# Radiation Safety Course

(School of Science, the University of Tokyo)

# Biological Effects of Radiation to Human Body

FY2022

# 「復興五輪」、福島県の復興や放射線の健康影響への認識を確かにするために重要なこと

第4回調査結果の報告（2021年実施）

The important things to recognize correctly ‘Recovery Olympics’, revitalization in Fukushima prefecture and health effects of radiation



2022.1.18

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三菱総合研究所は福島県の復興状況や放射線の健康影響に対する東京都民の意識や関心・理解などに着目したアンケート調査を、2017年、2019年、2020年に続き、2021年8月に実施した。

5年間にわたる東京都民の意識の変化を分析した結果から、福島県の復興や放射線の健康影響に関する理解は進んでいるものの、放射線による健康影響についての科学的知見が十分には浸透していないことが示唆された。

人気の記事

1  ウィズコロナ下での世界・日本経済の展望｜2022年2月

2  カーボンニュートラルを契機とした日本のエネルギー安定供給と経済成長（後編）

3  ウィズコロナ下での世界・日本経済の展望｜2021年11月

4  廃止措置コストを合理化する鍵は業界連携にあり

5  人材流動化時代の企業戦略　第3回：実践的な人事施策に繋がるHR-Tech活用

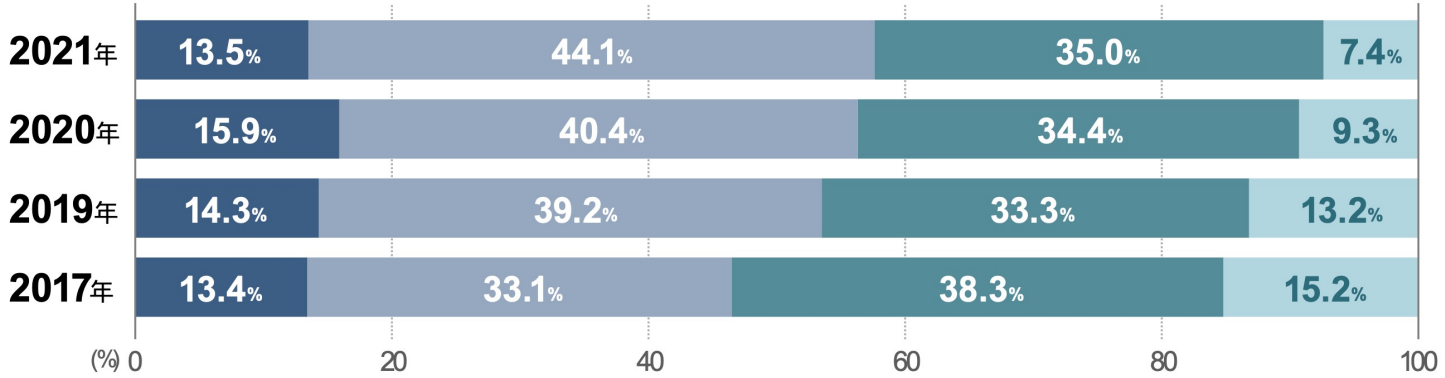
もっと見る

Investigators in Mitsubishi Research Institute have conducted questionnaire surveys focused on interests of citizens of Tokyo in the progress in recovering in Fukushima or in heath effects of radiation.
Their survey results suggest that scientific knowledge about health effects of radiation doesn’t fully pervade the public.

Cited from the website of Mitsubishi Research Institute
https://www.mri.co.jp/knowledge/column/20220118.html

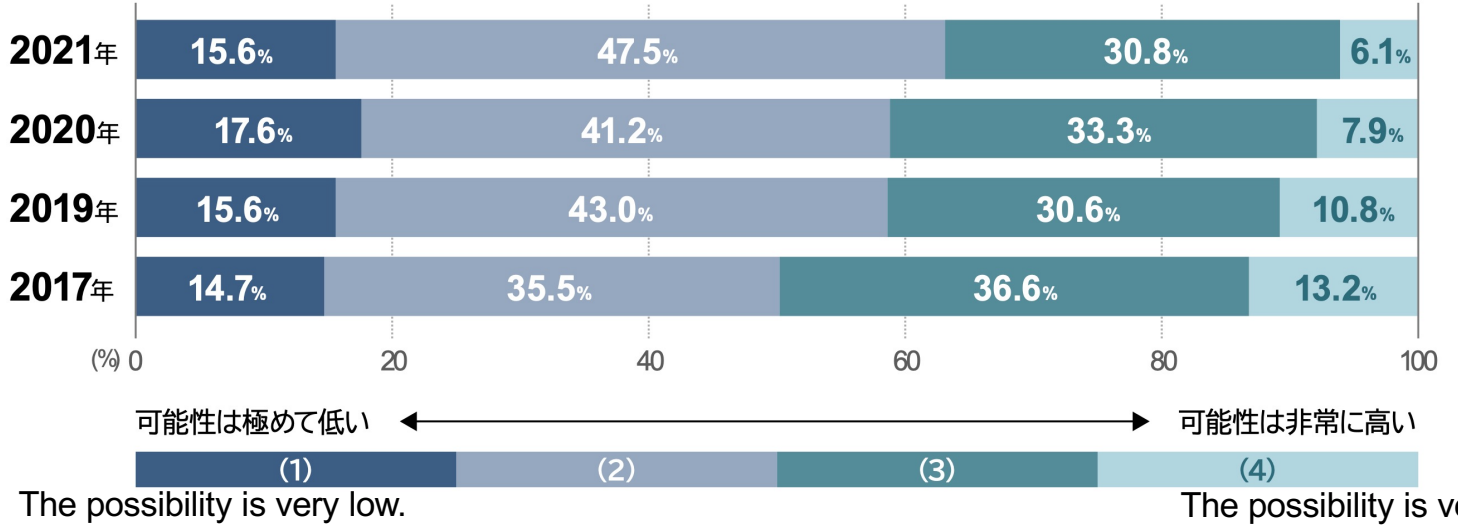
現在の放射線被ばくで、後年に生じる健康障害（例えば、がんの発症など）が福島の方々にどのくらい起こると思いますか（SA）

How likely do you think that current level of radiation exposure causes people in Fukushima health problems in later years (e.g. cancerization etc) ?




現在の放射線被ばくで、次世代以降の人（将来生まれてくる自分の子や孫など）への健康影響が福島県の方々にどのくらい起こると思いますか（SA）

How likely do you think that current level of radiation exposure causes people in Fukushima next-generation effects ?




The possibility is very low.

The possibility is very high.

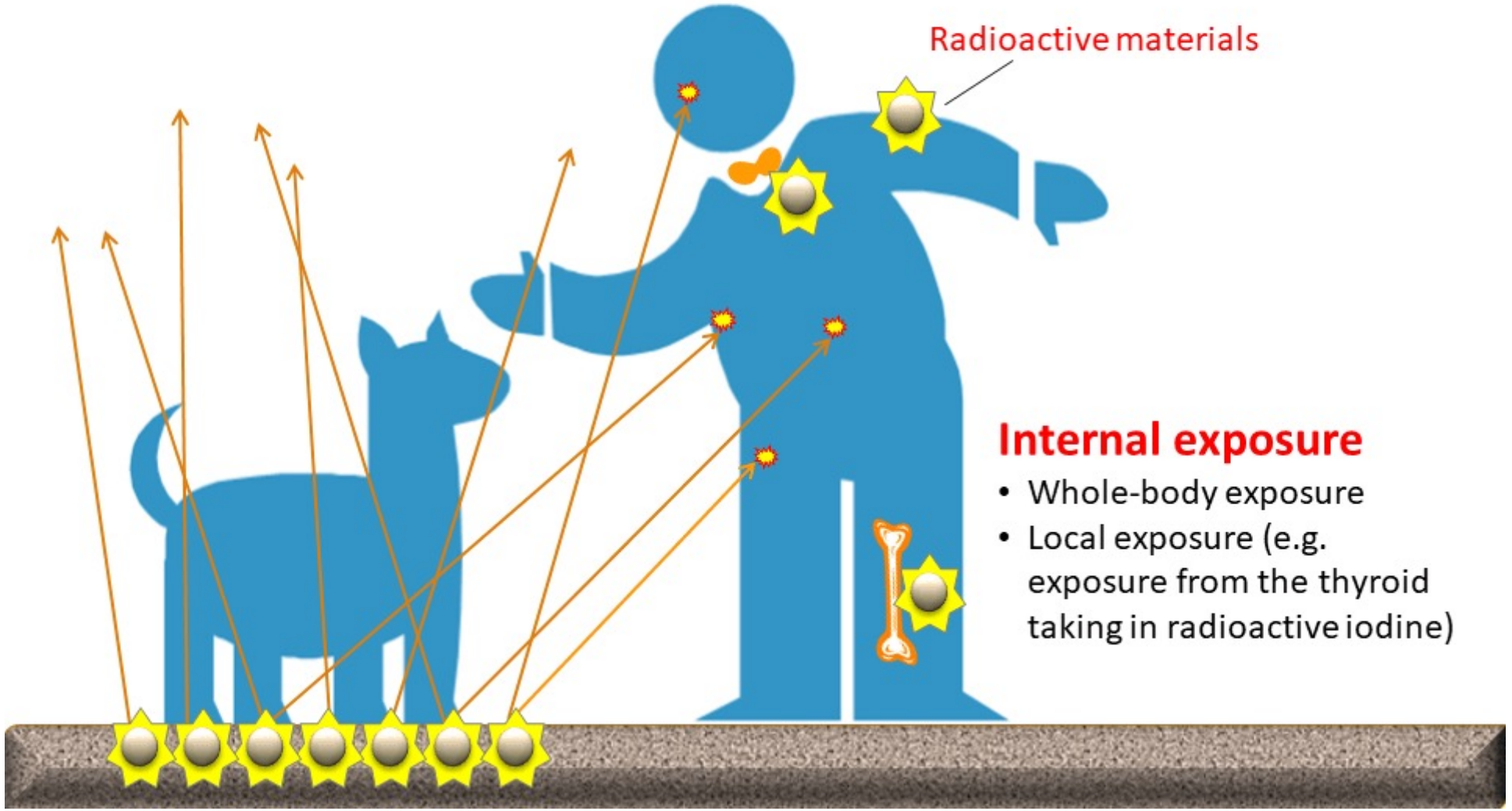
Cited from the website of Mitsubishi Research Institute
https://www.mri.co.jp/knowledge/column/20220118.html

Exposure Routes

# Various Forms of Exposure

## External exposure

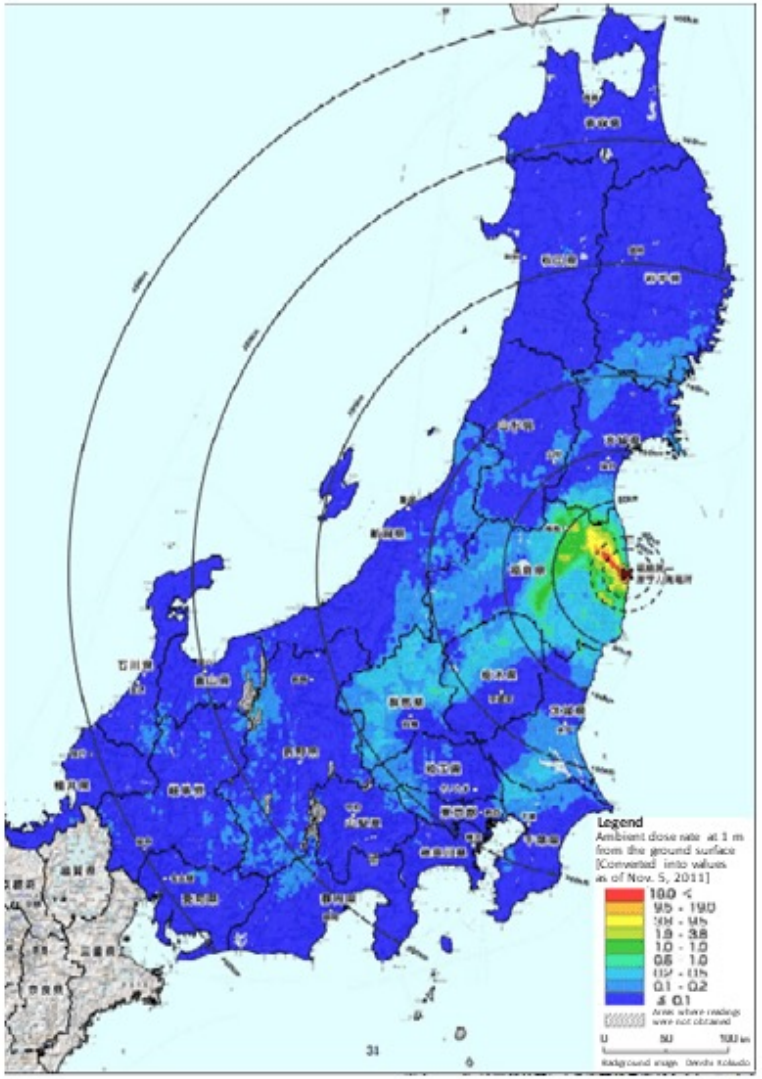
- Whole-body exposure
- Local exposure (e.g. exposure by X-ray examination or local body surface contamination)



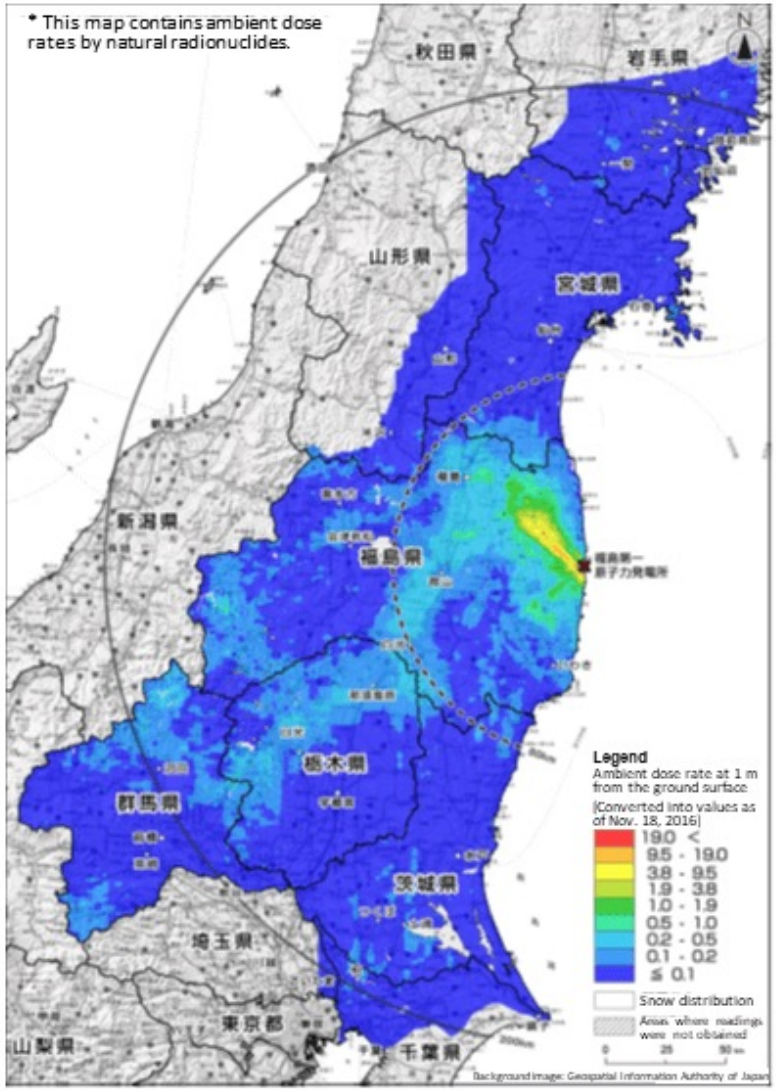

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

**Spatiotemporal Distribution of Ambient Dose Rates**

# Distribution of Ambient Dose Rates in Fukushima Prefecture and Neighboring Prefectures




Released by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) on Dec. 16, 2011



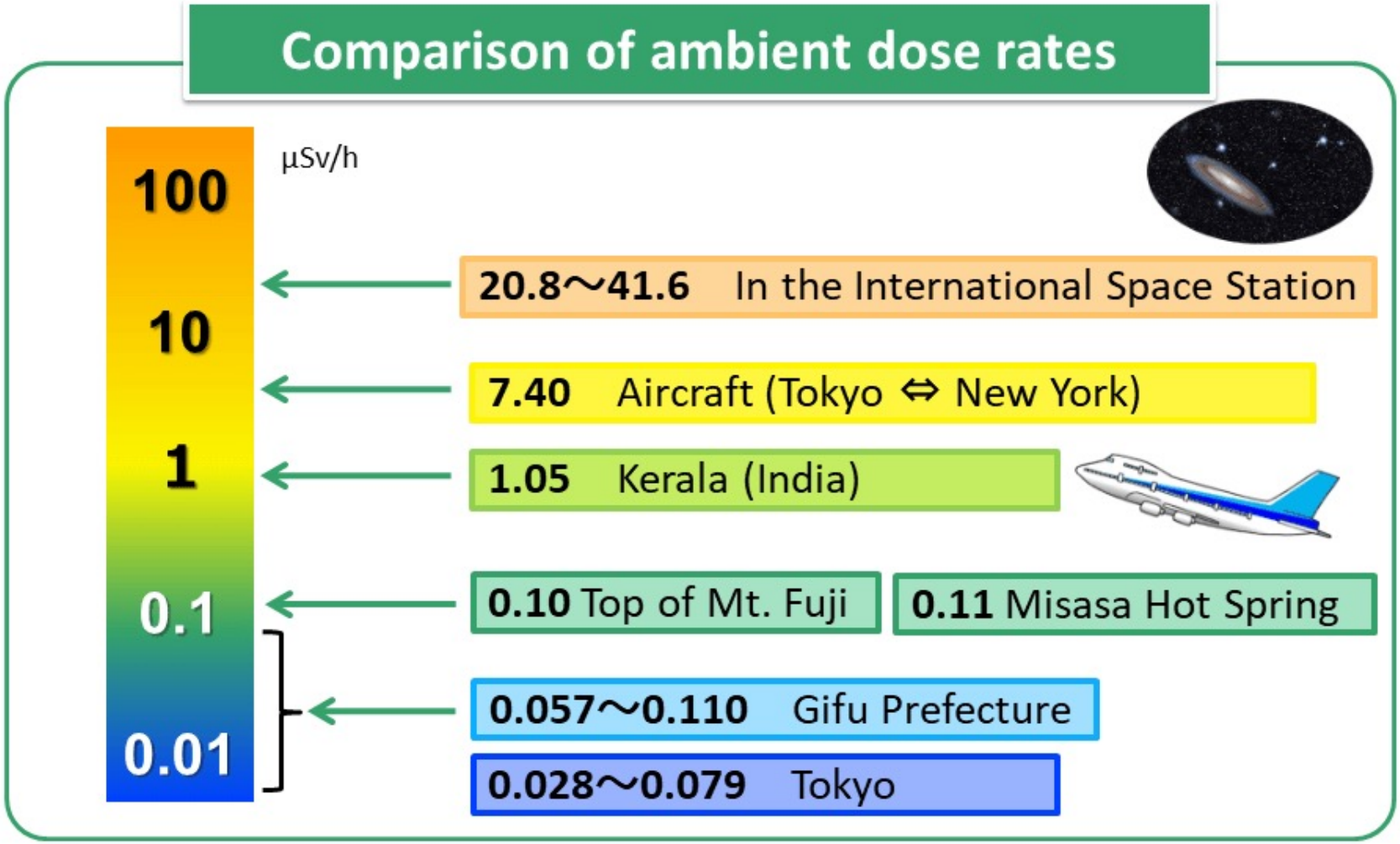

Released by the Nuclear Regulation Authority on Feb. 13, 2017

Most areas were less than 0.5 μSv/h.

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

# Radiation around Us Comparison of Exposure Doses per Hour

## Comparison of ambient dose rates



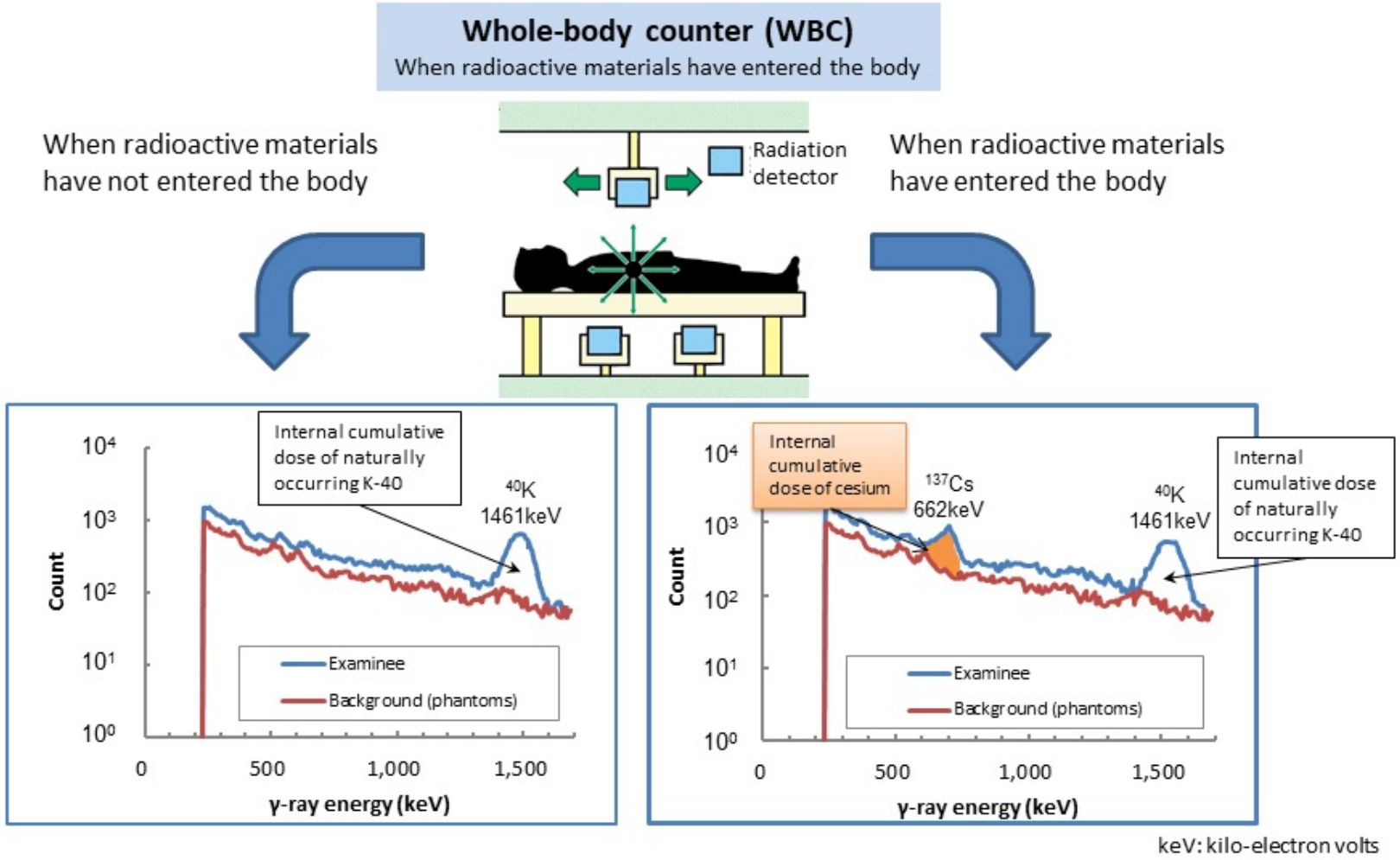

Sources: Prepared based on "Radiation Exposure Management," the website of the JAXA Space Station Kibo PR Center, 2013; "Japanese Internet System for Calculation of Aviation Route Doses (JISCARD)," the website of the National Institute of Radiological Sciences; "Research on Ambient Gamma-ray Doses in the Environment," the website of the National Institute of Radiological Sciences; Furuno, p.25-33 of the 51st report of the Balneological Laboratory, Okayama University, 1981; and Nuclear Regulation Authority Radiation Monitoring Information (range of previous average values at monitoring posts)

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

External Counting Survey

# Internal Exposure Measurement Using a Whole-body Counter

**Whole-body counter (WBC): A device to measure radiation from radioactive materials within the body**
**It can measure radionuclides emitting γ-rays, such as Cs-134 and Cs-137.**




Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

External Counting Survey

# Results of the Internal Exposure Measurement Using a Whole-body Counter

Targeting the residents of the Evacuation Areas and the areas where internal and external exposure doses are likely to be higher than in other areas based on the results of the environmental monitoring survey, etc. (Yamakiya District in Kawamata Town, Iitate Village and Namie Town), the internal exposure measurement using a whole-body counter commenced on June 27, 2011. The targeted areas were expanded sequentially, and measurements were conducted for a total of 328,354 people by November 30, 2017. For over 99.9% of them, committed effective doses due to Cs-134 and Cs-137 were below 1 mSv and even the maximum measured value was below 3 mSv. Measured values were all unlikely to cause any health effects.

(i) Targeted local governments: All 59 municipalities in Fukushima Prefecture

(ii) Organizations that conducted the measurement

Fukushima Prefecture; Hirosaki University Hospital; Minamisoma City General Hospital; Japan Atomic Energy Agency; Niigata Prefecture Radiation Examination Office; Hiroshima University Hospital; Nagasaki University Hospital; Japanese Red Cross Otsu Hospital; Mori no Miyako Industrial Health Association; National Hospital Organization Kanazawa Medical Center; Ehime University Hospital; and the National Institute of Radiological Sciences

(iii) 'Mobile measurement' using whole-body counter vehicles outside Fukushima Prefecture

Fukushima Prefecture runs whole-body counter vehicles for mobile measurement so that evacuees outside the prefecture can also receive measurement. By March 2016, mobile measurement was conducted in 38 prefectures including the Tokyo Metropolis (other than Aomori, Ibaraki, Niigata, Ishikawa, Shiga, Hiroshima, Aichi and Nagasaki Prefectures), where there is no permanent organization to which Fukushima Prefecture commissions the measurement.

(iv) Measurement results (committed effective doses) (Results up to November 2017 were released on December 26, 2017.

| | Jun. 27, 2011 – Jan. 31, 2012 | Feb. 1, 2012 – Nov. 30, 2017 | Total |
|---|---|---|---|
| Less than 1 mSv | 15,384 people | 312,944 people | 328,328 people |
| 1 mSv | 13 people | 1 person | 14 people |
| 2 mSv | 10 people | zero | 10 people |
| 3 mSv | 2 people | zero | 2 people |
| Total | 15,409 people | 312,945 people | 328,354 people |

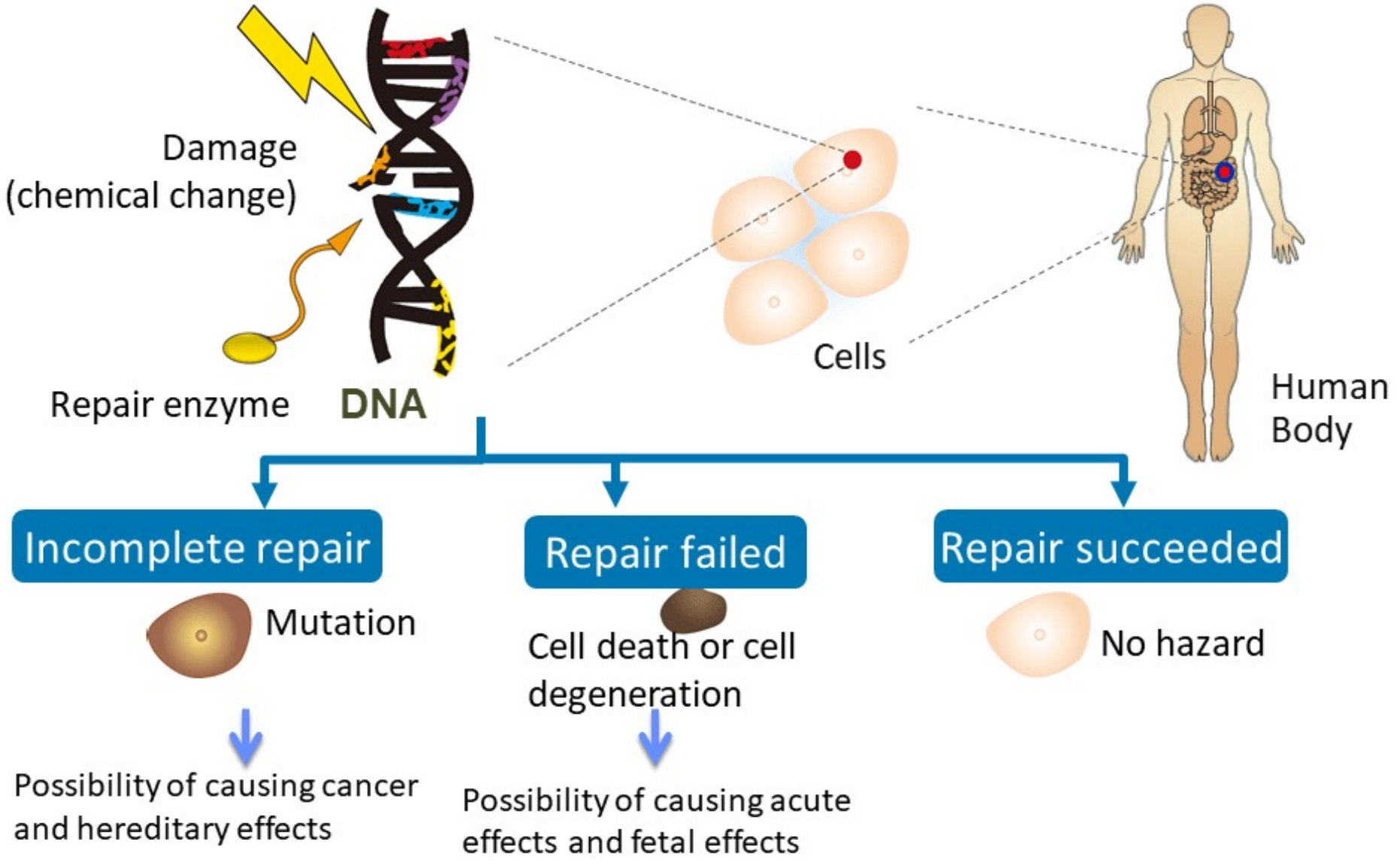
* Committed effective dose: Assuming that until the end of January 2012, a person ingested radiation once on March 12, 2011, and, from February 2012 onward, a person orally ingested the equal amount of radiation every day from March 12, 2011, to the day preceding the measurement date, the person's lifetime internal doses are calculated by summing up the doses for fifty years in the case of an adult and for the years elapsed until becoming 70 years old in the case of a child.

Prepared based on the website of Fukushima Prefecture, "Results of the Internal Exposure Measurement Using a Whole-body Counter"

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Mechanism of Causing Effects on Human Body

# DNA→Cells→Human Body




Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Effects on Human Body

# Classification of Radiation Effects

| Categories of effects | | Incubation period | e.g. | Mechanism of how radiation effects appear |
|---|---|---|---|---|
| | Physical effects | Within several weeks = Acute effects (early effects) | Acute radiation syndromes*1<br>Acute skin disease | Deterministic effects caused by cell deaths or cell degeneration*2  |
| | | After the lapse of several months = Late effects | Abnormal fetal development (malformation) | |
| | | | Opacity of the lens | |
| | | | Cancer and leukemia | Stochastic effects due to mutation  |
| | Hereditary effects | | Hereditary disorders | |

*1: Major symptoms are vomiting within several hours after exposure, diarrhea continuing for several days to several weeks, decrease of the number of blood cells, bleeding, hair loss, transient male sterility, etc.

*2: Deterministic effects do not appear unless having been exposed to radiation exceeding a certain dose level.

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

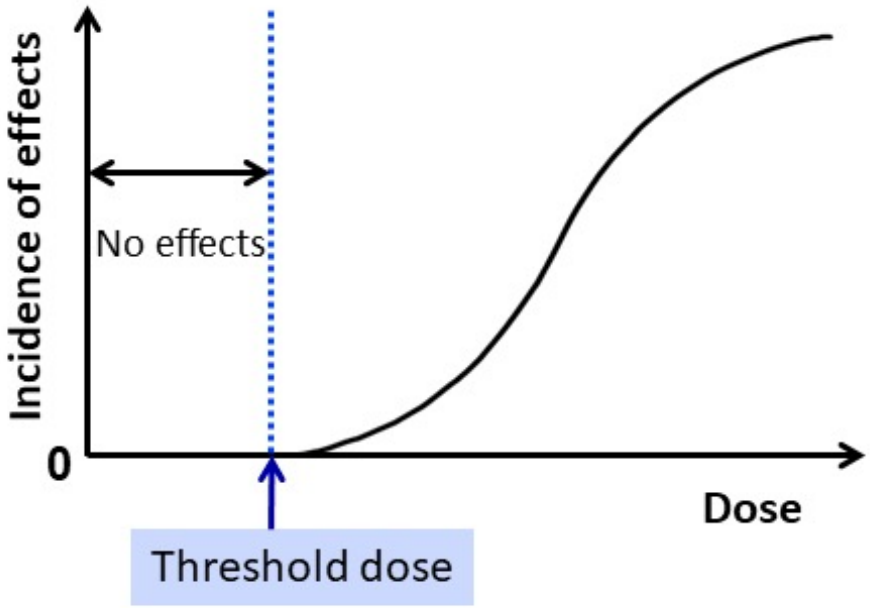
# Deterministic Effects and Stochastic Effects



## Deterministic effects

(Hair loss, cataract, skin injury, etc.)

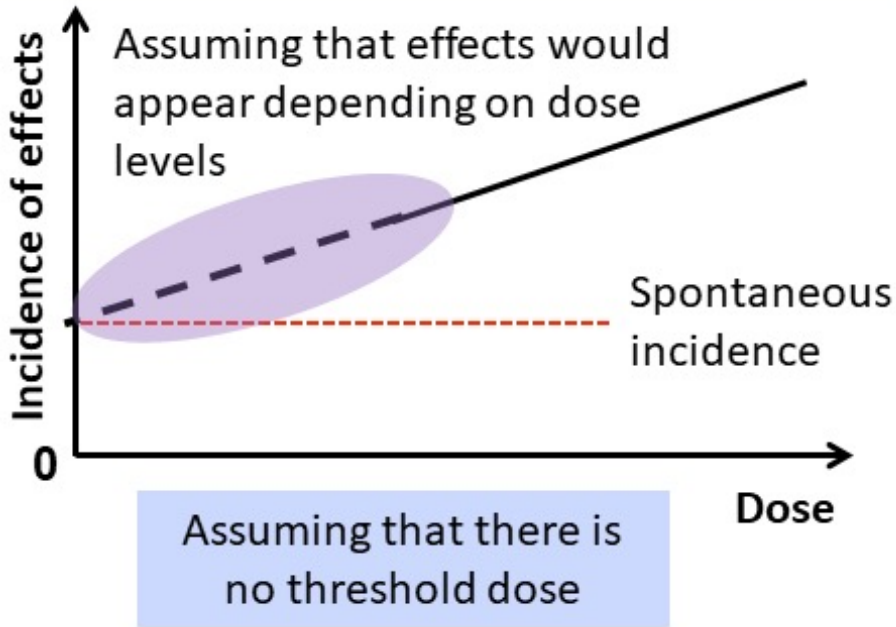
When a number of people were exposed to the same dose of radiation and certain symptoms appear in 1% of them, said dose is considered to be the threshold dose.
(2007 Recommendations of the International Commission on Radiological Protection (ICRP))




## Stochastic effects

(Cancer, leukemia, hereditary effects, etc.)

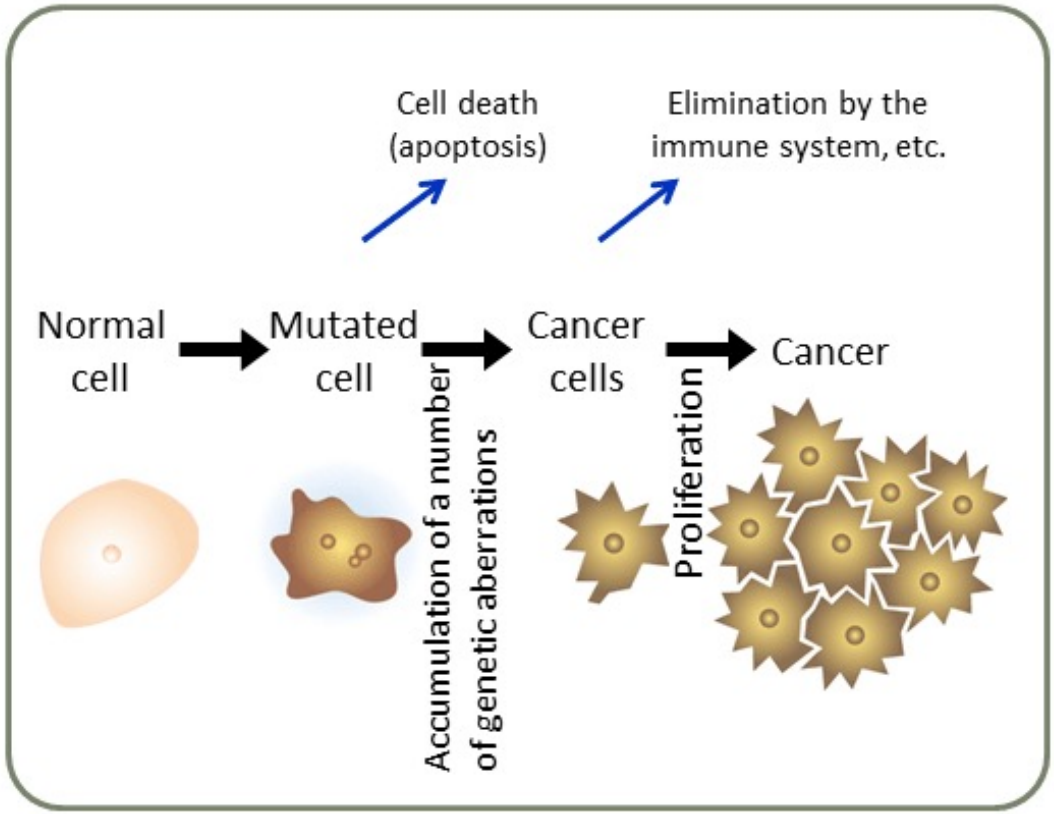
Effects of radiation exposure under certain doses are not clear because effects of other cancer-promoting factors such as smoking and drinking habits are too large. However, the ICRP specifies the standards for radiological protection for such low-dose exposures, assuming that they may have some effects as well.

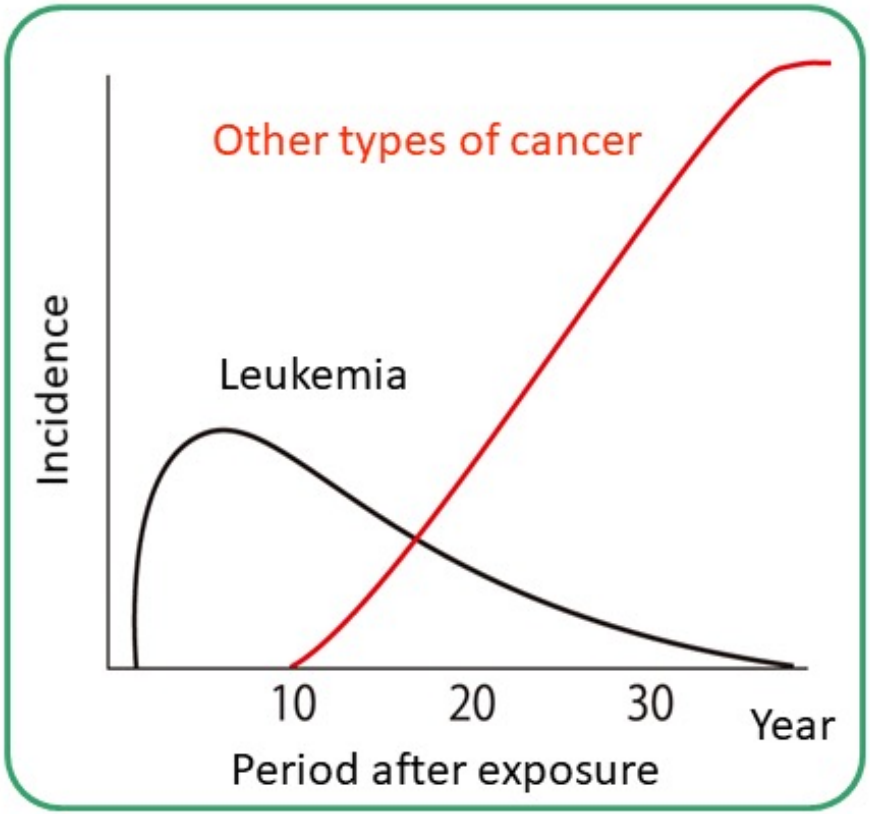



Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

# Mechanism of Carcinogenesis






- Radiation is only one of various factors that induce cancer.

- Mutated cells follow multiple processes until developing into cancer cells.
  → It takes several years to decades.

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

# Risks Risks of Cancer (Radiation)

| Radiation doses (mSv) | Relative risks of cancer* |
|---|---|
| 1,000 ~ 2,000 | 1.8 [estimated to be 1.5 times per 1,000 mSv] |
| 500 ~ 1,000 | 1.4 |
| 200 ~ 500 | 1.19 |
| 100 ~ 200 | 1.08 |
| Less than 100 | Difficult to detect |

Source: Website of the National Cancer Center Japan

* Risks of developing radiation-induced cancer are based on the data (solid cancers only) obtained from the analysis of instantaneous exposure due to the atomic bombing in Hiroshima and Nagasaki, and are not based on the observation of long-term exposure effects.
* Relative risks indicate how many times larger the cancer risks are among people exposed to radiation when assuming the risks among non-exposed people as 1.

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

# Risks Risks of Cancer (Life Habits)

| Lifestyle factors | Relative risks of cancer |
|---|---|
| Smokers | 1.6 |
| Heavy drinking (450 g or more/week)* | 1.6 |
| Heavy drinking (300 to 449 g or more/week)* | 1.4 |
| Obese (BMI ≧ 30) | 1.22 |
| Underweight (BMI<19) | 1.29 |
| Lack of exercise | 1.15 ～ 1.19 |
| High-salt foods | 1.11 ～ 1.15 |
| Lack of vegetable intake | 1.06 |
| Passive smoking (nonsmoking females) | 1.02 ～ 1.03 |

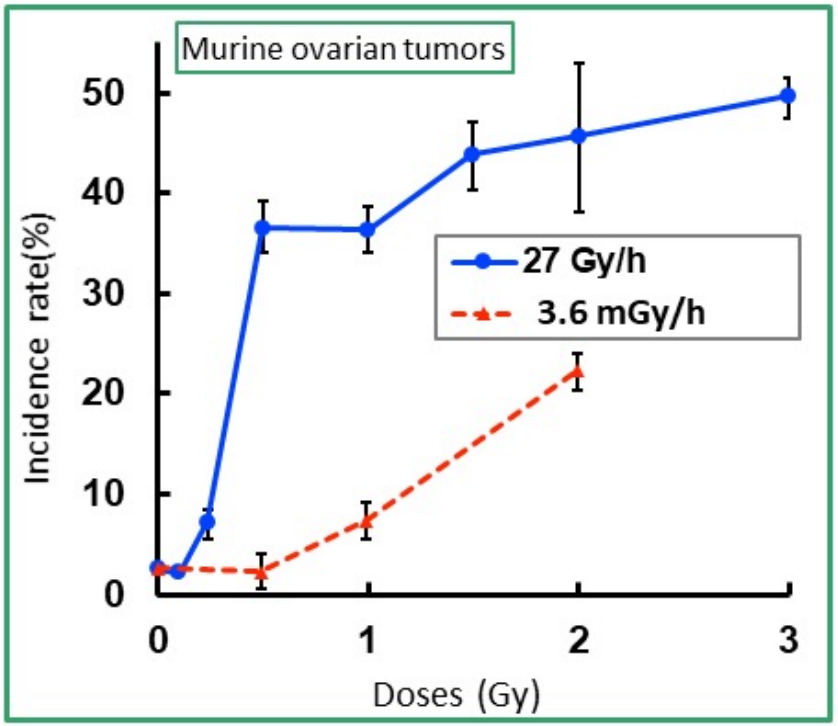
* Alcohol consumption is in ethanol equivalent.

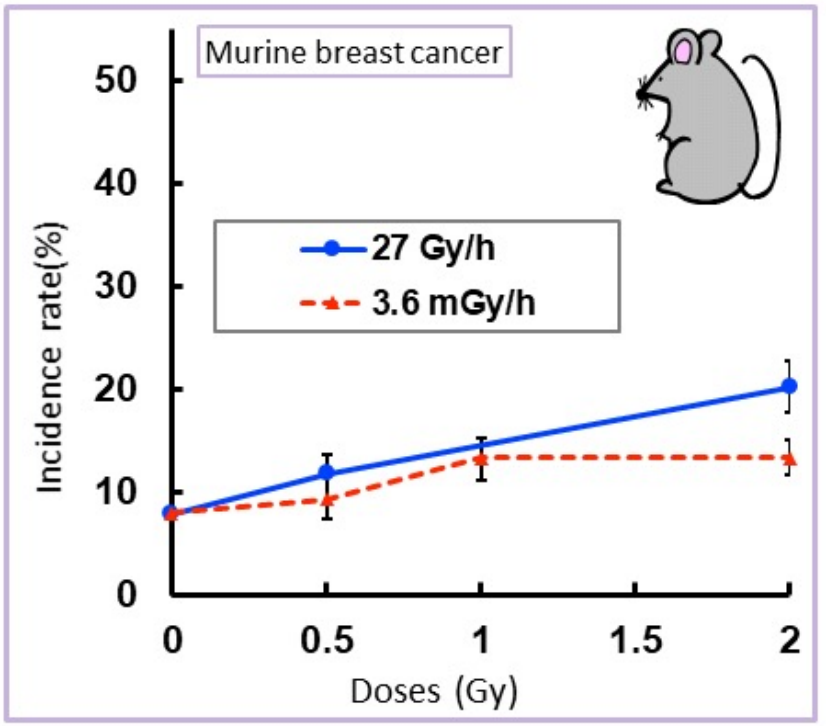
Source: Website of the National Cancer Center Japan

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Cancer and Leukemia

# Cancer-promoting Effects of Low-dose Exposures




Source: United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 1993

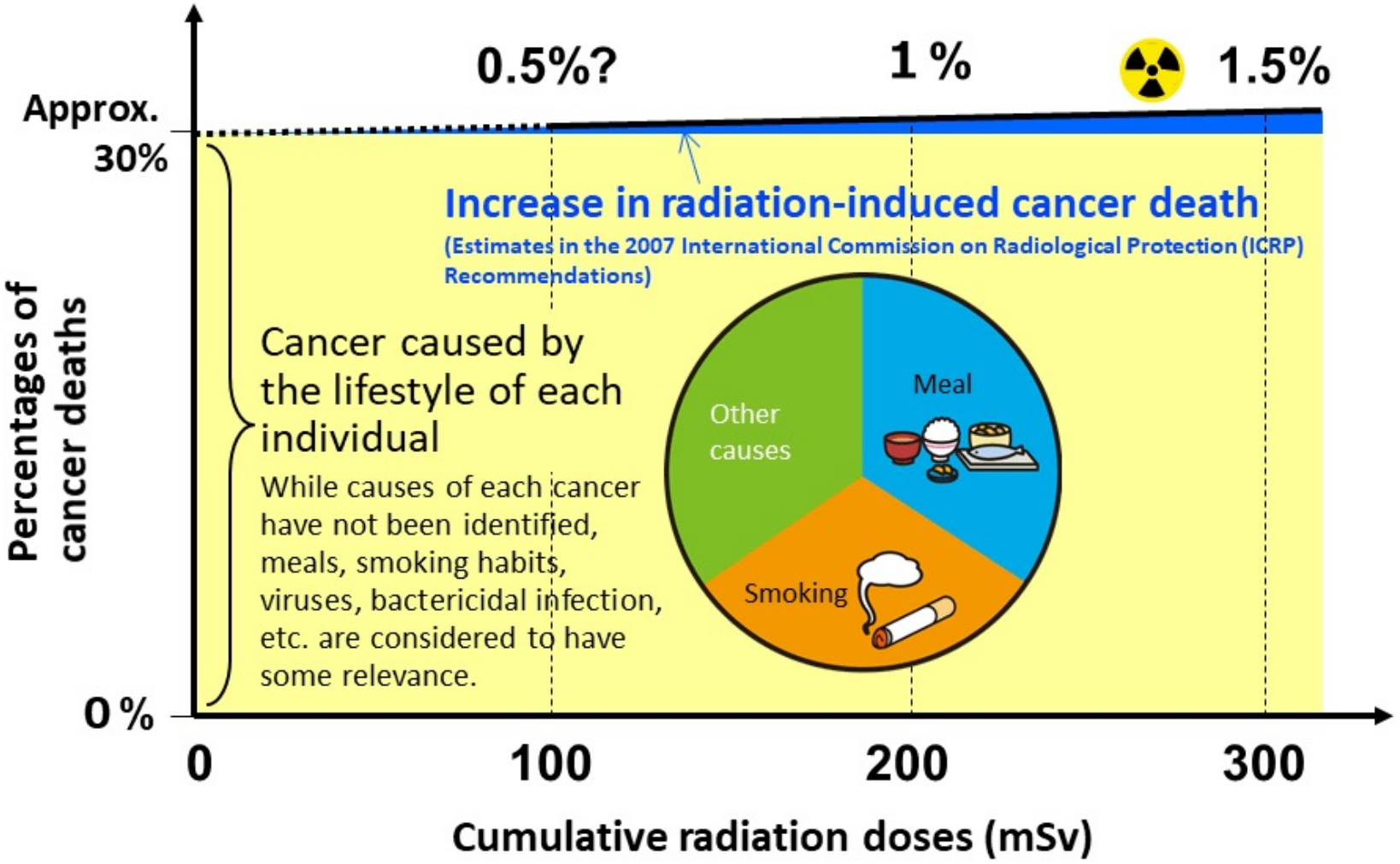
Risks of low-dose and low-dose-rate exposures

$$= \frac{\text{Risks of high-dose and high-dose-rate exposures}}{\text{Dose and dose-rate effectiveness factor}}$$

| Organizations | Dose and dose-rate effectiveness factors |
|---|---|
| UNSCEAR 1993 | Less than 3 (1 to 10) |
| National Academy of Sciences (NAS) 2005 | 1.5 |
| International Commission on Radiological Protection (ICRP) 1990 and 2007 | 2 |

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

# Risks Risks of Cancer Death from Low-Dose Exposure




Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Hereditary Effects

# Risks of Hereditary Effects for Human Beings

■ Radiation effects on gonads (reproductive cells)

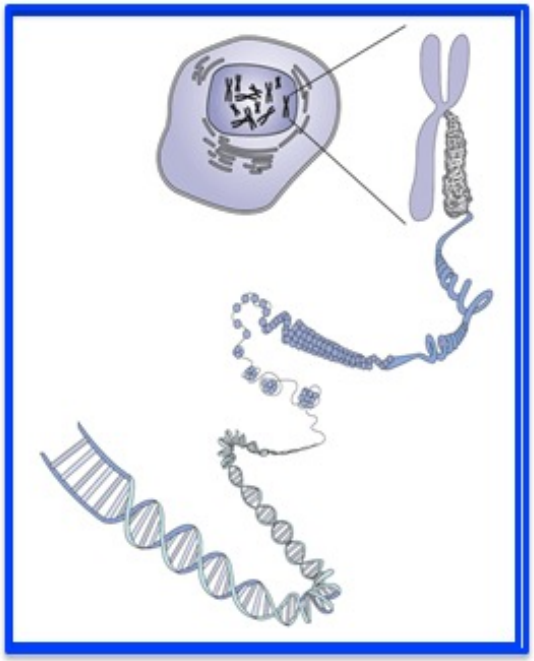
◎ Gene mutations

Changes in genetic information in DNA (point mutation)

◎ Chromosome aberrations

Structural chromosomal aberrations

* Increases in hereditary diseases in the offspring have not been proved among human beings.



■ Risks of hereditary effects (up to children and grandchildren)

= Approx. 0.2%/Gy (Two out of 1,000 people per gray)

(2007 Recommendations of the International Commission on Radiological Protection (ICRP))

This value is indirectly estimated using the following data:

- Spontaneous incidences of hereditary diseases among a group of human beings
- Average spontaneous gene mutation rate (human beings) and average radiation-induced mutation rate (laboratory mice)
- Correction factor for extrapolating potential risks of induced hereditary diseases among human beings based on radiation-induced mutation rate among laboratory mice

■ Tissue weighting factor for gonads (ICRP Recommendations)

0.25 (1977) → 0.20 (1990) → 0.08 (2007)

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

Hereditary Effects

# Chromosomal Aberrations among Children of Atomic Bomb Survivors


## Stable chromosome aberrations among children of atomic bomb survivors

| Sources of aberrations | Number of children with chromosome aberrations (percentage) | |
|---|---|---|
| | Control group (7,976 children) | Exposed group (8,322 children) Average exposure dose: 0.6 Gy |
| Derived from either of the parents | 15 (0.19%) | 10 (0.12%) |
| Newly developed cases | 1 (0.01%) | 1 (0.01%) |
| Unknown (Examination of parents was not possible.) | 9 (0.11%) | 7 (0.08%) |
| **Total** | 25 (0.31%) | 18 (0.22%) |

Source: "Chromosomal Aberrations among Children of Atomic Bomb Survivors (1967 - 1985 surveys)" on the website of the Radiation Effects Research Foundation (https://www.rerf.or.jp/programs/roadmap/health_effects/geneefx/chromeab/)

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation

# Other Epidemiological Surveys of Children of Atomic Bomb Survivors



■ Deaths from leukemia or possibly hereditary tumors, etc. developed by the age of 20

The follow-up survey of 41,066 subjects revealed no correlation between parents' gonadal doses (0.435 Sv on average) and their children's deaths.

(Source: Y. Yoshimoto et al.: Am J Hum Genet 46: 1041-1052, 1990.)

■ Deaths from cancer (1958 - 1997)

As a result of the follow-up survey of 40,487 subjects, development of solid tumors and blood tumors was found in 575 cases and 68 cases, respectively, but no correlation with parents' doses was observed (the survey is still underway).

(Sourse：S. Izumi et al.: Br J Cancer 89: 1709-13, 2003.)

■ Incidence rates of lifestyle-related diseases (2002 - 2006)

The clinical cross-sectional survey of approx. 12,000 subjects revealed no correlation between parents' doses and their children's incidence rates of lifestyle-related diseases (the survey is still underway).

(Source：S Fujiwara et al.: Radiat Res 170: 451-7, 2008.)

Source: BOOKLET to Provide Basic Information Regarding Health Effects of Radiation