放射線業務従事者のための教育訓練
－講習A・講習X：新規教育－

2013/07/05(Fri.)
Biology, ooe

EFFECT OF RADIATION ON THE HUMAN BODY

Accident example (RI related)

１）At Non-Destructive Inspection Co., Ltd., the location of the sealed radioisotope was unknown.
【International Nuclear Event Scale 1】

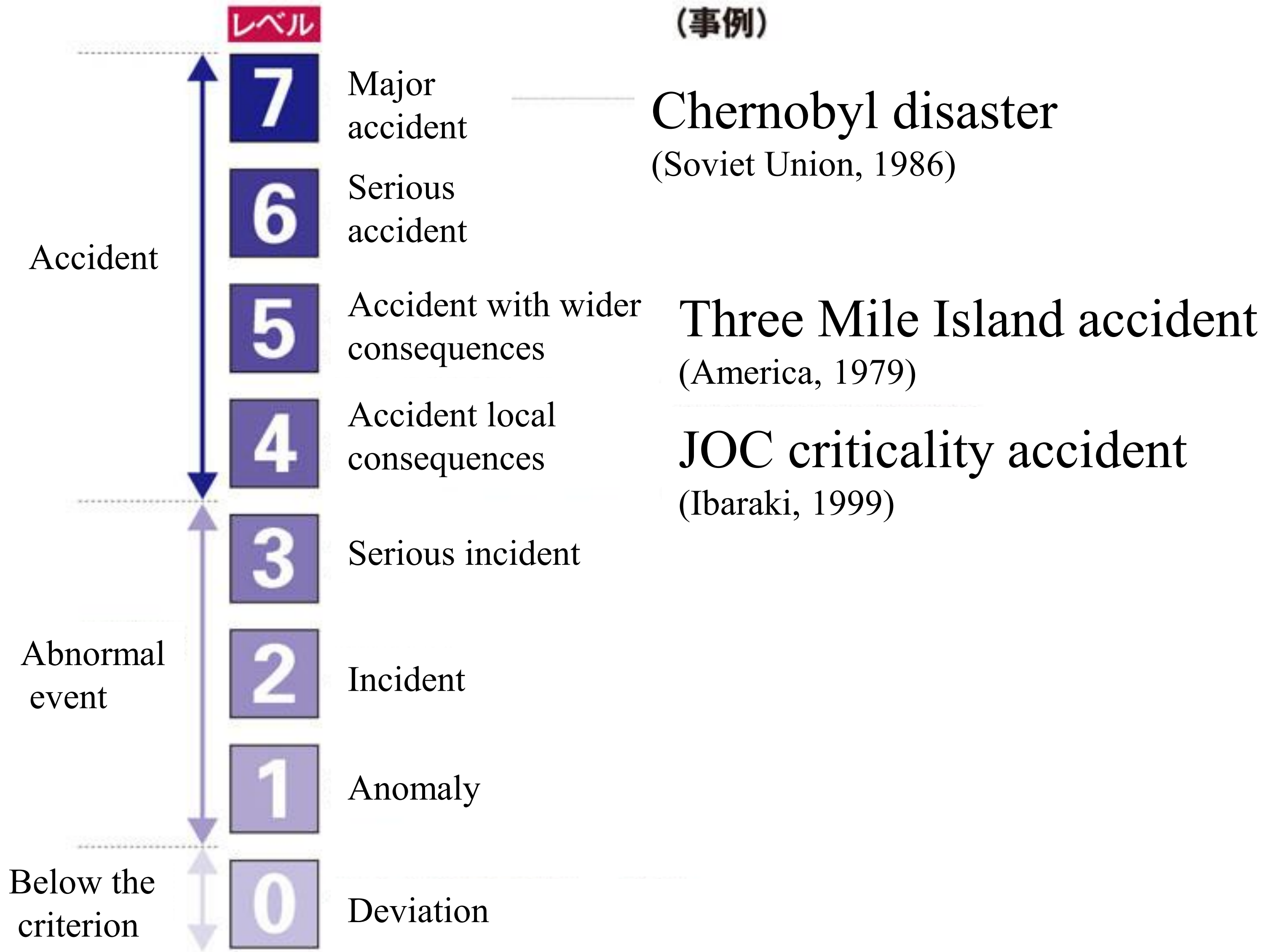
２）An exposure accident occurred at Sumitomo Test Inspection Co., Ltd. due to a radiation generator.
【International Nuclear Event Scale 2】

３） The location of the radioactive isotope during transportation by NRS Corporation was unknown.
【International Nuclear Event Scale 0】

4） Wastewater leaked out of the controlled area from the drainage pipe at Tohoku University.
【International Nuclear Event Scale 0】

文部科学省　HP

《 International Nuclear Event Scale（INES） 》



Accident example (X-rays related)

April 28th, 1994

1) While manufacturing an X-ray diffractometer (RINT2500, 50kV, 200mA), the shutter was disassembled without knowing that X-rays were being emitted in order to find the cause of the X-ray leakage. He was exposed to the right palm for about 3 seconds, but when he felt warm at the bases of his 4th and 5th fingers (?), He noticed the exposure and turned off the power.

2) At this point, there were no particular symptoms, and no treatment was performed.

14 days after exposure

3) A part of the skin turned white and the change worsened, so he reported to the company and visited the Department of Radiology, University of Tokyo Hospital.

4) The estimated skin absorbed dose was 100-200 Gy.

RADIOISOTOPES, 44, 440-450 (1995)

X-ray exposure disorder

440-445(1995)

22 days

Fig. 1 The right palm 22 days after the exposure.

29 days

Fig. 2 The right palm 29 days after the exposure.

36 days

Fig. 4 The right palm 36 days after the exposure.

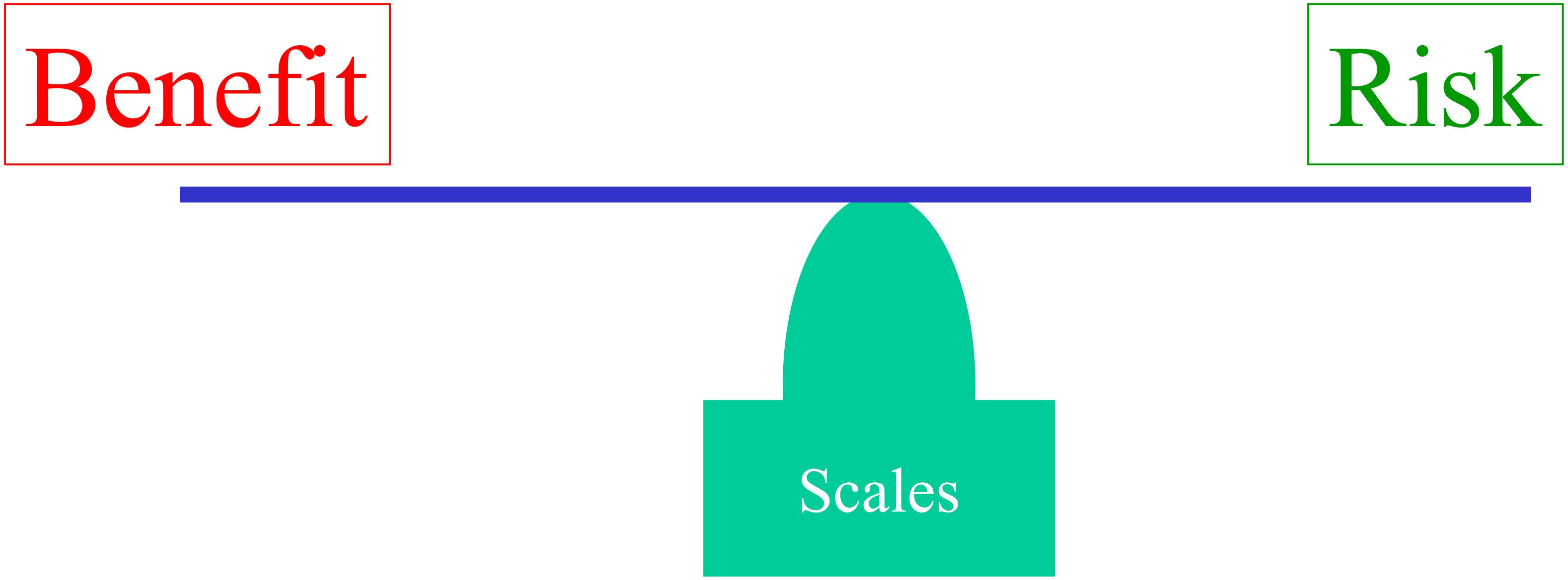
55 days

Fig. 5 The right palm 55 days after the exposure.

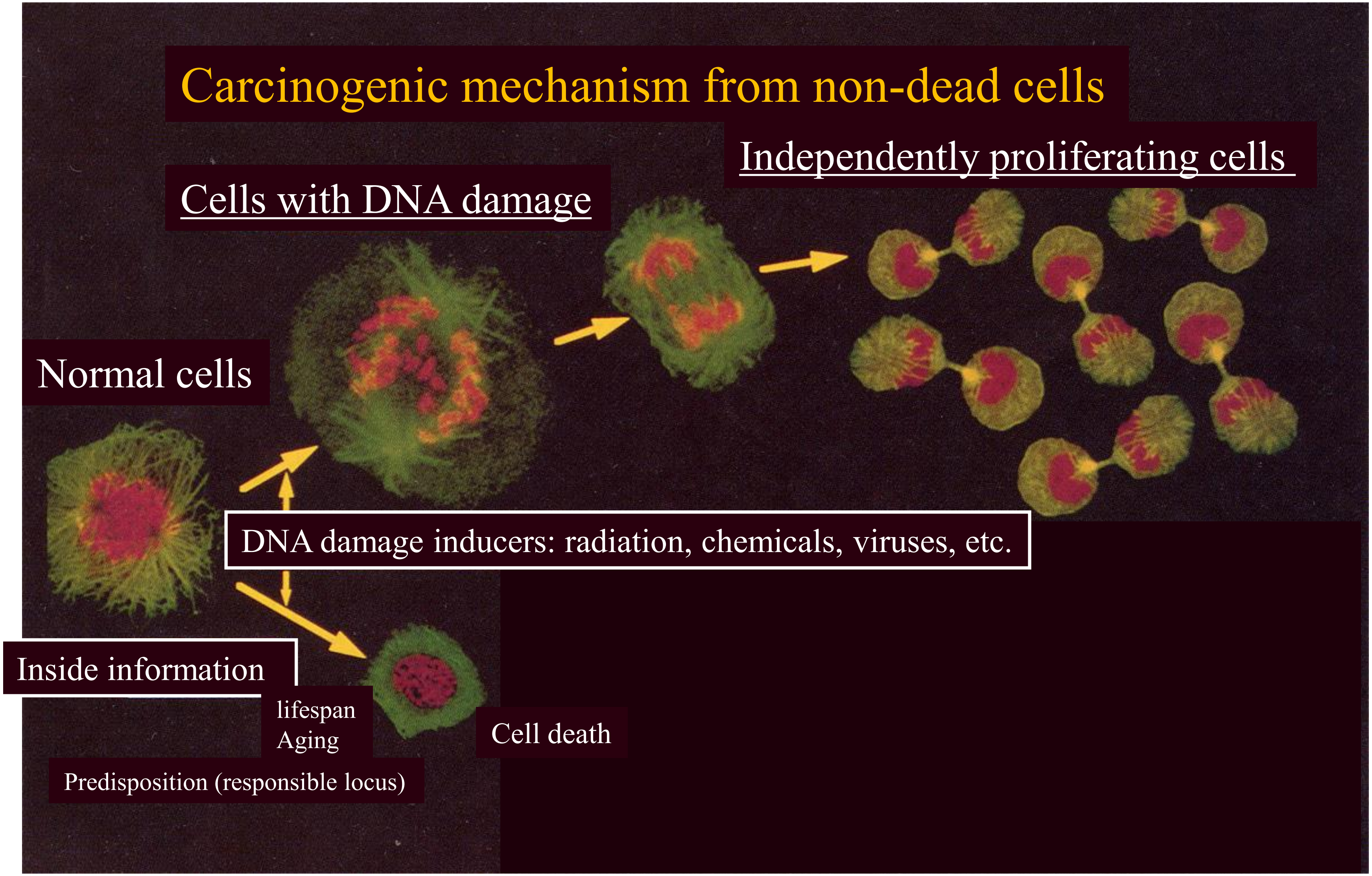
81 days

Fig. 6 The right palm 81 days after the exposure.

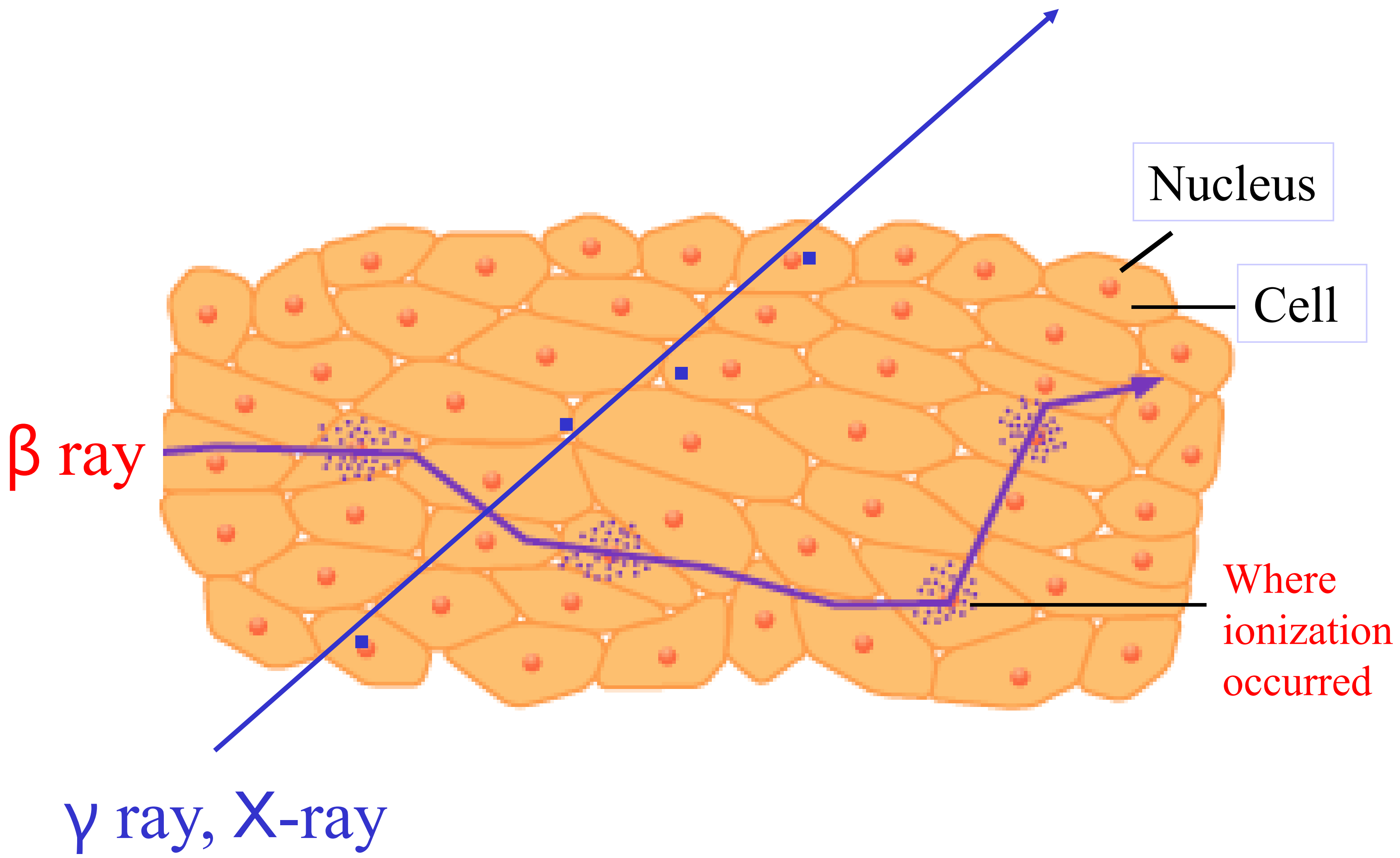
Balance of radiation utilization



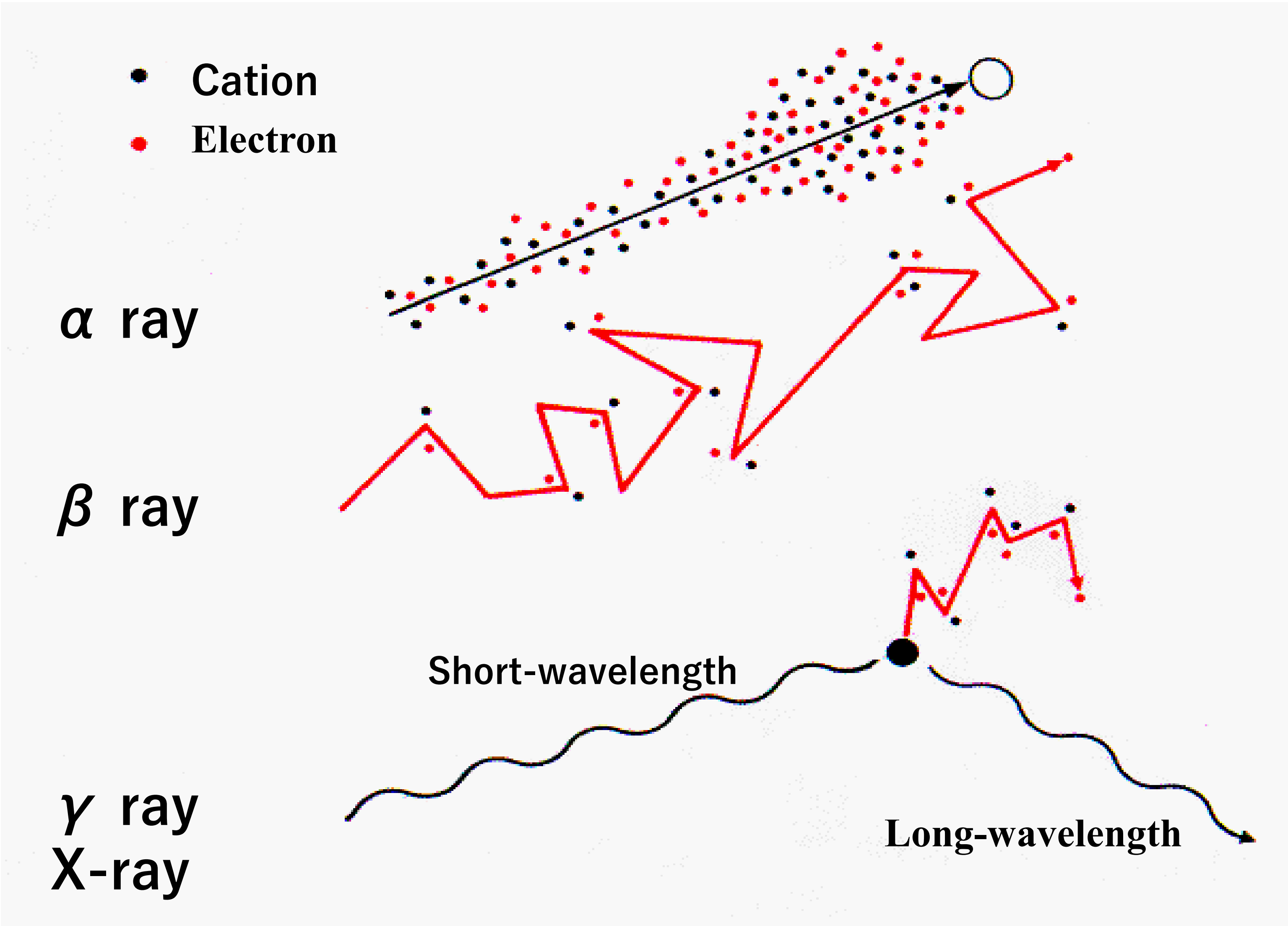
Radiation injury begins with one cell death!



Radiation track model in tissue



Difference in ionization by radiation



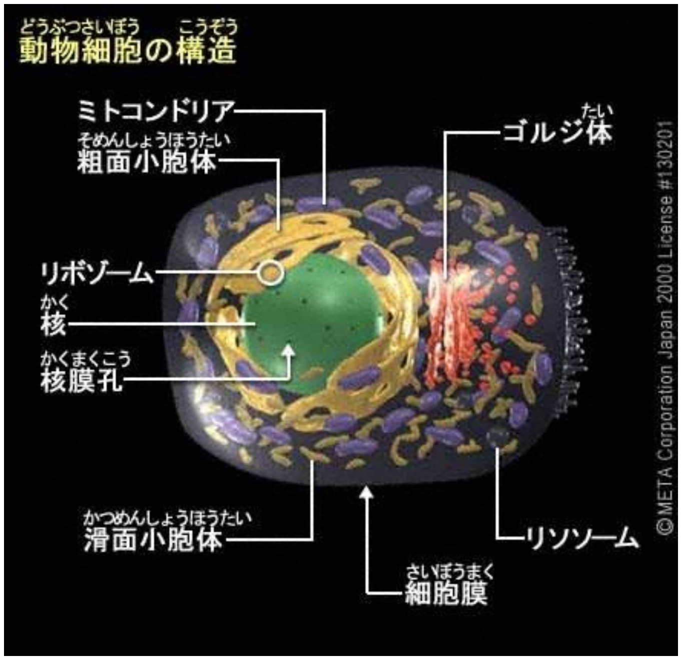
When radiation passes through a substance, it gives its energy to atoms and molecules along the way, causing ionization and excitation.

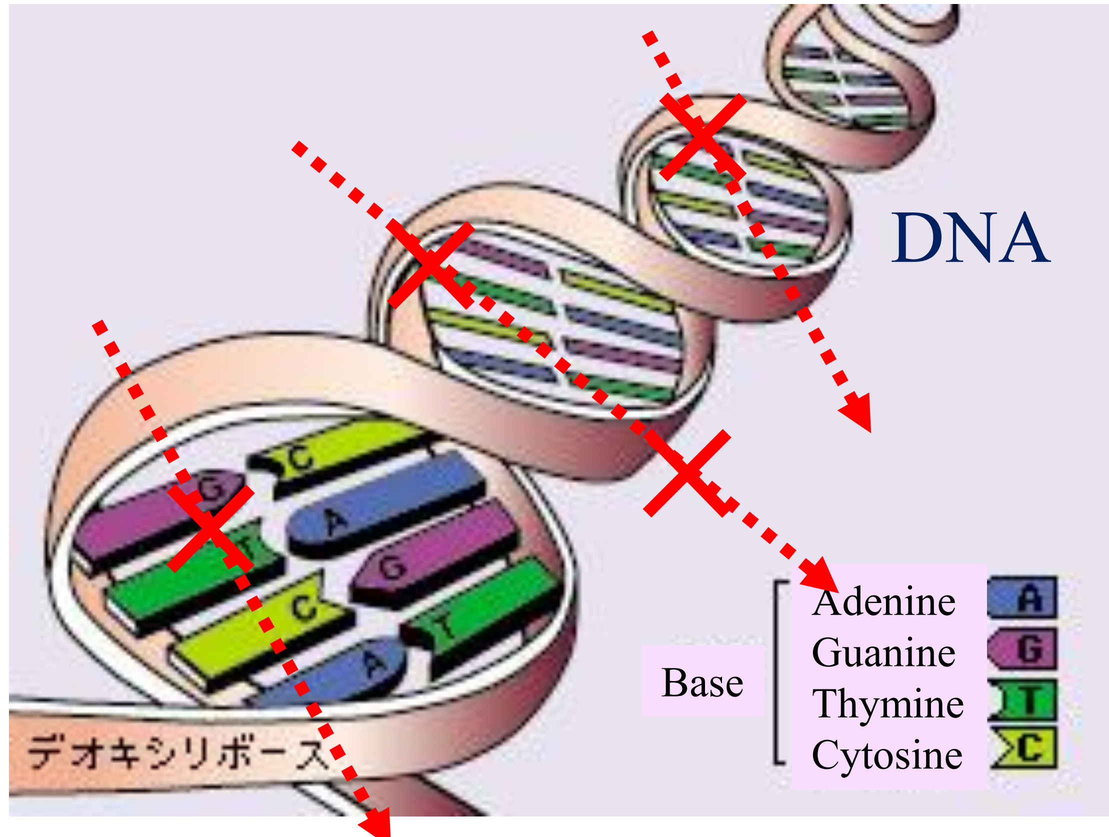
Table. 1-3 Average of radiation tracks in water (living body)

Radiation	LET:L∞ (keV/μm)
^{60}Co γ ray	0.3
250kVp X-ray	2.5
170～200kVp X-ray	3.3～3.8
^{3}H β^{-} ray	5.5
14MeV neutron (7MeV proton)	12
4MeV neutron (2MeV proton)	17
Fission neutrons (0.95MeV proton)	45
8.3MeV α ray	61
3.4MeV α ray	86
5.2MeV α ray	140
10B(n,α) α ray	200

出展：医学のための放射線生物学　坂本澄彦、佐久間定行　編著　秀潤社　P12

DNA is an important radiation target that is the origin of the biological action of living cells.



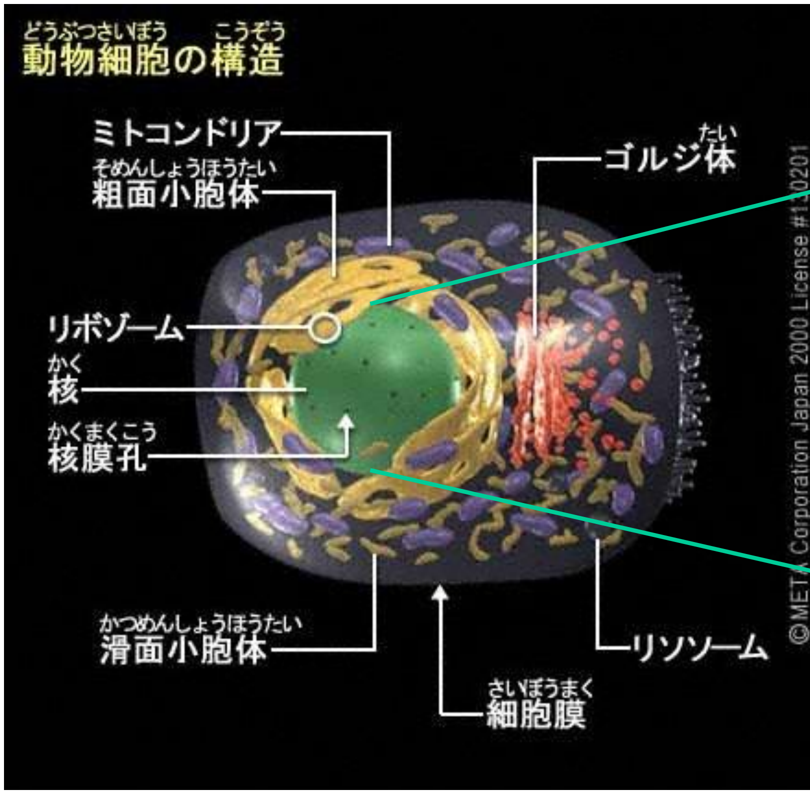


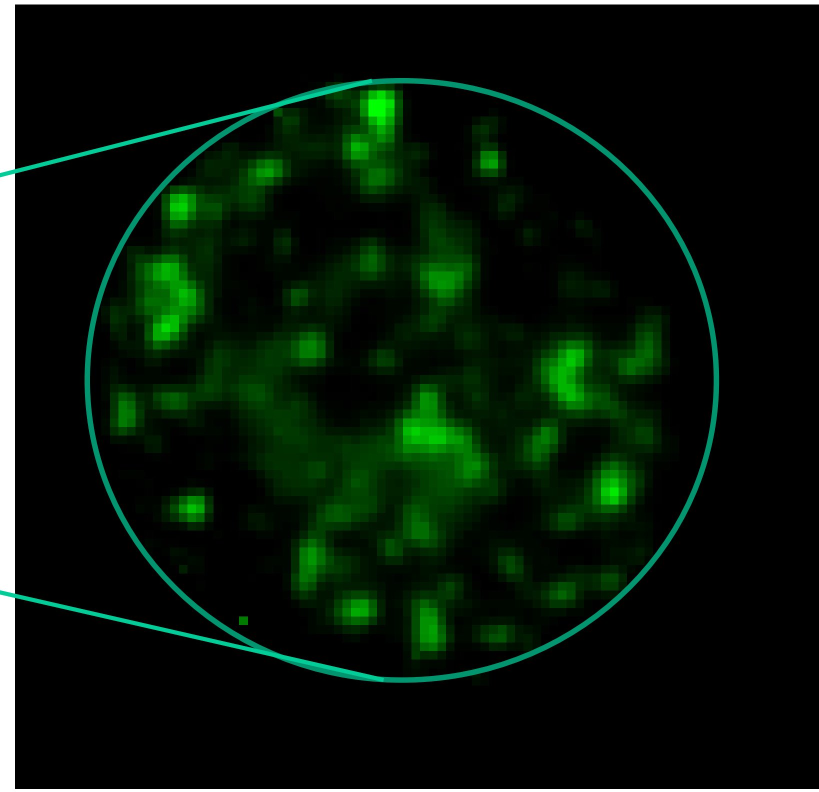
High LET radiation: direct action

Low LET radiation: Indirect action (radical generation by radiolysis of water)

$\cdot H$ $\cdot OH$ e^-_{aq}

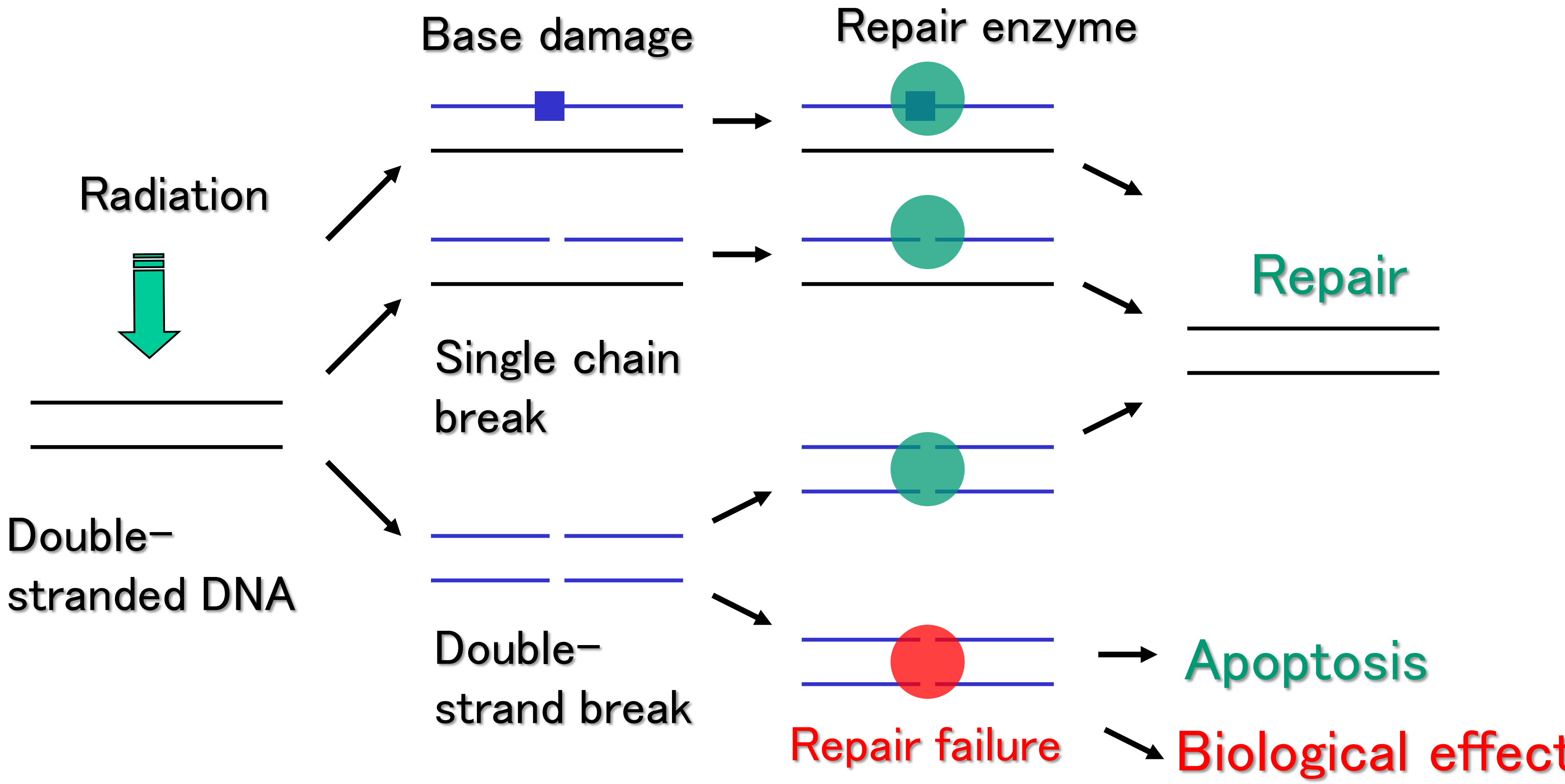
Evidence of radiation-induced DNA damage





DNA double-strand break in the nucleus
（γ-H2AX immunostaining）

Radiation-induced DNA damage and repair



Damage	Spontaneous (/cell/day)	Radiation induction (/cell/Gy)
Base damage	20,000	6,400
Single chain break	50,000	600 - 1,000
Double-strand break	10	16 - 40

放射線障害の程度を決める要因

放射線感受性

- 放射線の種類・エネルギー（放射線荷重係数、RBE）
- 組織（組織荷重係数）
- 部位
- 内部被ばく（核種、摂取量・形態、有効半減期）
- 細胞周期
- （G2期DNA合成終期～M期細胞分裂期が感受性大）
- 年齢
- 健康状態

線量率効果、酸素効果、温度効果

放射線増感物質、放射線防護物質など

Differences in radiosensitivity by tissue

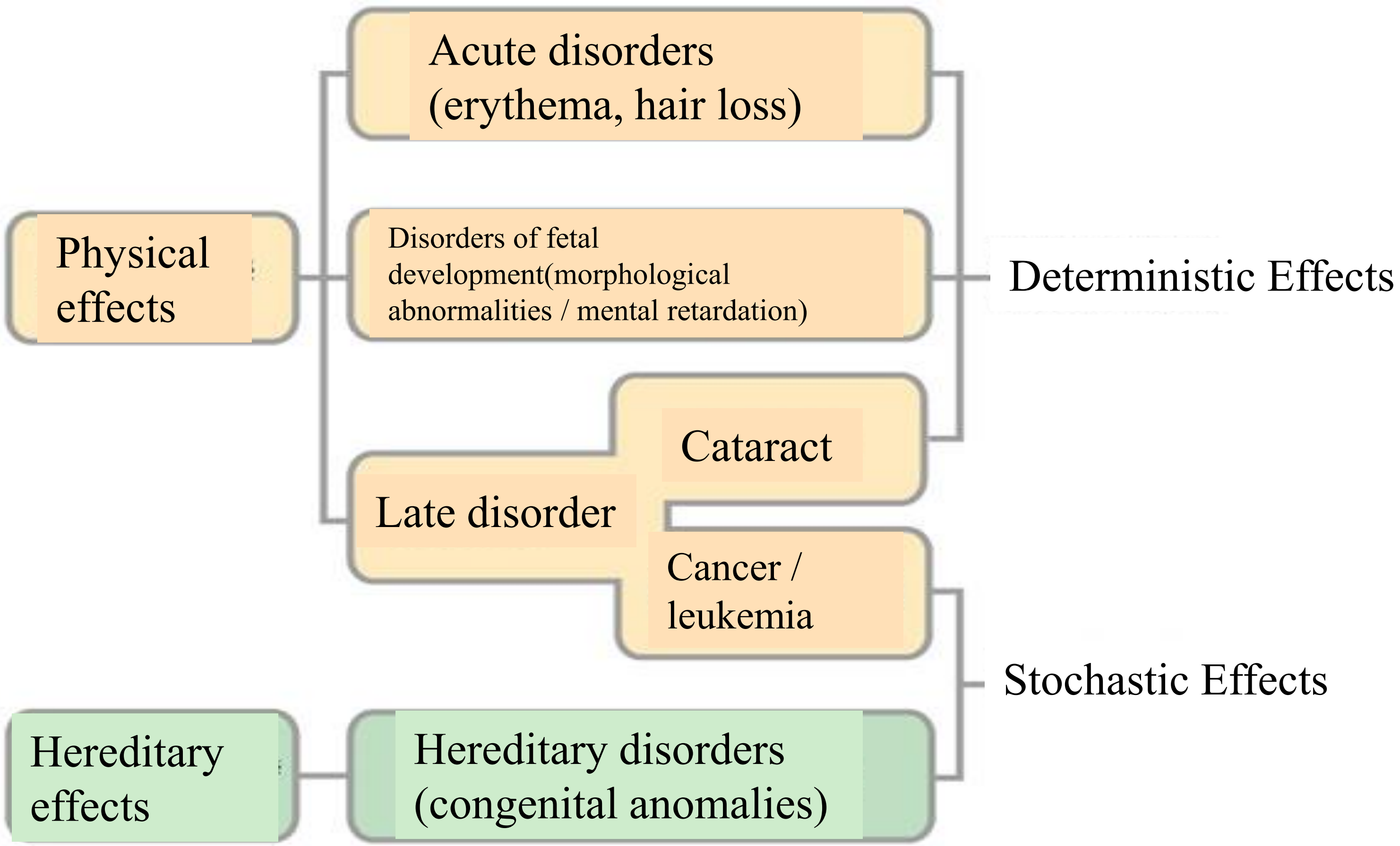
Bergonie-Tribondeau's Law

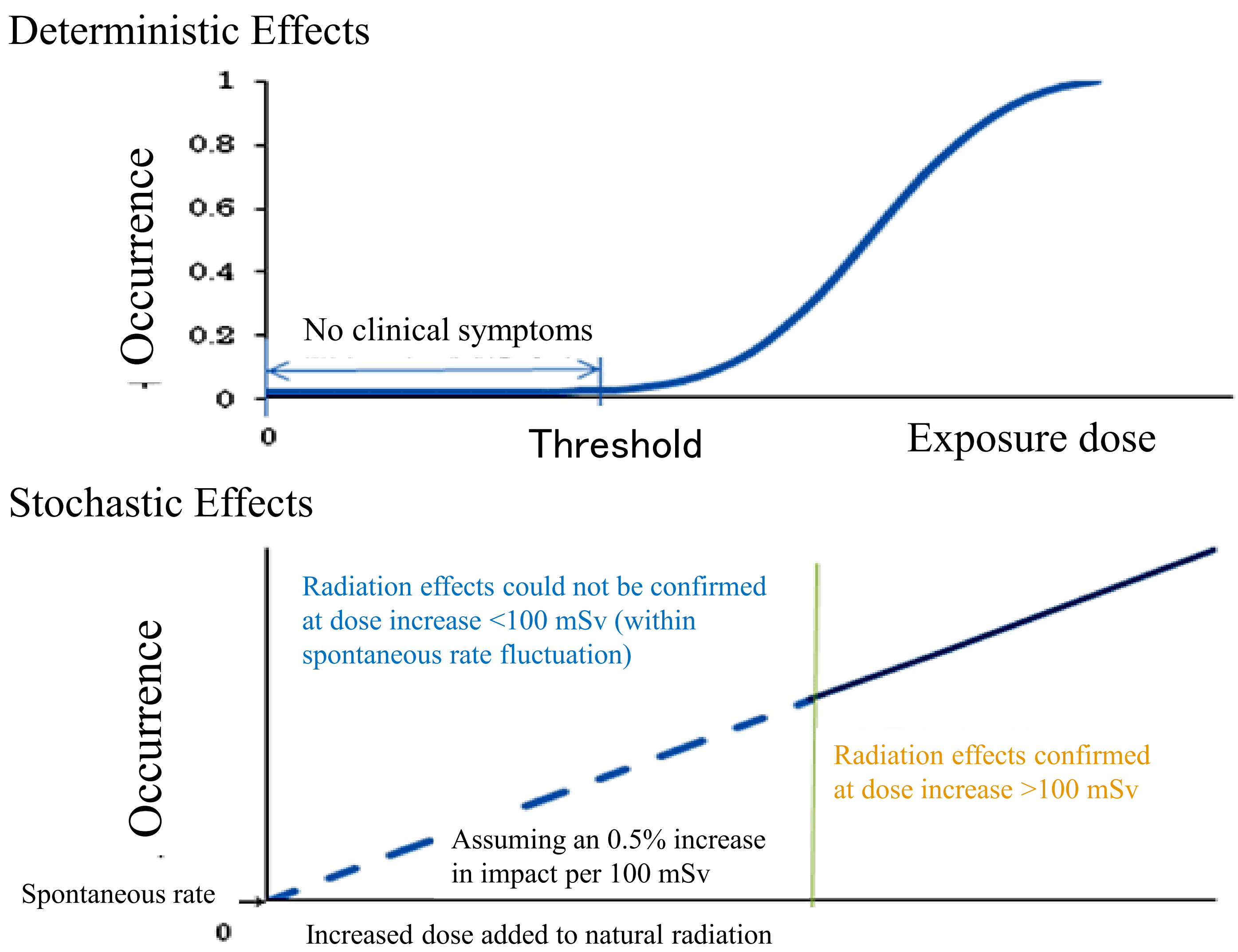
"The higher the cell division ability, the longer the cell division process, and the more morphologically and functionally undifferentiated, the higher the radio sensitivity."

Order of radiosensitivity of cells

1． lymphocytes
2． Neutrophils (and eosinophils)
3． Epithelial cells
　1） The basal epithelium of a secretory gland, especially the pancreatic juice gland
　2） Testicular seminoma or ovarian follicle epithelium
　3） Skin basal epithelium, mucosal layer and gastrointestinal basal epithelium
　4） Alveolar epithelium, bile duct epithelium
　5） Tubular epithelium of the kidney
4． Endothelial cells of blood vessels, pleura, peritoneum
5． Connective tissue cells
6． Muscle cells
7． Nerve cell

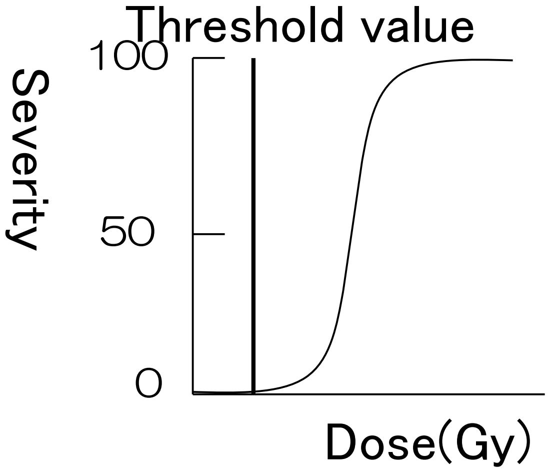
Effects of radiation on the human body





Deterministic Effects vs. Stochastic Effects

Deterministic Effects



Deterministic Effects and Threshold value

<table>
<tr><th>Tissue</th><th colspan="2">Effect</th><th>Absorbed dose（Gy）</th></tr>
<tr><td rowspan="3">Bone marrow</td><td colspan="2">Leukopenia</td><td>0.5</td></tr>
<tr><td colspan="2">Red blood cell depletion</td><td>2 – 6</td></tr>
<tr><td colspan="2">Thrombocytopenia</td><td>2 – 6</td></tr>
<tr><td rowspan="4">Infertility</td><td rowspan="2">Man</td><td>Temporary infertility</td><td>0.15</td></tr>
<tr><td>Permanent infertility</td><td>3.5 – 6</td></tr>
<tr><td rowspan="2">Women</td><td>Temporary infertility</td><td>0.65 – 1.5</td></tr>
<tr><td>Permanent infertility</td><td>2.5 – 7</td></tr>
<tr><td rowspan="2">Eye</td><td colspan="2">Opacified lens</td><td>0.5 – 2</td></tr>
<tr><td colspan="2">Cataract</td><td>5</td></tr>
</table>

Deterministic Effects and Threshold value

Tissue	Effect	Absorbed dose（Gy）
Fetus	Embryo death/ abortion	0.05 – 0.1
	Malformation	0.1
	Mental developmental delay	0.12 – 0.2
Skin	Temporary erythema	2
	Temporary hair loss	3
	Necrosis	18

Systemic exposure dose and symptoms

Dose (Gy)	Effects
0.05～0.25	Minimum dose at which changes can be detected by chromosomal analysis (no change in blood image)
0.5～0.75	Minimum dose at which changes are detected for a particular person
0.75～1.25	The lowest dose that is thought to cause nausea in about 10% of exposed people
1.5～2	Dose (acute exposure) that is thought to cause temporary helplessness and obvious changes in blood image to most of the exposed people
3～4	50% lethal dose: LD50, short-term acute exposure

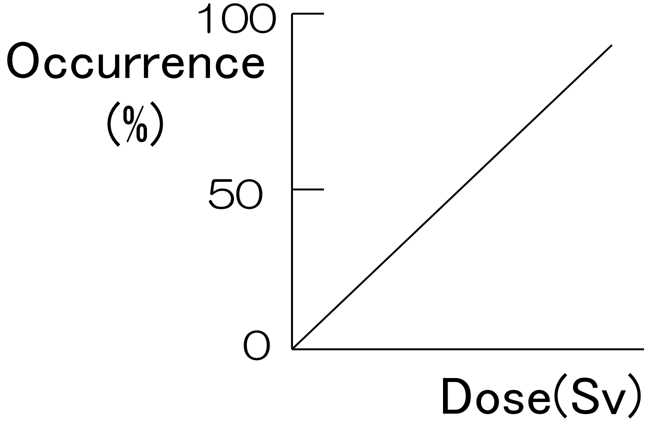
Acute radiation sickness [large intestine]

Large intestine of exposed person (6 Gy or more)

Control

【長崎原子爆弾の医学的影響（長崎大学、1995）より抜粋】

Stochastic Effects



確率的影響を示す場合

実効線量:(Sv)

等価線量(Sv):H_{TR}

臓器・組織Tの吸収線量 D_{TR}(Gy)

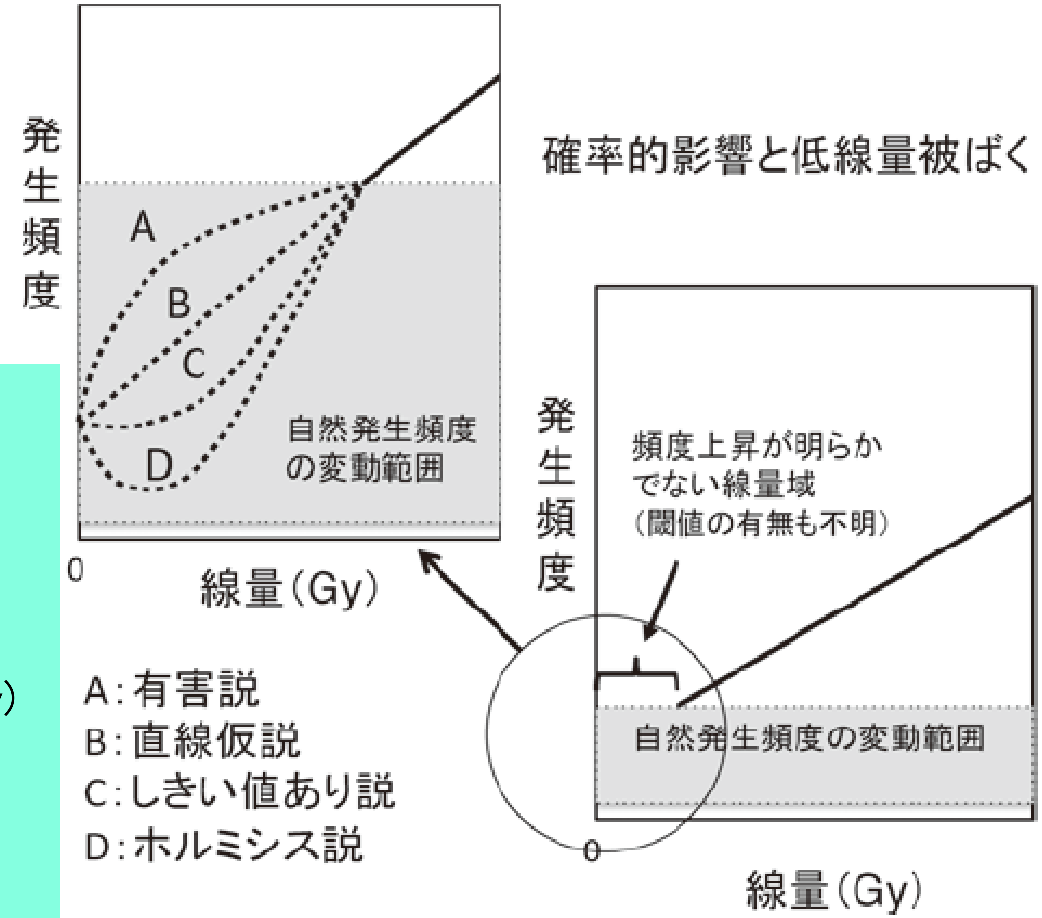
放射線荷重係数 W_R

$$H_{TR} = W_R \times D_{TR}$$

実効線量(Sv):E

組織荷重係数 W_T

$$E = \sum_T W_T \cdot H_{TR}$$



2　低線量被ばく影響（確率的影響）に関する複数の説．低線量被ばくによる確率的影響では，ある線量よりも低くなると発生頻度が自然発生の揺らぎの中に埋没してしまい，放射線影響があるのかどうかがわからなくなる．そのため，実験系の違いなどにより，大きく分けて４つの説（A~D）が唱えられている．現時点で最も妥当とされているのは直線仮説（直線しきい値なし仮説）である．

出典：田内広,馬田敏幸,立花章　J.Plasma Fusion Res. Vol88,No2(2012)119-124

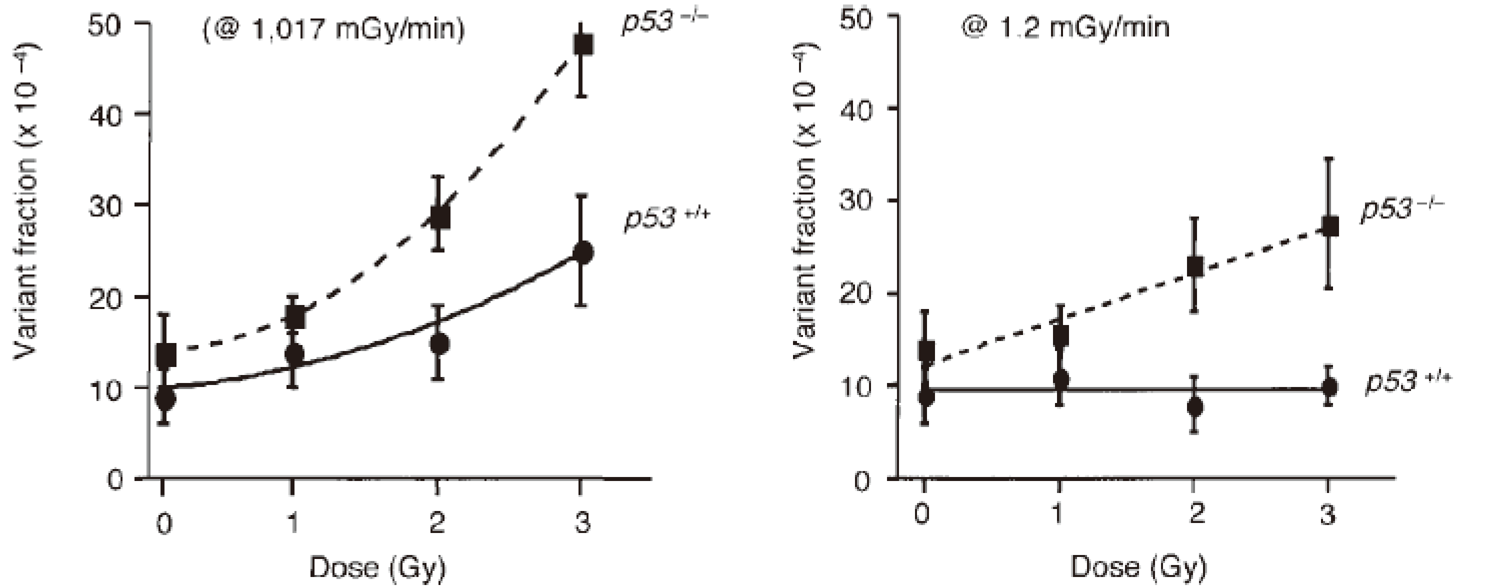


図６　*p53* ノックアウトマウスは低線量率でも線量依存的に突然変異が増加する．
左は高線量率照射，右は低線量率照射である．*p53* が正常な　（*p53+/+*）マウスは，低線量率照射で突然変異頻度が上昇しなくなるが，*p53* ノックアウト（*p53-/-*）マウスでは，低線量率照射でも線量依存的に上昇し続け，線量率の影響が見られない．

(出典：田内広,馬田敏幸,立花章　J.Plasma Fusion Res. Vol88,No2(2012)119-124)

Nominal carcinogenesis risk factor (Radiation handler)

ICRP1990	4.8×10^{-5} / mSv
ICRP2007	4.1×10^{-5} / mSv

If you have been exposed to the annual average dose limit (20mSv) for 40 years

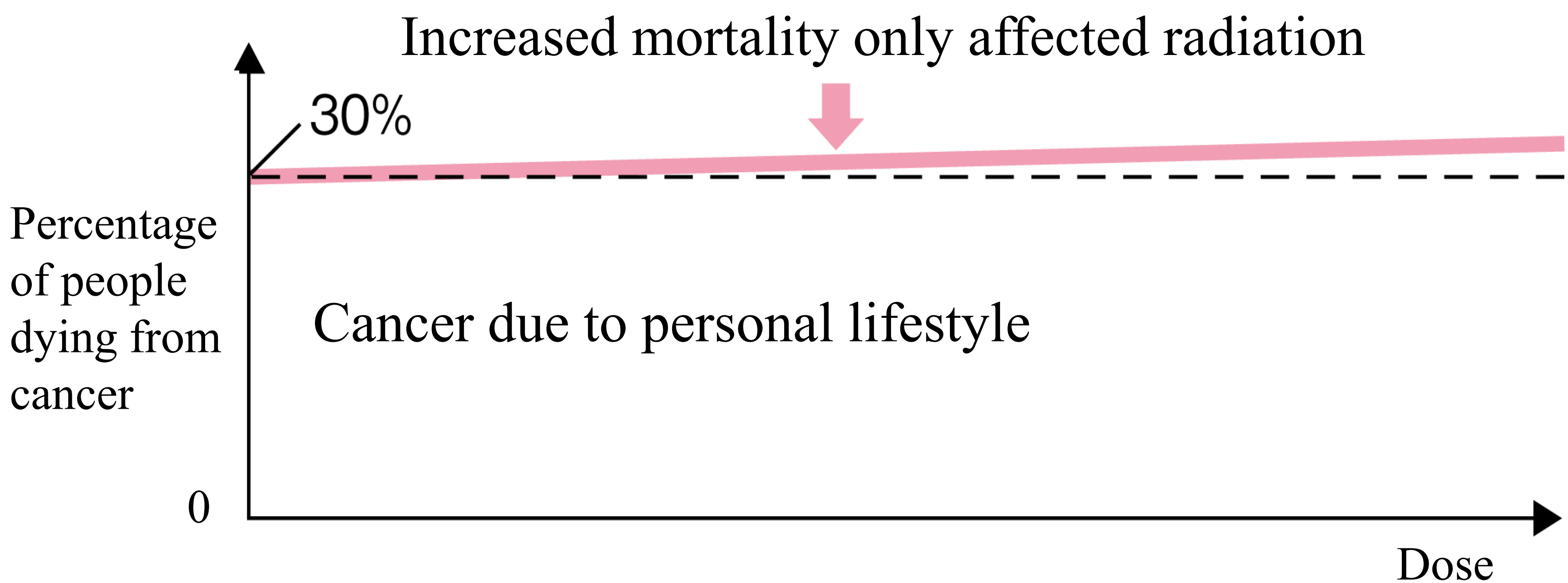
$4.1 \times 10^{-5} \times 20 \times 40 = 0.0328$

328 persons / 10000 persons

Increase in cancer and leukemia caused by radiation

The ICRP calculates that if 1000 people receive 100 millisieverts in accumulation, about 5 people could die of cancer. About 30% of Japanese people today die of cancer in their lifetime.

◆ Increase in cancer and leukemia caused by radiation



出典:(独)放射線医学総合研究所

Risk comparison

(approximate annual death toll per 100,000 population)

All-case	848.5	Radiation carcinogenesis (Radiation handler)	4.1
Cancer	255.1	Water accident	0.70
Heart disease	135.4	Influenza	0.55
Cerebrovascular disease	103.9	Murder	0.52
Smoking carcinogenesis (current situation)	80.0	Natural disasters	0.10
Smoking carcinogenesis	30.0	H I V	0.04
Suicide	23.9	Food poisoning	0.004
Traffic accident	9.1	Lightning strike	0.002
Radiation carcinogenesis (General public)	5.5	Creutzfeldt-Jakob disease by BSE-infected cattle	0.0009

いろいろな事項についての10万人あたりの年間死亡数、体質研究会、http://www.taishitsu.or.jp/risk/risk2006.html
リスクのモノサシ、中谷内一也、NHKブックス

“IT'S EASY TO BE TOO OPTIMISTIC OR SCARED, BUT IT'S HARD TO BE LEGITIMATELY SCARED. “ (TORAHIKO TERADA)

When using radiation, it is essential to learn the correct knowledge about handling and management, and to be humble and fearful.