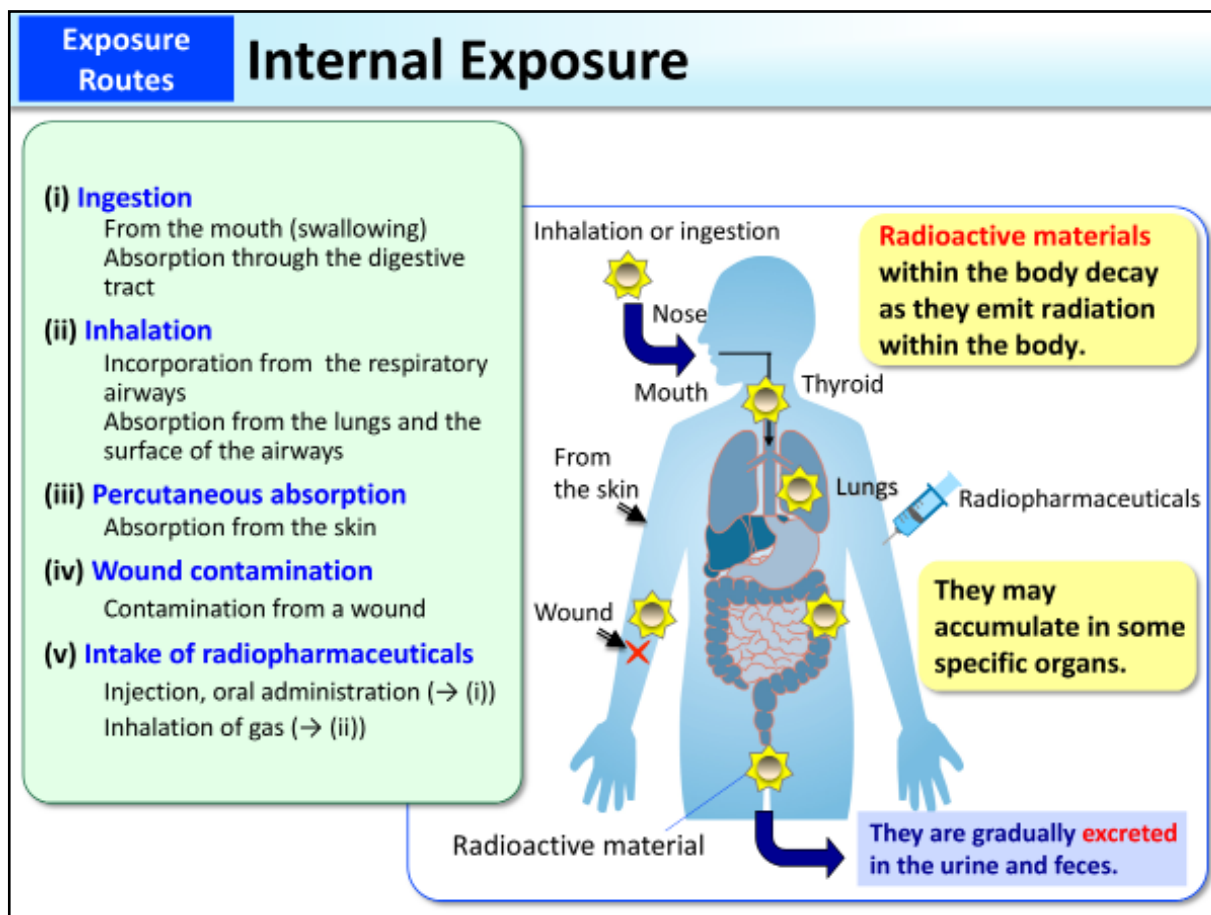


In external exposure,  $\alpha$  (alpha)-particles having weak penetrating power stop at the epidermis and therefore do not produce any effects, but if a large amount of radioactive materials that emit  $\beta$  (beta)-particles adheres to the surface of the body for an extended period of time, they will affect the skin's basal cells and hair-root cells that have high sensitivity to radiation, possibly causing skin erythema that is characterized by reddening of the skin, hair loss, etc. However, such exposure is extremely rare, and the major problems with external exposure are associated with radioactive materials emitting  $\gamma$ -rays that affect the inside of the body.

(Related to p.21 of Vol. 1, "Penetrating Power of Radiation within the Body," and p.22 of Vol. 1, "Penetrating Power and Range of Effects on the Human Body")

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Internal exposure occurs due to radioactive materials being taken in the following routes: ingestion together with food (ingestion); incorporation while breathing (inhalation); absorption from the skin (percutaneous absorption); penetration from a wound (wound contamination), and administration of radiopharmaceuticals through injection, etc.

Radioactive materials incorporated into the body emit radiation within the body. Accumulation in some specific organs may occur depending on the types of radioactive materials.

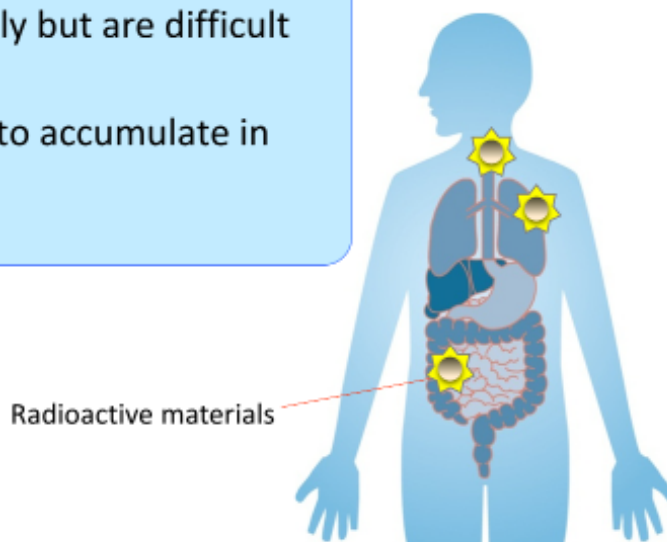
This is largely due to the physicochemical properties of radioactive materials. For example, strontium, having similar properties to calcium, tends to accumulate in calcium-rich parts such as bones once it enters the body; cesium, because of its properties similar to potassium, tends to distribute throughout the body once it enters the body.

Iodine, being a constituent element of thyroid hormones, tends to accumulate in the thyroid, whether it is radioactive iodine or stable iodine (p.127 of Vol. 1, "Thyroid").

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**The characteristics of radioactive materials that especially cause problems in internal exposure**

- (i)  $\alpha$ -emitters >  $\beta$ -emitters or  $\gamma$ -emitters
- (ii) Materials that enter easily but are difficult to excrete
- (iii) Materials that are likely to accumulate in specific organs



Radioactive materials within the body disintegrate into other elements and are gradually excreted in the urine and feces through metabolism. The time required for radioactive materials to reduce to half by disintegration is called physical half-life ( $T_p$ ), and the time required for radioactive materials within the body to reduce to half through metabolism is called biological half-life ( $T_b$ ). Radioactive materials that enter the body decrease both through their physical half-life and biological half-life. The time required for such radioactive materials to reduce to half is called effective half-life ( $T_e$ ), and the following relationship is found between  $T_p$  and  $T_b$ :

$$1/T_e = 1/T_p + 1/T_b$$

A major problem with internal exposure is caused by radioactive materials that have a long half-life and emit  $\alpha$  (alpha)-particles. In terms of the chemical nature and element-specific biokinetic behavior, radioactive materials that are easily incorporated into the body but are difficult to be excreted, and also those that tend to be accumulated in particular organs/tissues cause problems as they result in increasing internal exposure doses.

Plutonium, which is not easily absorbed in the digestive tract, for example, could be a concern if taken into the lungs during inhalation rather than being taken into the body via food. It has been known that plutonium then enters blood vessels from the lungs and is transported by blood flow to bones and the liver, where it settles. Since plutonium emits  $\alpha$ -particles within such organs, it could cause lung cancer, bone tumors or liver cancer.

Radioactive cesium, on the other hand, easily enters the body because of its properties similar to potassium but it also tends to be easily excreted. It does not accumulate in any specific organs but is taken in mainly in muscles. For adults, the time required for radioactive cesium that enters the body to reduce to half is said to be about 70 days (p.31 of Vol. 1, "Radioactive Materials Derived from Nuclear Accidents").

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