

# 放射線の人体への影響(生物学)

## Effects of Radiation

on Human Health

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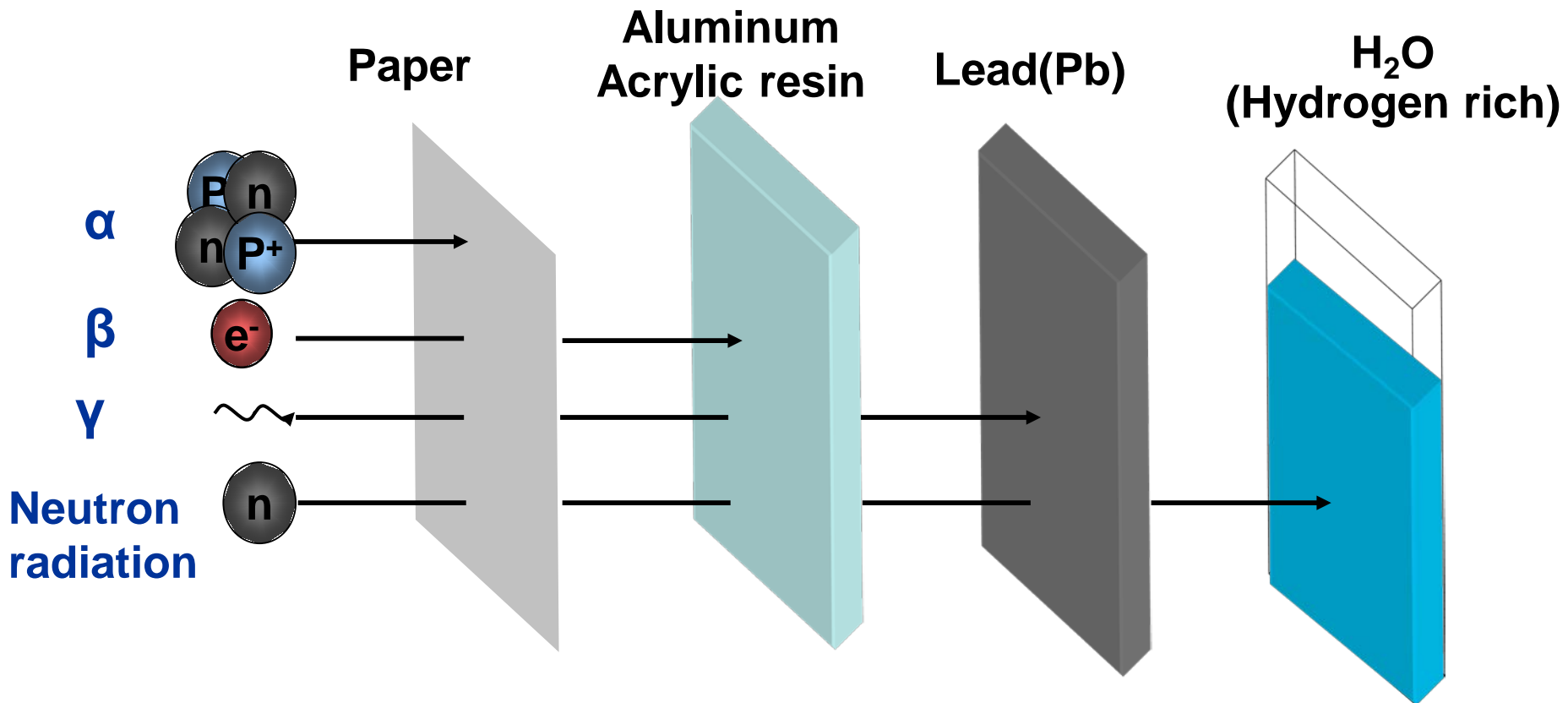
大学等放射線施設協議会

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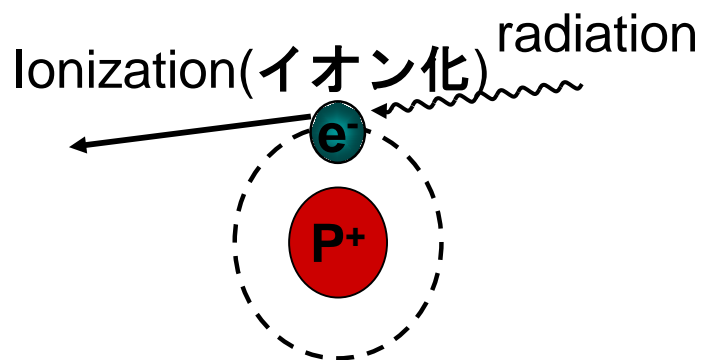
# Factors that relate to biological effects (生物学的影響に関する要因)

1. Penetrating ability (透過能)
2. Linear Energy Transfer (LET)  
(線エネルギー付与)

# 1. Penetrating Ability of Radiations



## 2. Linear Energy Transfer (LET) (線エネルギー付与)

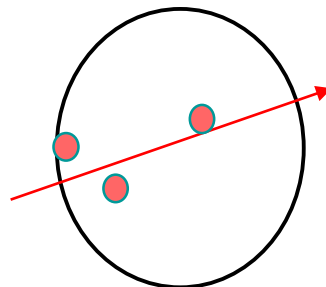


The energy transferred per  
given distance of track

||

**Linear Energy Transfer  
(LET)**

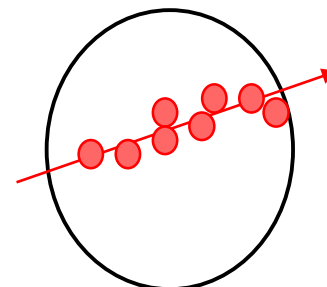
Low LET  
radiations  
(X,  $\gamma$ ,  $\beta$ )



**Sparsely ionizing**

Less biological effect

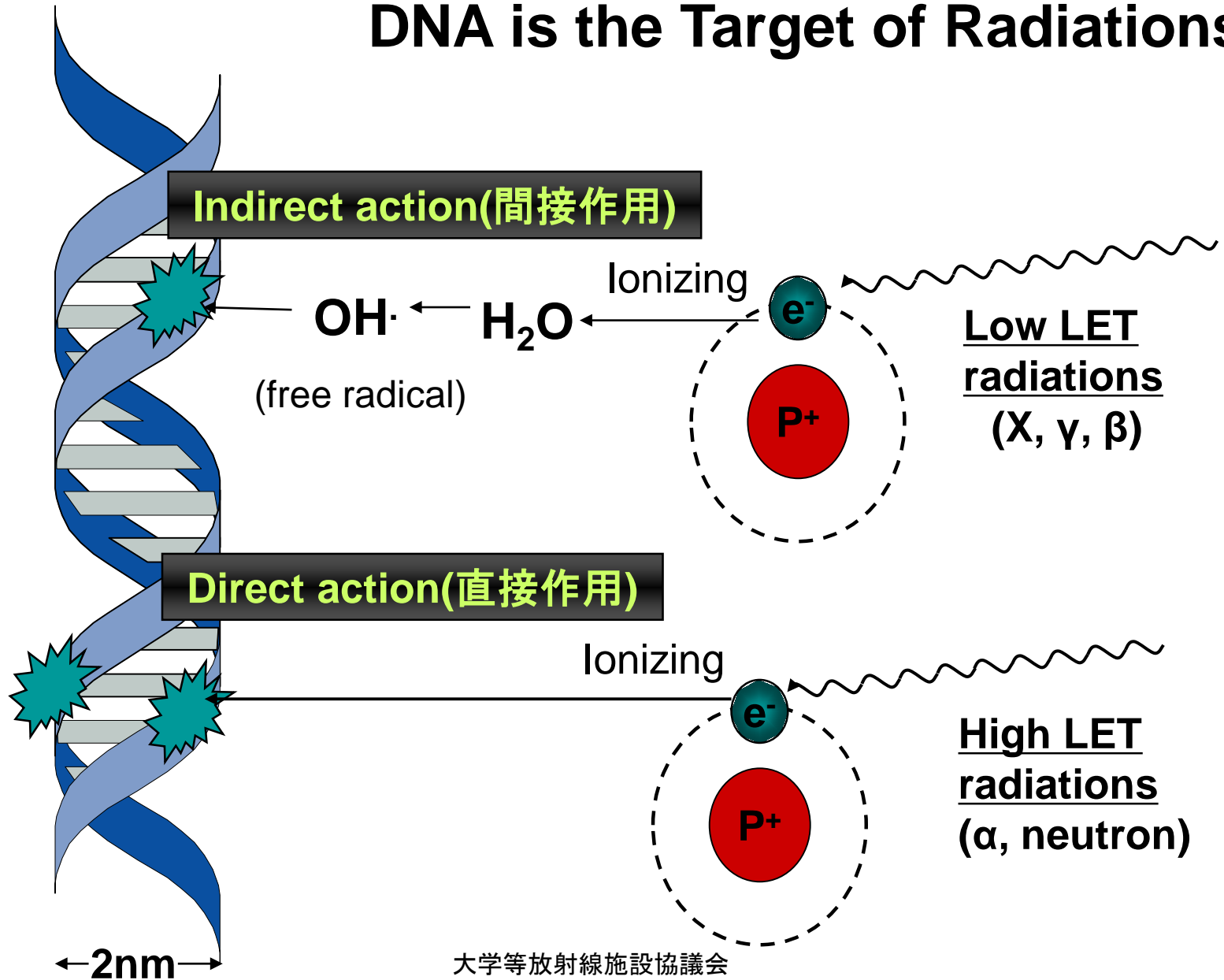
High LET  
radiations  
( $\alpha$ , neutron)



**Densely ionizing**

More biological effect

# DNA is the Target of Radiations



# Classification of Biological effects of Radiations on the Human Body

- **Acute Effects vs. Late Effects**  
(急性影響) (晚發影響)
- **Deterministic Effects vs. Stochastic Effects**  
(確定的影響) (確率的影響)
- **Somatic Effects vs. Genetic Effects**  
(身体的影響) (遺傳的影響)

# Classification of Biological effects of Radiation on the Human Body

- **Acute Effects vs. Late Effects**
- **Deterministic Effects vs. Stochastic Effects**
- **Somatic Effects vs. Genetic Effects**

# Acute Effects

Symptoms of acute effects and dose delivered  
(Whole body, single exposure to gamma rays (or X-rays))

Dose (Gy)	Symptoms 症状
0.25 or less	Almost no clinical symptoms 影響なし
0.5	Temporary reduction of white blood cells (lymphocytes) 一時的白血球数の減少
1	Nausea, vomiting, whole-body languor, substantial reduction of lymphocytes (吐き気、嘔吐、全身のだるさ、リンパ球の大幅な減少)
1.5	Radiation sickness to 50% 放射線宿酔
1	Death to 5%
4	Death to 50% within 30 days
6	Death to 90% within 14 days
7	Death to 100%

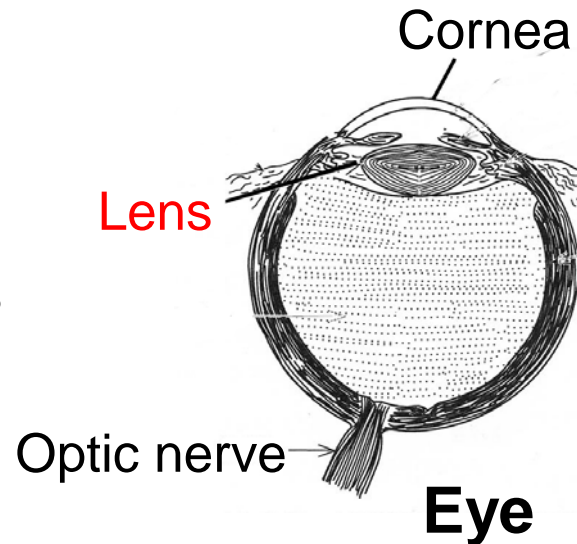


# Late Effects

## Cataracts (白内障)

: clouding of the lens of the eye

- Latent period: several years to a few decades
- Do not occur below a single exposure dose of 2 Sv



## Cancers (がん)

- Latent period: several years to a few decades

## Genetic effects (遺伝的影響)

- Could be
- But not verified in human beings so far

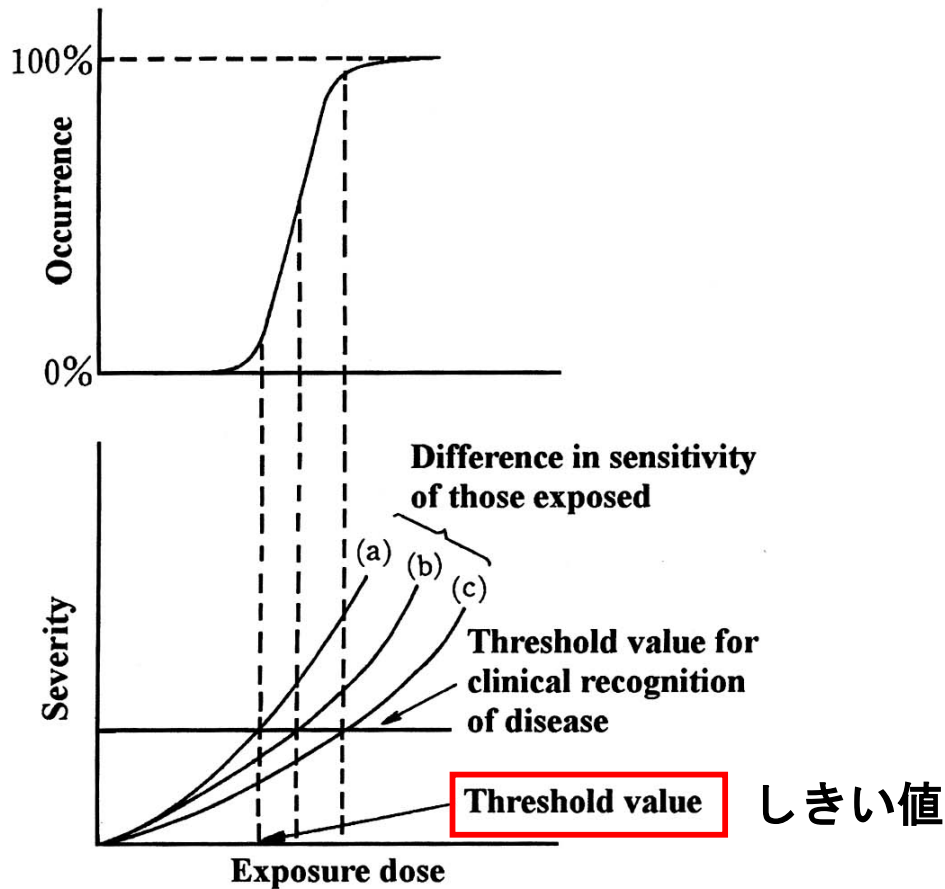


Use a appropriate shield in front of your eyes

# Classification of Biological effects of Radiation on the Human Body

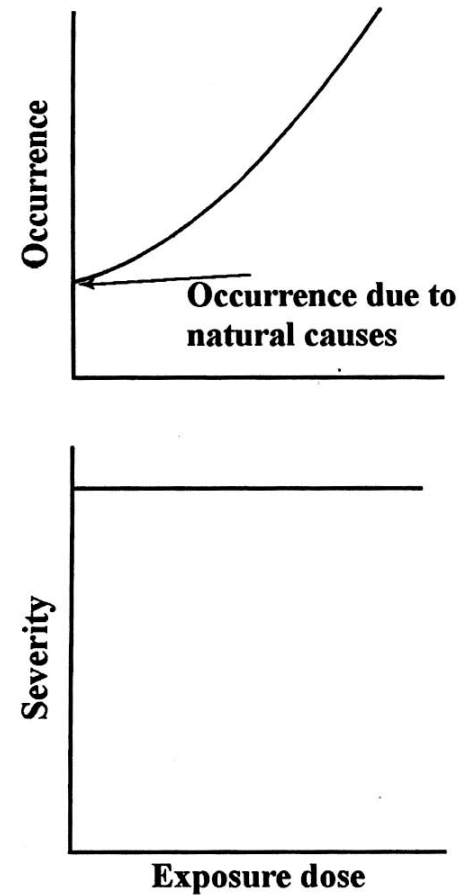
- Acute Effects vs. Late Effects
- **Deterministic Effects vs. Stochastic Effects**
- Somatic Effects vs. Genetic Effects

# Deterministic Effects vs. Stochastic Effects



**Deterministic Effects**  
確定的影響

- Acute effects
- Cataract



**Stochastic Effects**  
確率的影響

- Cancer, leukemia
- Genetic effects

# Deterministic effects(確定的影響)

Projected threshold estimates of the acute absorbed dose for 1% morbidity after whole body gamma ray exposures

Effect	Organ/Tissue	Time to develop effect	Absorbed dose (Gy)
Temporary sterility(一時的不妊)	Testes(精巢)	3-9 weeks	~ 0.1
Permanent sterility	Testes	3 weeks	~ 6
	Ovaries(卵巢)	< 1 week	~ 3
Depression of blood forming process(造血障害)	Bone marrow (骨髓)	3-7 days	~ 0.5
Skin reddening	Skin (large areas)	1-4 weeks	< 3-6
Skin burns	Skin (large areas)	2-3 weeks	5-10
Temporary hair loss	Skin	2-3 weeks	~ 4
Cataract (visual impairment)	Eye	Several years	~ 1.5

ICRP publication 103, pp168, Table A.3.4, 2007

# Deterministic effects(確定的影響)

Projected threshold estimates of the acute absorbed dose for 1% mortality after whole body gamma ray exposures

Exposed population	Organ/Tissue	Time to develop effect	Absorbed dose (Gy)
Bone marrow syndrome (骨髓障害)			
without medical care	Bone marrow	30-60 days	~ 1
with good medical care	Bone marrow	30-60 days	2-3
Gastro-intestinal syndrome (消化器系障害)			
without medical care	Small intestine (小腸)	6-9 days	~ 6
with good medical care	Small intestine	6-9 days	> 6
Pneumonitis (間質性肺炎)	Lung	1-7 months	6

ICRP publication 103, pp168, Table A.3.4, 2007

# Stochastic effects (確率の影響)

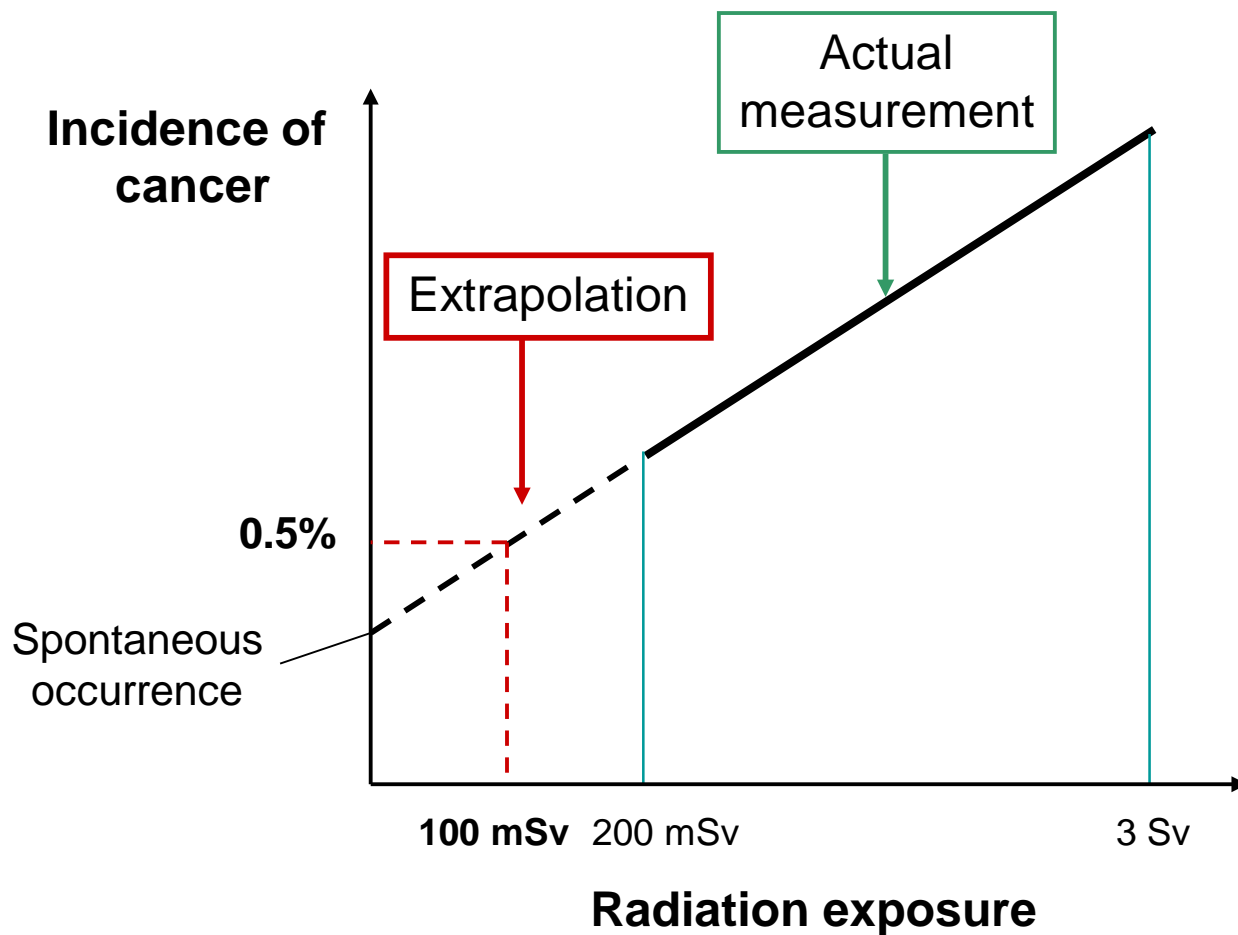
Detriment-adjusted nominal risk coefficients after exposure to radiation at low dose rate

Exposed population	Cancer	Heritable effects	Total
Whole population	$5.5 \times 10^{-2}/\text{Sv}$	$0.2 \times 10^{-2}/\text{Sv}$	$5.7 \times 10^{-2}/\text{Sv}$
Adult workers	$4.1 \times 10^{-2}/\text{Sv}$	$0.1 \times 10^{-2}/\text{Sv}$	$4.2 \times 10^{-2}/\text{Sv}$

ICRP publication 103, pp53, Table 1, 2007

# Risk Estimate for Cancers (Stochastic Effect)

## がんの発生リスクと放射線被ばくとの相関



# Classification of Biological effects of Radiation on the Human Body

- Acute Effects vs. Late Effects
- Deterministic Effects vs. Stochastic Effects
- Somatic Effects vs. Genetic Effects



## **Somatic Effects (身体的影響)**

Effects of radiation limited to the exposed individual, as distinguished from genetic effects, that may also affect subsequent unexposed generations.

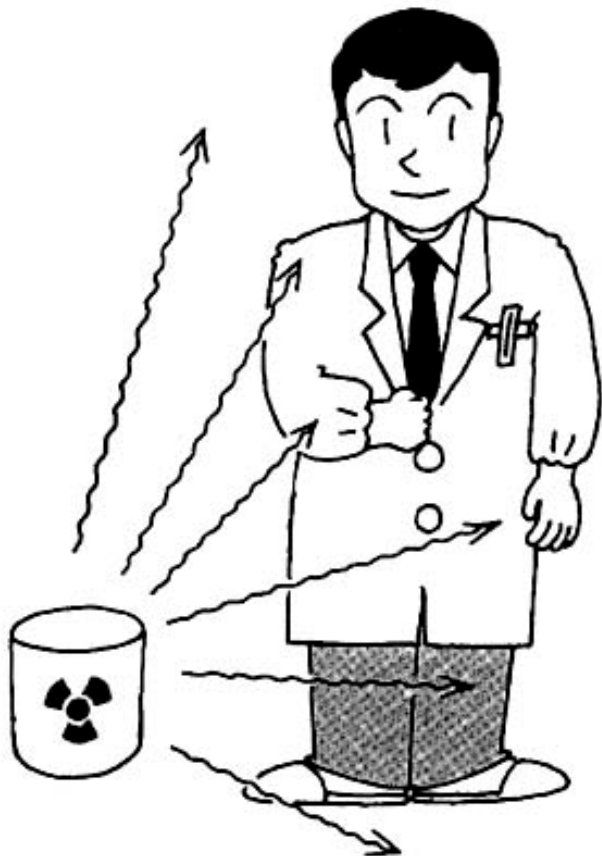
## **Genetic Effects (遺傳的影響)**

The radiation induced change in the DNA of germ cells resulting in the passing of the altered genetic information to future generations.

# External Exposures (外部被ばく)

vs.

# Internal Exposures (内部被ばく)

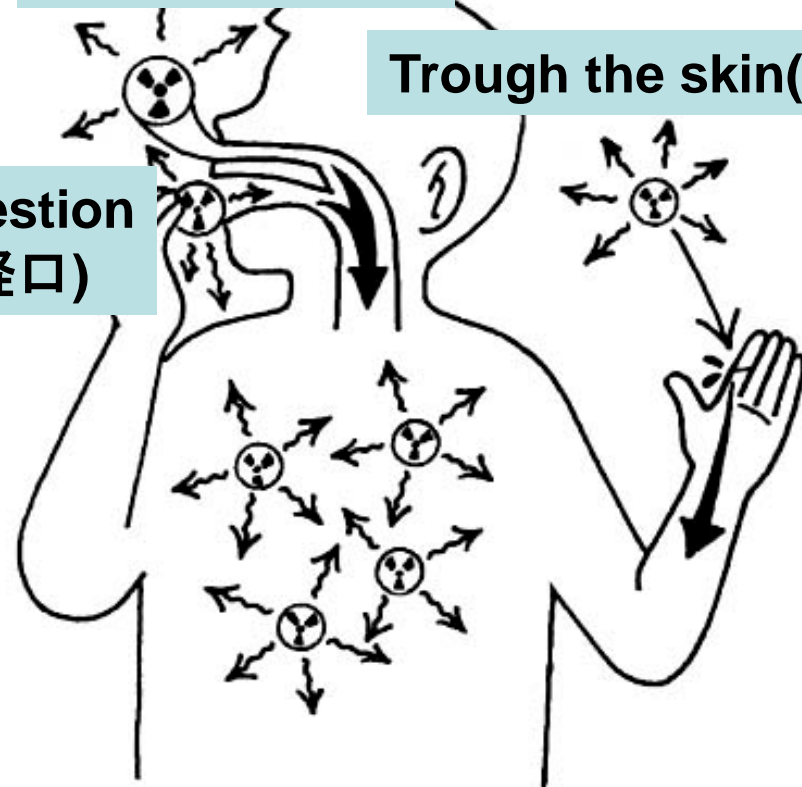


External exposure

Inhalation(呼吸)

Trough the skin(経皮)

Ingestion  
(経口)



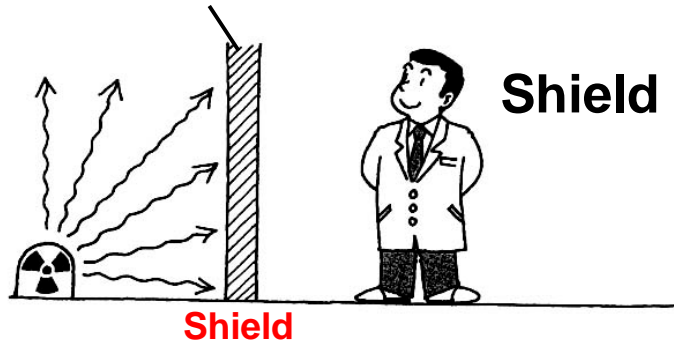
Internal exposure

# Protecting Against External Exposure (外部被ばくに対する防護)

3 principles  
3原則

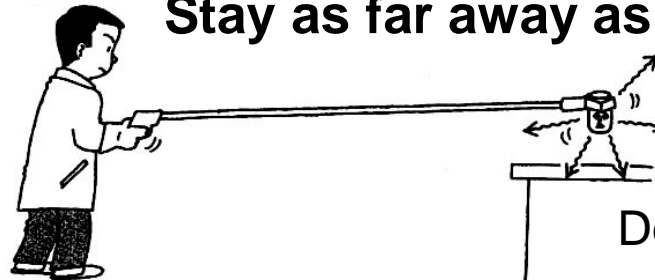
Shielding  
遮へい

As near to the radiation source as possible



Distance  
距離

Stay as far away as possible.



Dose rate =  $K/R^2$   
K: constant  
R: distance

Time  
時間



Keep exposure time short !

# Protecting Against Internal Exposure (内部被ばくに対する防護)

## Intake routes of radioisotopes RIの内部への取り込み経路



(1)

**Inhalation**  
呼吸



(2)

**Ingestion**  
経口

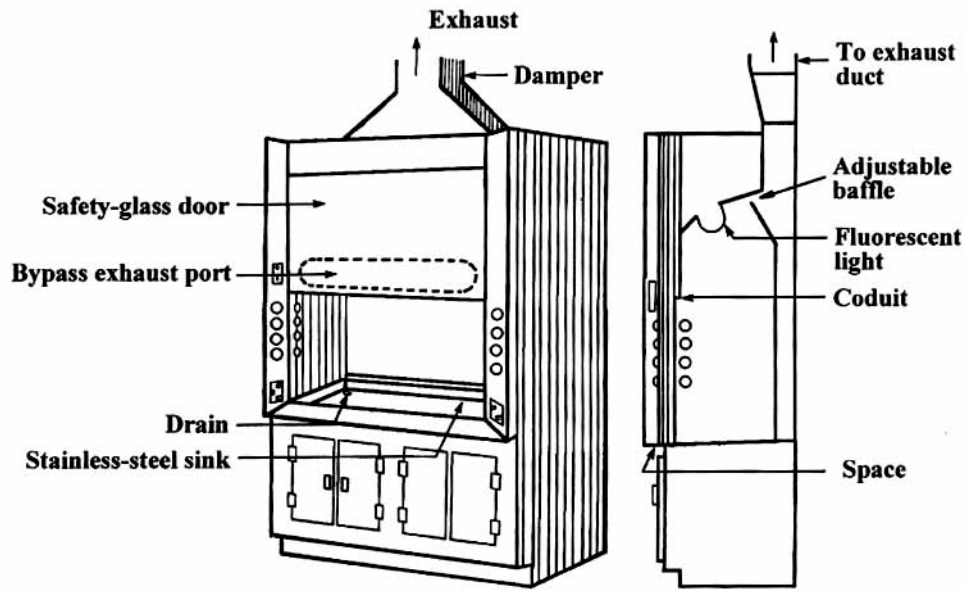


(3)

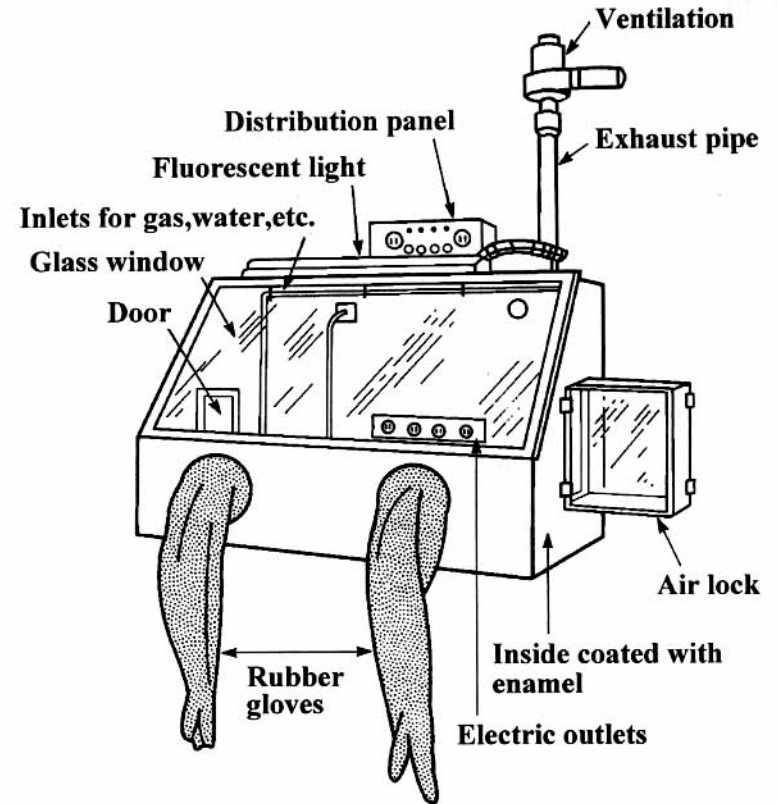
**Through the skin**  
経皮 (wound)

# To Prevent the inhalation of radioisotopes

## RIの吸入防止のための設備



Oak Ridge-type hood



Glove box

# Prohibited Matters (禁止事項)

Eating or drinking(飲食)



Smoking  
(喫煙)



Wearing make-up  
(化粧)

# Radiation-Related Quantities and Units (放射線被爆に関する量と単位)

**Absorbed Dose**  
(吸収線量) : Gray (Gy)

- The energy absorbed per unit mass of the material
- A fundamental dosimetric quantity (physical unit)
- Regardless of the kind of radiation
- $1 \text{ Gy} = 1 \text{ J/ kg}$
- **Dose not reflect the degree of biological effects**

To calculate the risk of irradiation to the human body

**Equivalent Dose**  
(等価線量) : Sievert (Sv)

**Effective Dose**  
(実効線量) : Sievert (Sv)

# Equivalent Dose & Effective Dose (等価線量と実行線量)

**Equivalent Dose (等価線量:  $H_T$ )** : Sievert (Sv)

- a measure of biological effects on **a particular tissues or organs**

- $H_T = \sum_R w_R \cdot D_{T,R}$

$w_R$  : Radiation weighting factor

$D_{T,R}$  : Mean absorbed dose for a tissue or organ (Gy)

## Radiation weighting factor ( $w_R$ ) (放射線荷重係数)

Radiation	Weighting Factor
$\gamma$ rays & X rays	1
Beta rays	1
Proton	2
$\alpha$ rays, fission fragments, heavy ion	20
Neutrons	Continuous function of the energy

(ICRP 2007)



# Equivalent Dose & Effective Dose (等価線量と実効線量)

**Effective Dose ( $E$ ) 実行線量** : Sievert (Sv)  
Stochastic effects

· a measure of biological effects **throughout the body** (cancers or genetic effects)

$$E = \sum_T w_T \cdot H_T = \sum_T w_T \cdot \sum_R w_R \cdot D_{T,R}$$

$H_T$  : Equivalent dose for tissues and organs

$w_T$  : Weighting factor for organs or tissues

## Tissue weighting factors

Tissue/Organ	Weighting factor
Red bone marrow	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Breast	0.12
Gonads	0.08
Bladder	0.04
Esophagus	0.04
Liver	0.04
Thyroid	0.04
Bone	0.01
Brain	0.01
Salivary gland	0.01
Skin	0.01
Others	0.12

## Annual average dose per person

Doctors	0.24 mSv
Nurse	0.12 mSv
Radiotherapy technicians	0.68 mSv
Those engaged in research	0.01 mSv
Nuclear power plant worker	1.3 mSv

# Effective Dose Limits and Tissue Equivalent Dose Limits for Radiation Workers (including Researchers)

## 放射線業務従事者の実効線量と等価線量限度

<b>Effective dose limit</b>	50 mSv/year; 100 mSv/5years
Women	5 mSv/3 months
Pregnant women *	1 mSv as internal exposure
<b>Tissue equivalent dose limit</b>	
1) Lens of the eye	150 mSv/year
2) Skin	500 mSv/year
3) Abdomen of pregnant women *	2 mSv

\*From the confirmation of pregnancy to delivery

# Personal Radiation Monitoring (個人被ばく線量系)

## Personal monitoring instrument



Effective dose (実効線量)

Equivalent dose (等価線量)  
for the lens, skin and abdomen

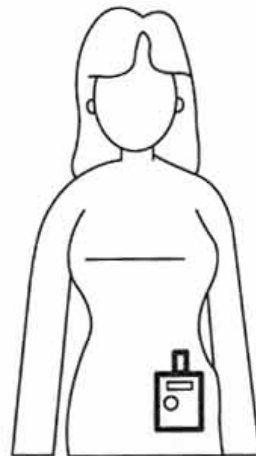
## Radiation exposure report

個人用報告書 個人用報告書 個人用報告書									
ご使用者名 京大 太郎 殿 京大 太郎 殿 京大 太郎 殿									
個人コード 30279640 30279640 30279640									
集計開始年月日 07年03月01日 07年01月01日 06年04月01日									
集計終了年月日 07年03月31日 07年03月31日 07年03月31日									
算定日 07年04月13日 07年04月13日 07年04月13日									
目 使用期間 (mSv) X件数 四半期計 (mSv) X件数 年度計 (mSv) X件数									
実効線量	0.1	0.2	0.1	0.2	10				
水晶体線量	0.1	0.2	0.1	0.2	10				
皮膚線量	0.1	0.2	0.1	0.2	10				
測定方法 放射線測定器使用 放射線測定器使用 放射線測定器使用									
胸部	モニタ名 ガラスバッチ FS型	モニタ名 H1cm H70um	モニタ名 ガラスバッチ FS型	モニタ名 H1cm H70um	モニタ名 ガラスバッチ FS型	モニタ名 H1cm H70um	モニタ名 ガラスバッチ FS型	モニタ名 H1cm H70um	モニタ名 ガラスバッチ FS型
	0.1	0.2	0.1	0.2	0.5	0.1	0.2	0.5	0.5
	0.1	0.2	0.1	0.2	0.5				
2006年	0.20	10 <sup>x</sup>	0.20	10 <sup>x</sup>	0.20	10 <sup>x</sup>			
2007年		x		x		x			
2008年		x		x		x			
2009年		x		x		x			
2010年		x		x		x			
累積値	10	0.20	10 <sup>x</sup>	100	0.20	10 <sup>x</sup>	10	0.20	10 <sup>x</sup>
調整・備考									
確認印									
測定機関名	株式会社千代田テクノル			株式会社千代田テクノル			株式会社千代田テクノル		
職員コード	7806			7806			7806		
26-0515	7806			7806			7806		
処理日	070414			070414			070414		
B 01409									

Where should a monitoring instrument be worn on?



Men



Women 大学等放射線施設協議会

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