Basic Theory of Mobile X-ray Vehicle Scanning System (MXRVSS)

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Introduction of Radiation

Radiation Protection

Radiation and Health

Safety Measures for MXRVSS

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Energy

What are some forms/ types of energy?

1. Electricity (Potential energy)
2. Kinetic energy
3. Heat
4. Radiation – like E.M. Wave (e.g. X-rays, visible light, microwave)

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Energy

Energy can be transform from one form into another.

Example: Electricity is converted to heat & X-rays.

Radiation Energy: electron volt [eV] (not SI Unit)

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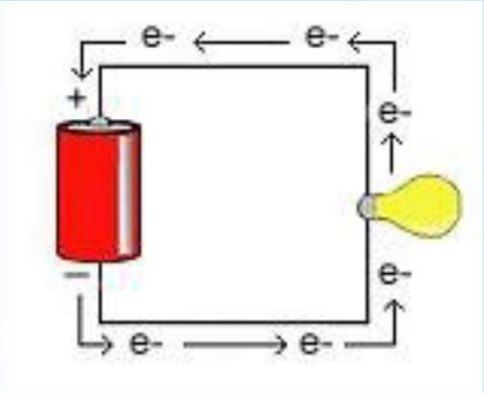
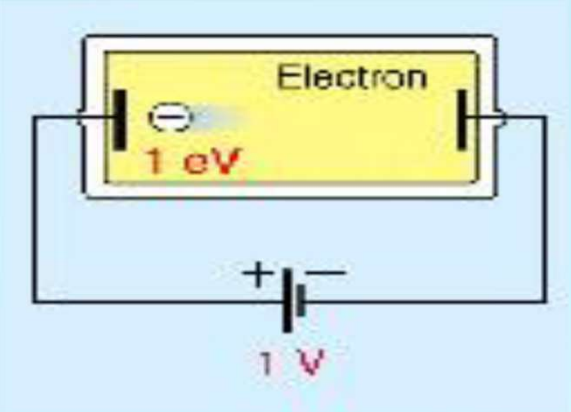
Electron Flow

Electric current [A] is generated when electrons move (kinetic energy) from the negative to the positive terminal by applying a voltage [V].



Electrons are the negatively charges which are actually moving.



The unit of charge is a Coulomb [C].

1 electron = 1.6×10^{-19} C

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Energy Units for Measuring Radiation

Radiation energies are typically measured in units of keV (1,000 electron volts) or MeV (million electron volts)

Examples:

X-Ray Energy 150 keV (generated by 150kV)

Cs-137 (gamma ray) 662 keV (0.662 MeV)

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What is X-rays

X-rays are a form of electromagnetic radiation.

X-rays have higher frequency and higher energy and can pass through most objects

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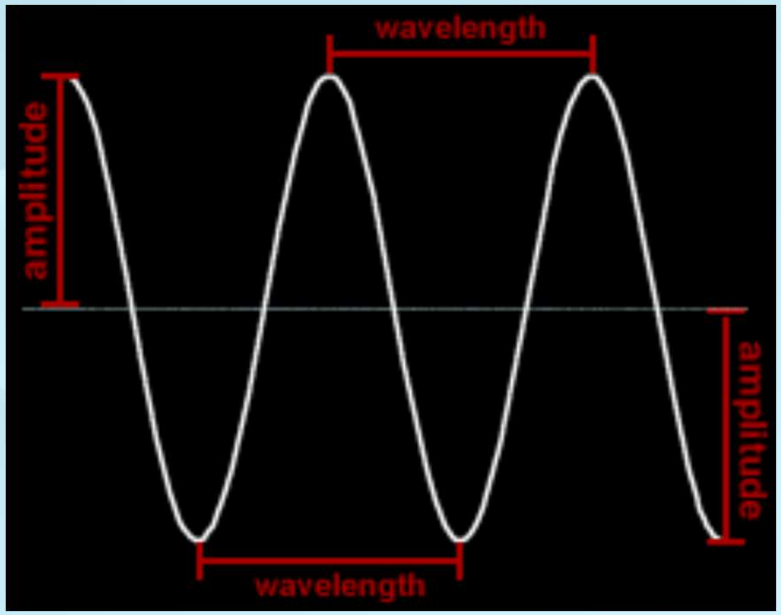
Electromagnet Wave

The speed of EM waves in "vacuum" is always $c = 3 \times 10^8$ [m/sec]

The wavelength (λ) is the distant from crest-to-chest

Velocity = wavelength x frequency



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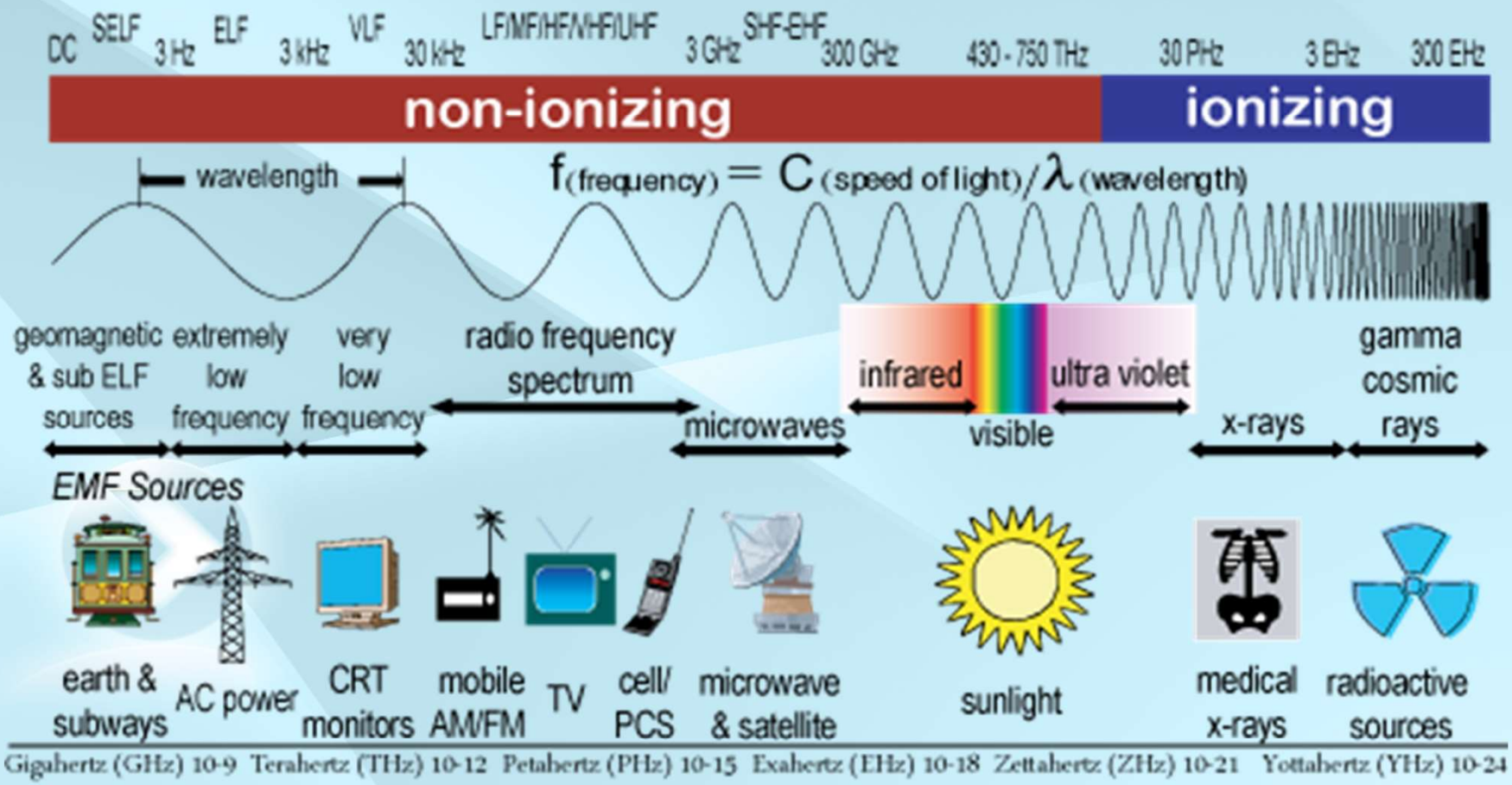
THE ELECTROMAGNETIC SPECTRUM



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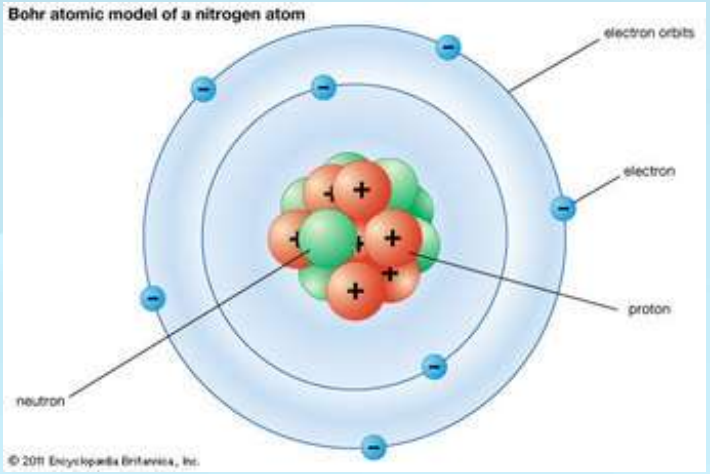
Atomic Nomenclature

Mass Number (A) – the number of protons and neutrons

Atomic Number (Z) – the number of protons

e.g. Atomic no. of Nitrogen = 7



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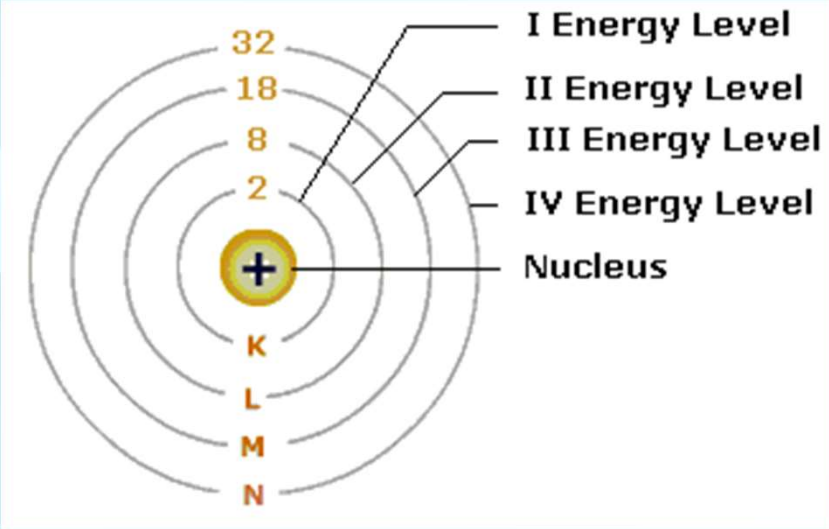
Shell Capacities

Shell	Electronic Capacity ($2x^2$)
1 (k)	2
2 (i)	8
3 (m)	18
4 (n)	32
5 (o)	50
6 (p)	72
7 (q)	98



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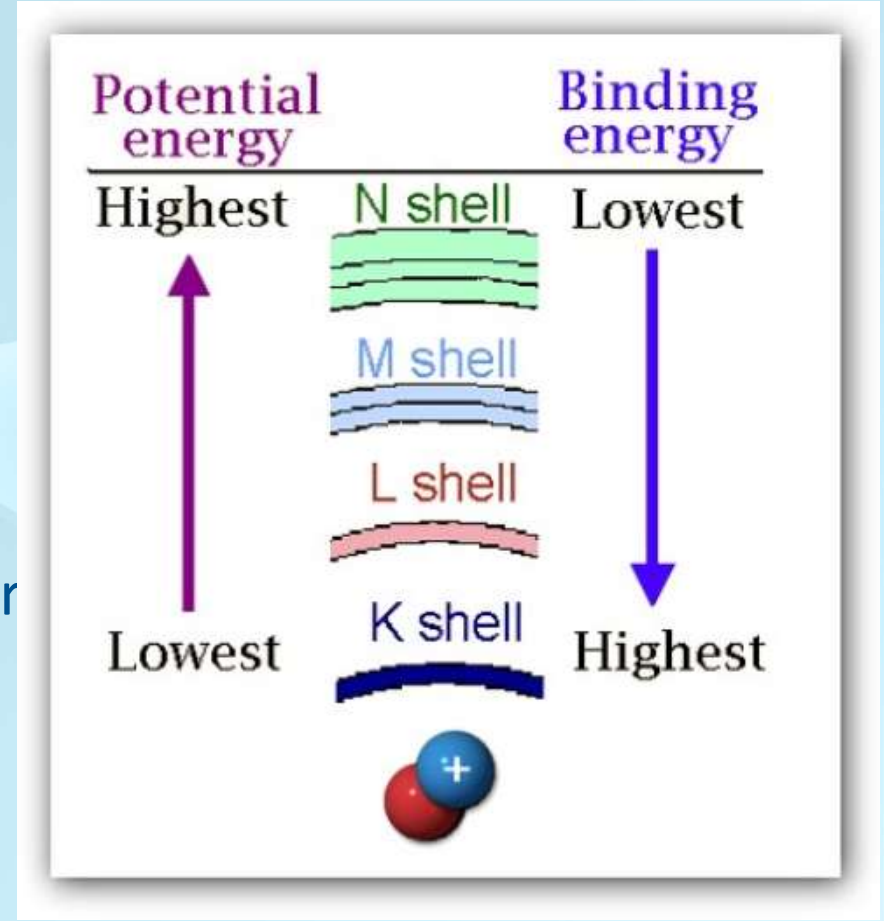
Binding Energy

- Negative electrons attracted to positive nucleus
- more binding energy for shells closer to nucleus
  - K shell has highest binding force
- higher atomic # materials (higher Z) result in more binding energy
  - more positive charge in nucleus
- energy required to remove orbital electron from atom



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What is Radiation?

In physics, **radiation** describes any process in which energy emitted by one body travels through a medium or through space, ultimately to be absorbed by another body.

Non-physicists often associate the word with ionizing radiation. (e.g., as occurring in nuclear weapons, nuclear reactors, and radioactive substances), but it can also refer to electromagnetic radiation (i.e., radio waves, infrared light, visible light, ultraviolet light, and X-rays) and acoustic radiation.

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Different Signs

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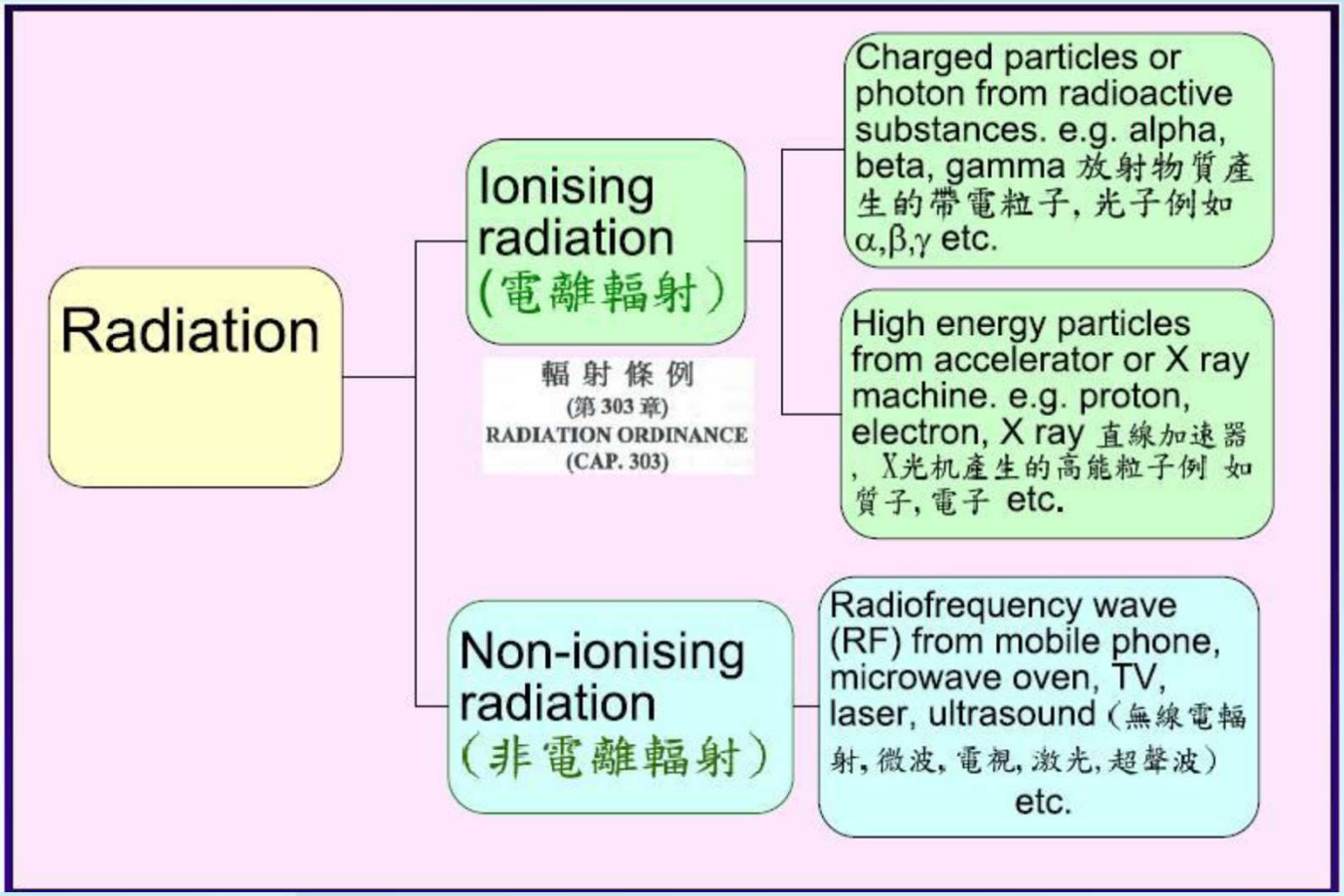
Ionisong & Non-Ionising Radiation



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Ionising Radiation

Ionising radiation is the energy produced from natural or artificial sources. It has more energy than non-ionising radiation, enough to cause chemical changes by breaking chemical bonds. This effect can cause damage to living tissue.

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Non-Ionizing Radiation

Non-ionising radiation is found at the long wavelength end of the spectrum and may have enough energy to excite molecules and atoms causing then to vibrate faster. This is very obvious in a microwave oven where the radiation causes water molecules to vibrate faster creating heat.

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Examples of Ionising Radiation

- alpha radiation (corpuscular radiation) (粒子輻射)
- beta radiation (corpuscular radiation)
- gamma and X-ray radiation (EM radiation) (電磁幅射)
- neutron radiation (corpuscular radiation)

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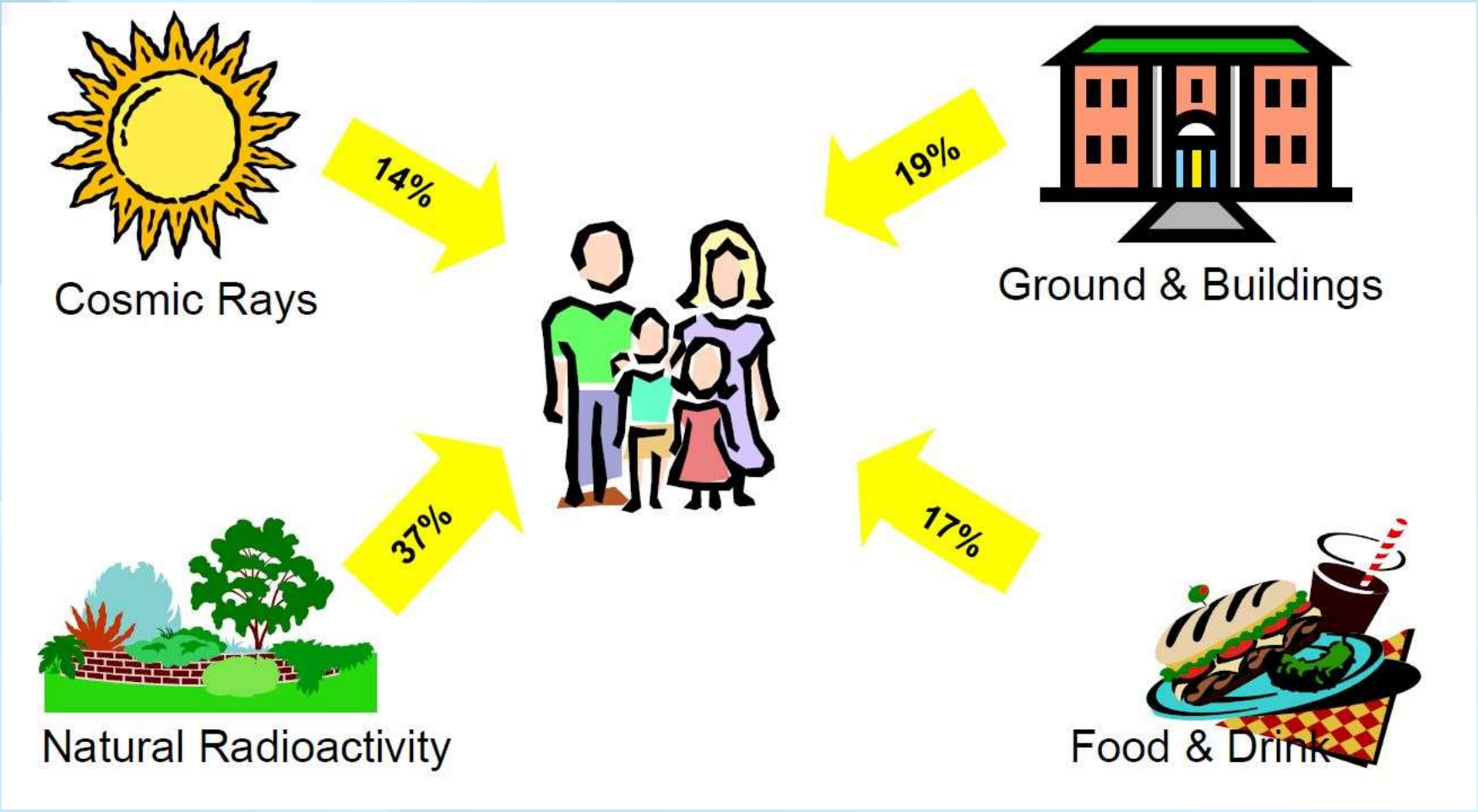
Background Ionising Radiation



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Types of ionizing Radiation

Type	Charge	Mass	Origin
α	+2	4	Nucleus
β	-1	0	Nucleus
X-ray	0	0	Electron Shell
γ	0	0	Nucleus

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Types and Properties of Radiation

Alpha Radiation (α)

- Helium nuclei: 2 protons and 2 neutrons
- Directly ionizing particles (直接電離粒子)
- Mass: 4 amu
- Charge: +2

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Types and Properties of Radiation

Beta Radiation (β)

- An electron
- Directly ionizing particles
- Mass: 1/1840 amu
- Charge: +1 or –1 (正電子/負電子)

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Types and Properties of Radiation

Gamma radiation (γ)

- Electromagnetic radiation: quanta of energy transmitted in wave motion
- Indirectly ionizing radiation(非直接電離輻射)
- No charge and no mass
- Energy is inversely proportional to wavelength

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Types and Properties of Radiation

X-ray

Invisible, highly penetrating ionizing radiation of higher frequency (much shorter wavelength) and higher energy than visible light.

Devices produce X-ray	Energy
Electron striking to TV	20,000 eV (20KeV)
Diagnostic X-ray	150,000 eV (150KeV)
Therapy X-ray (Liners Accelerator)	4,000,000 eV (4MeV)

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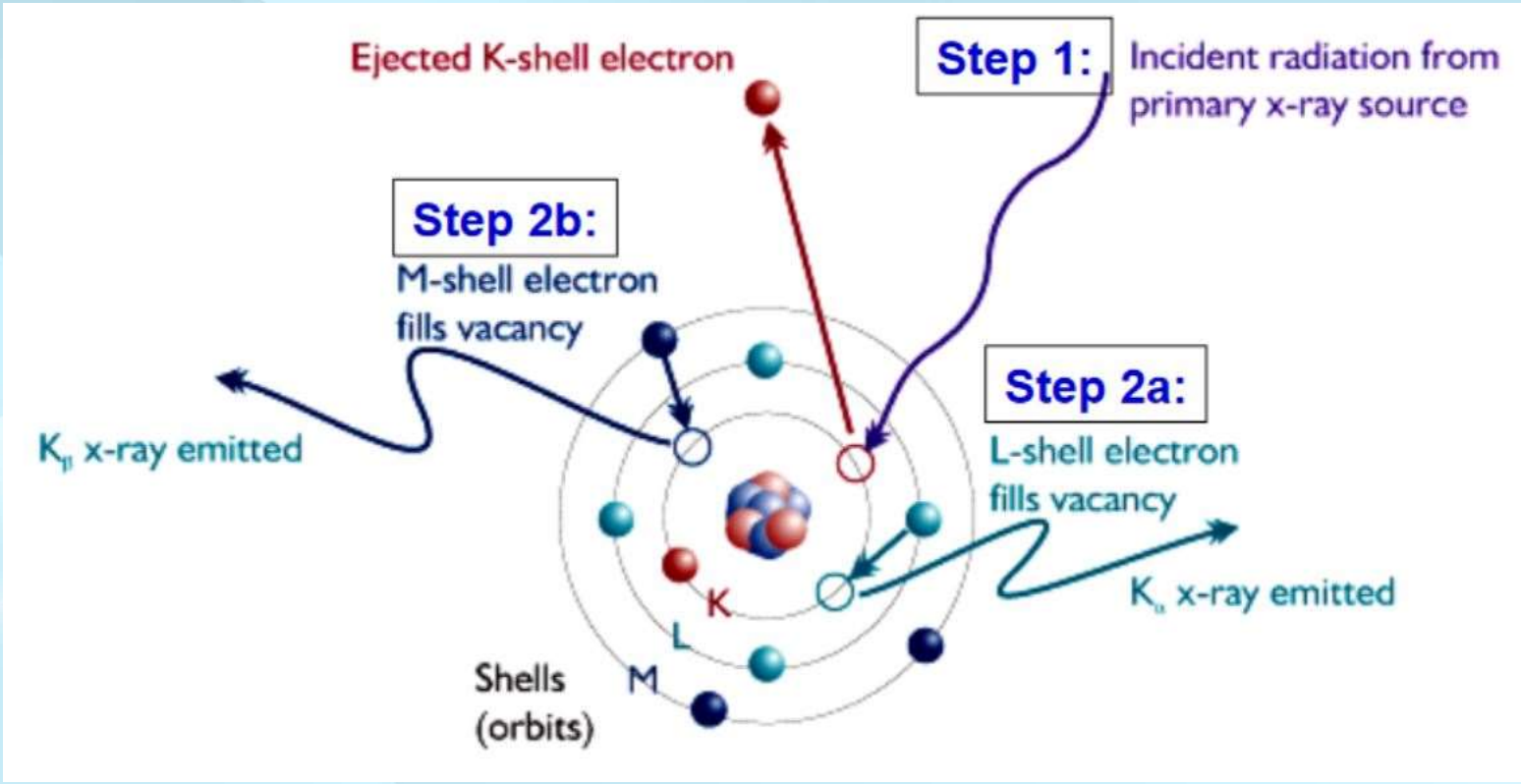
X-ray Generation

Characteristic X-ray



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X-ray Generation

Characteristic X-ray

Step 1: When an X-ray photon of sufficient energy strikes an atom, it dislodges an electron from one of its inner shells. (K in this case)
Step 2a: The atom fills the vacant K shell with an electron from the L shell; as the electron drops to the lower energy state, excess energy is released as a K_{α} X-ray.
Step 2b: The atom fills the vacant K shell with an electron from the M shell; as the electron drops to the lower energy state, excess energy is released as a K_{β} X-ray

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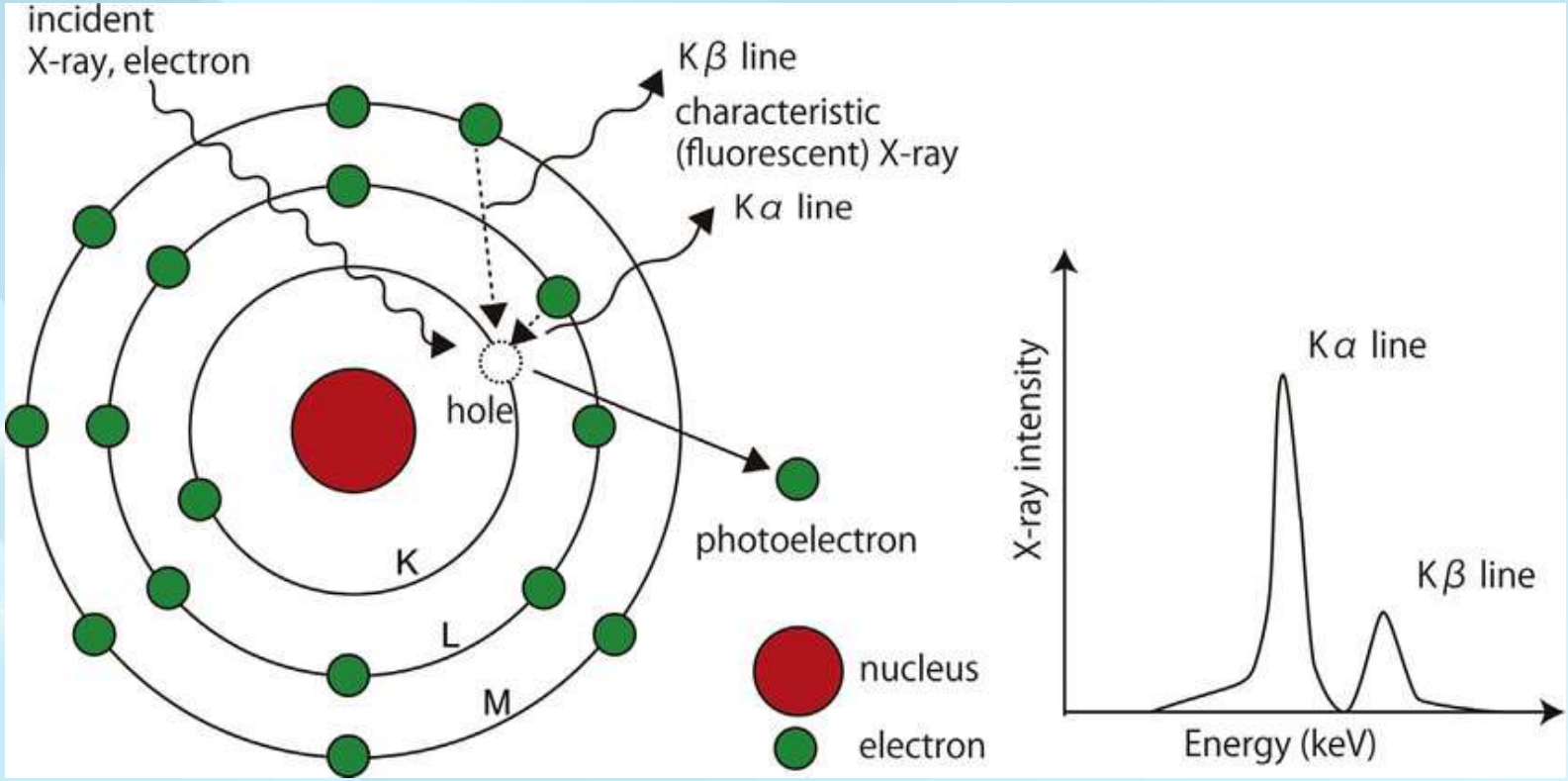
X-ray Generation

Characteristic X-ray



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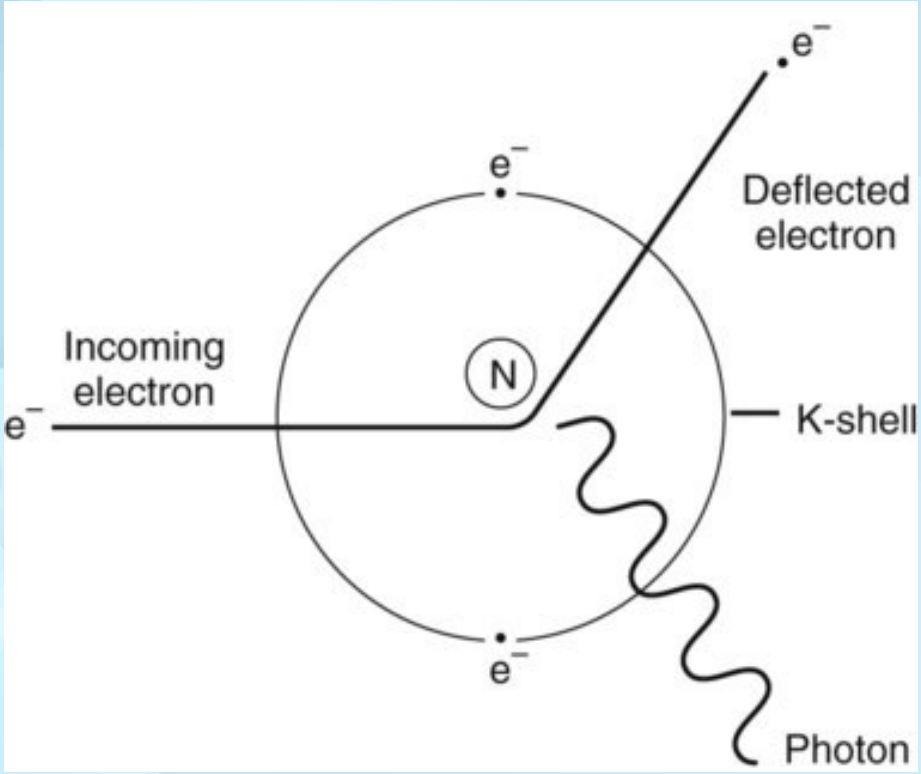
X-ray Generation

Bremsstrahlung (Breaking Radiation)



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X-ray Generation

Bremsstrahlung (Breaking Radiation)

Step 1: High speed electron is attracted to bend and slow down as it gets close to nucleus.
Step 2: Bremsstrahlung occurs as the electron loses it kinetic energy in the form of X-ray energy.

The large the bending (depends on the passing distant between nucleus and electrons), the higher the energy of the X-ray will be.

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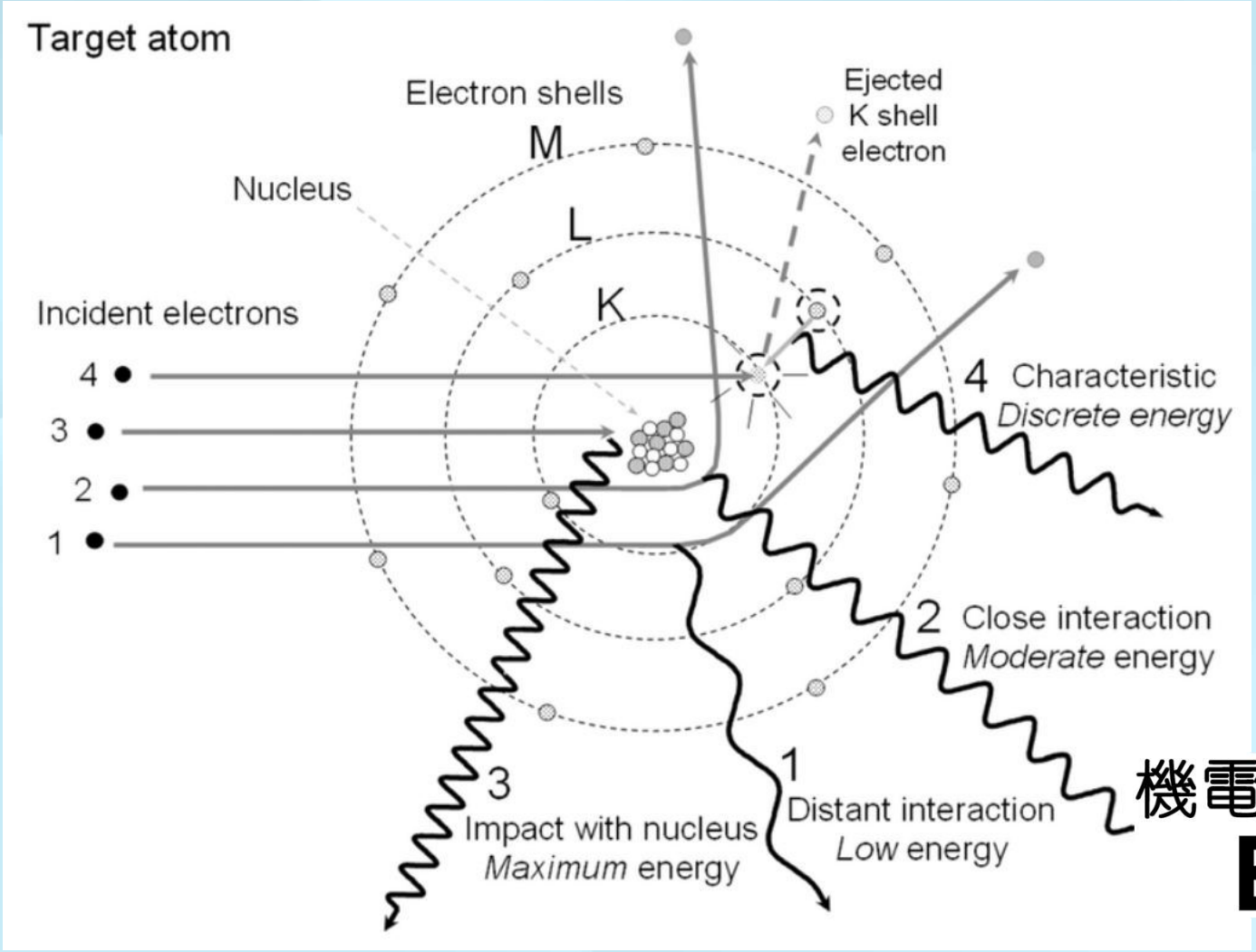
X-ray Generation

Characteristic X-ray & Bremsstrahlung X-ray



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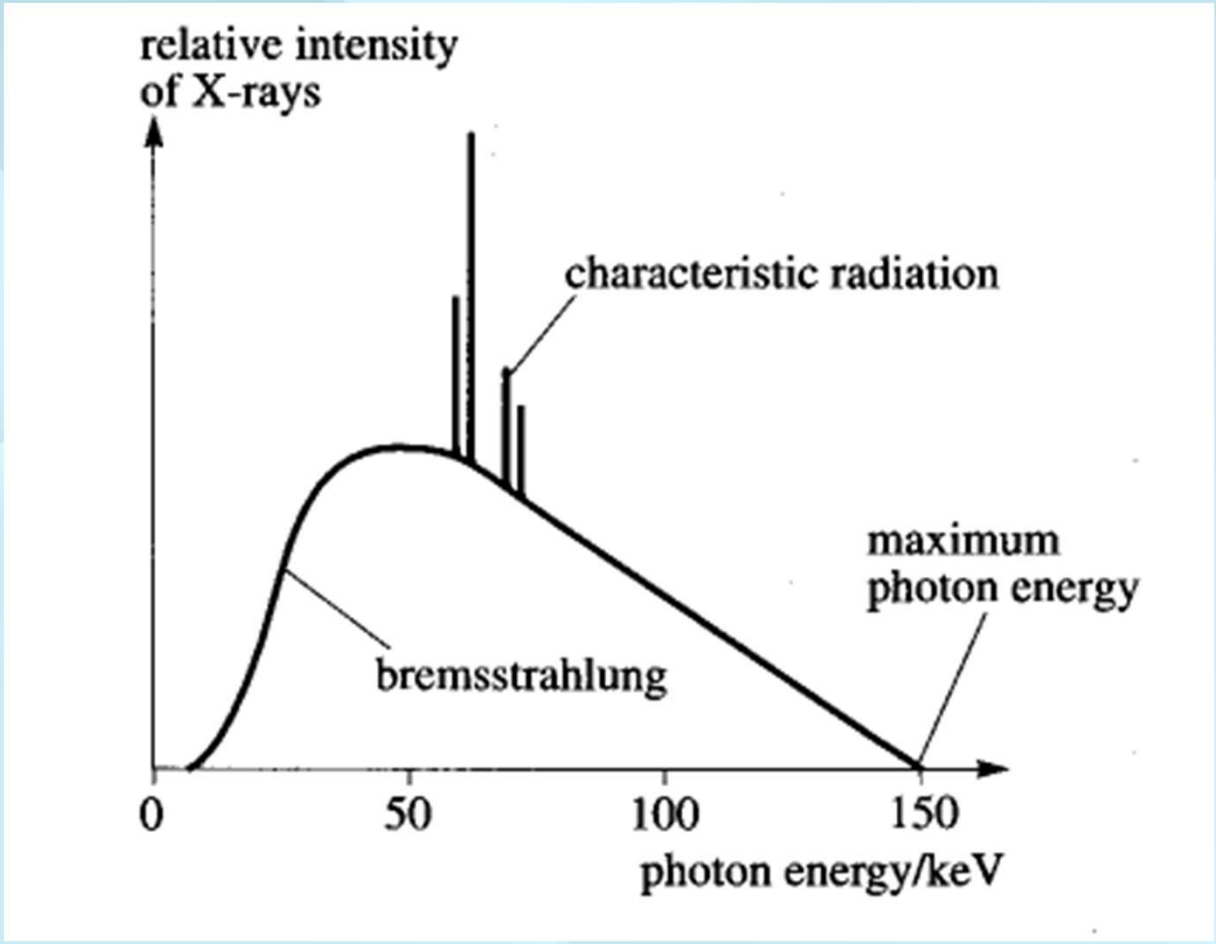
X-ray Generation

Characteristic X-ray & Bremsstrahlung X-ray



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Absorbed Dose Rate

- Absorbed dose rate is the amount of absorbed dose delivery within a period of time.

$$Dose\ rate = \frac{measured\ dose}{time}$$

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Equivalent Dose

- Dose in which the type of radiation has been taken into account 已經考慮了輻射類型的劑量
- Not all types of radiation produce the same responses in living tissue.並非所有類型的輻射在活組織中產生相同的反應。
- calculated by multiplying the absorbed dose by a “Quality Factor”
- It measures the biological effect to a tissue or organ by different types and energies of radiation.
- SI Unit : Sievert (Sv)

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Equivalent Dose

- Different types of radiation have different effects on tissue

Equivalent dose = Σ Absorbed dose x W_R

W_R reflects the severity of biological effects due to different and energies of radiation.

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Equivalent Dose

ICRP Publication 103

Table 2. Recommended radiation weighting factors.

Radiation type	Radiation weighting factor, w_R
Photons	1
Electrons[a] and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A continuous function of neutron energy

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Effective Dose

ICRP Publication 103

Table 3. Recommended tissue weighting factors.

Tissue	w_T	$\sum w_T$
Bone-marrow (red), Colon, Lung, Stomach, Breast, Remainder tissues*	0.12	0.72
Gonads	0.08	0.08
Bladder, Oesophagus, Liver, Thyroid	0.04	0.16
Bone surface, Brain, Salivary glands, Skin	0.01	0.04
	Total	1.00

* Remainder tissues: Adrenals, Extrathoracic (ET) region, Gall bladder, Heart, Kidneys, Lymphatic nodes, Muscle, Oral mucosa, Pancreas, Prostate (♂), Small intestine, Spleen, Thymus, Uterus/cervix (♀).

組織加權因數（W_T）-
用來衡量不同器官和生物體受影響的程度

Tissue weighting factor represents the relative risk of cancer and genetic effects from irradiation of healthy tissue.
(ICRP 60)

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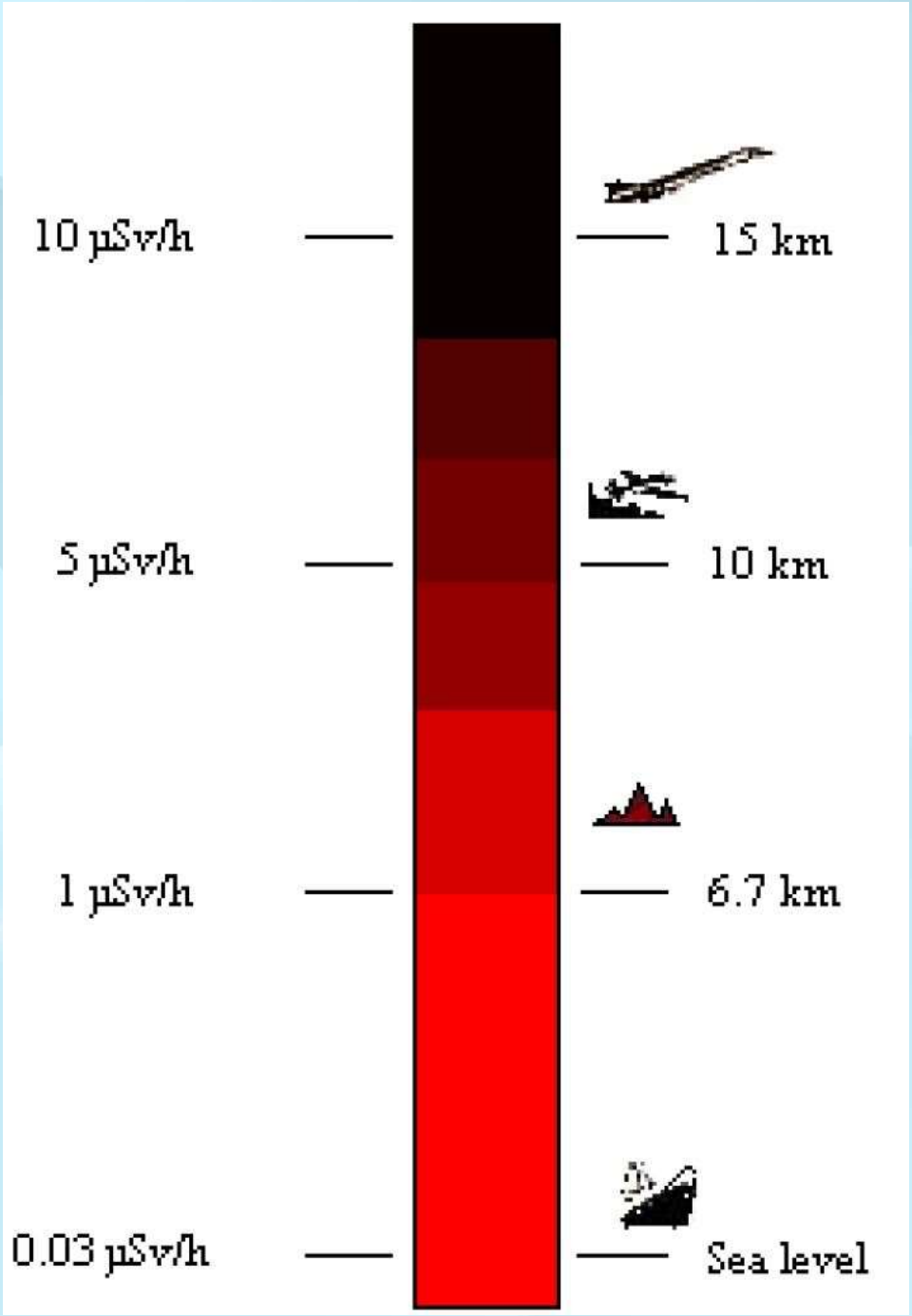
Effective Dose



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Radiation Protection

- **No smell** and **No taste**.
- **Invisible** You can't see these kinds of radiation (except visible light).
- **Cannot feel them** unless the doses are high enough to burn your skin or damage your body organs.
- The only way to prove their present around us is **to measure them**.

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Radiation Protection

Three principles:

- Justification (正當化): Do more good than bad
- Optimization (最優化): ALARA concept (**A**s **L**ow **A**s **R**easonably **A**chievable) 可合理達到的盡量低原則
- Dose limit(個人劑量限制): imposed to restrict unnecessary radiation dose delivered to radiation workers and the public.

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Dose Reduction Measures for External Radiation

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Radiation Protection - Time

Total Dose = dose rate x time

- Reduce time reduces dose.
- Plan all your procedures to minimize time spend with source.

Reduce Time Spent in the Vicinity of Sources of Radiation

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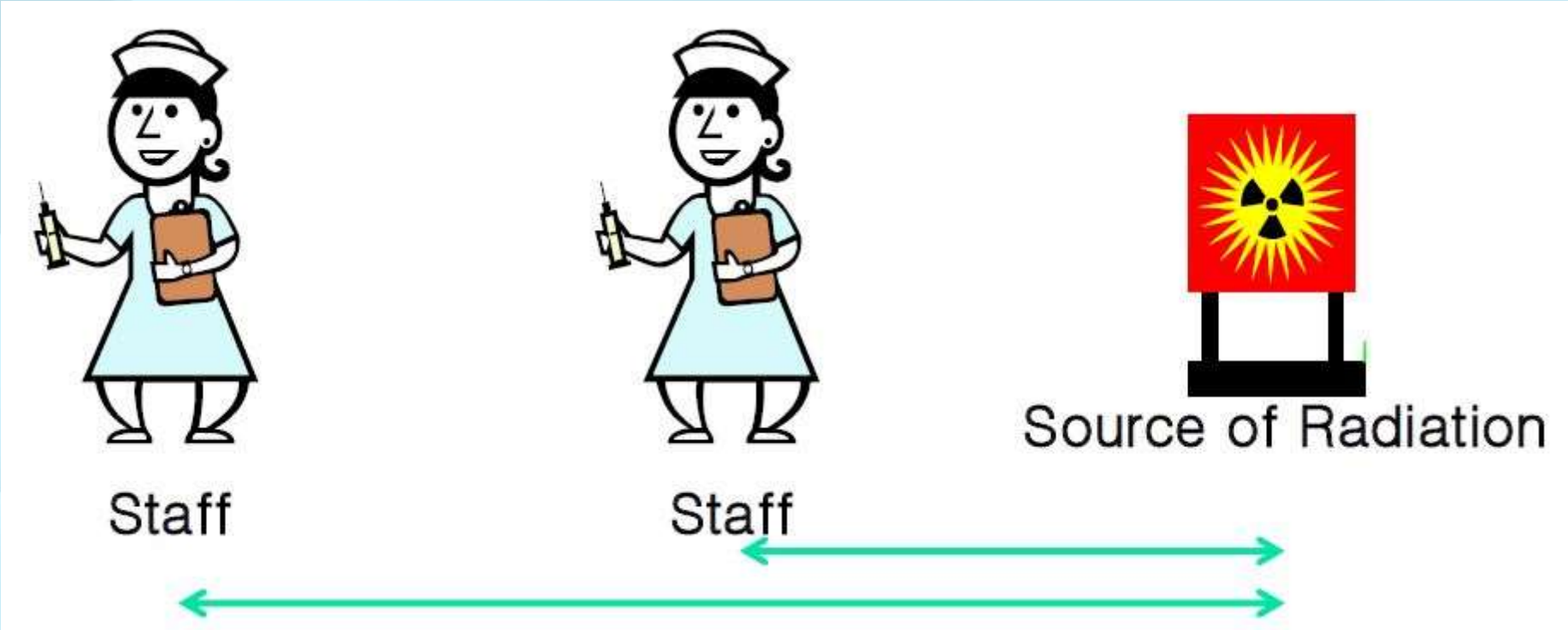
Radiation Protection - Distant



Increasing the distance by 2 times will decrease the dose by ¼!

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Radiation Protection - Distant

Intensity of a source decreases with distance.

- Point source – dose fall off with inverse square law (平方反比定律):

$$Dose \propto \frac{1}{distant^2}$$

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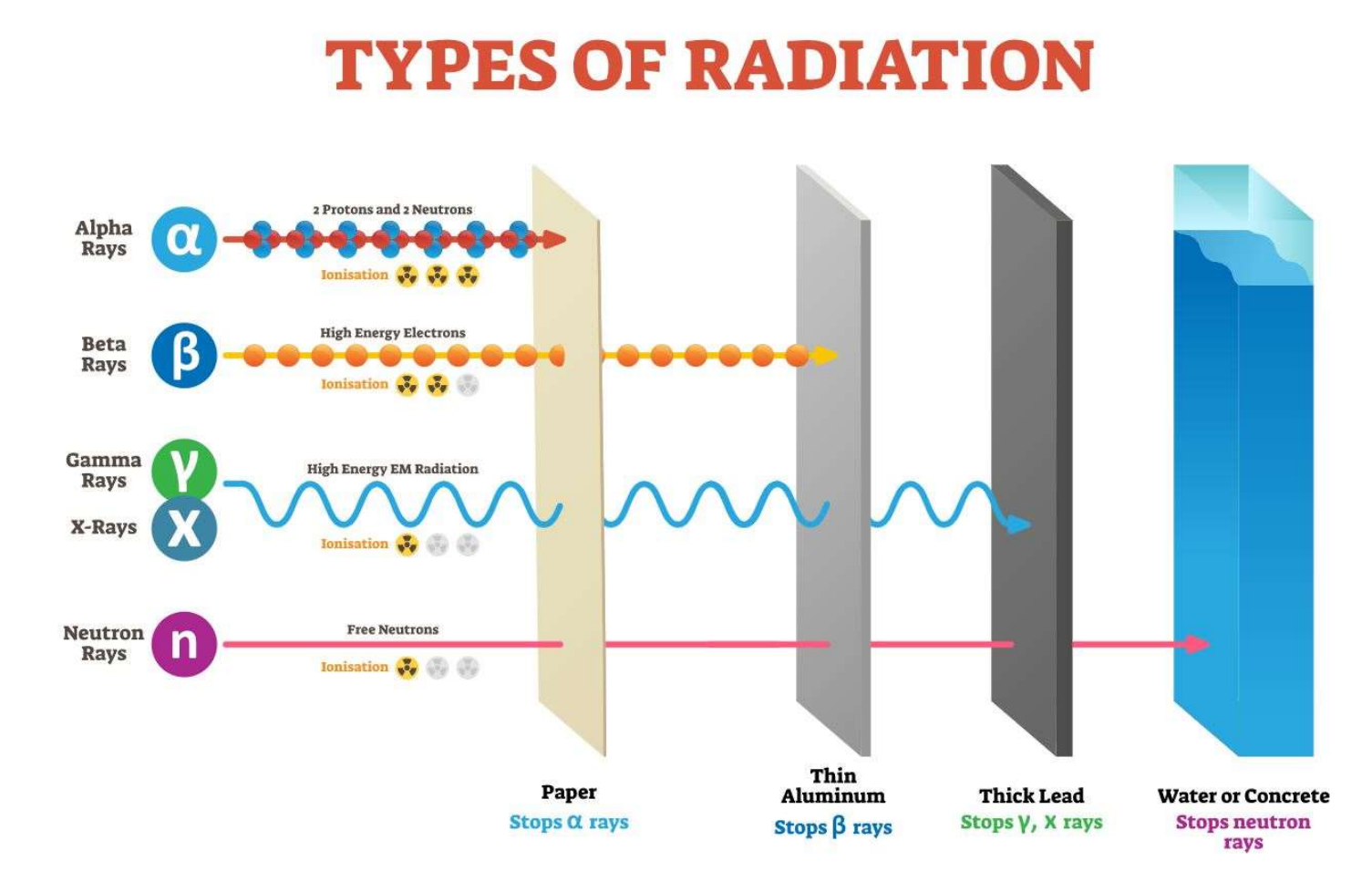
Radiation Protection - Shielding



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Radiation and Health

How does ionizing radiation affect health?

電離輻射如何影響健康？

- It penetrates into the body and deposits energy into tissues to cause cell damage. 它深入身體並將能量沉積在組織中，導致細胞損傷
- The energy from ionizing radiation can break the chemical bonds that hold together groups of atoms called **molecules.**

電離輻射的能量會破壞原子的化學鍵。

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Health Concerns - Radiation Sickness (High Dose)

Symptoms

- Vomiting (嘔吐)
- High fever
- Weakness, fatigue (疲勞),
- Loss of appetite (食慾不振),
- Diarrhea (腹瀉)
- Dehydration (脫水)
- Hair loss
- Skin redness (皮膚發紅), Skin irritation (皮膚過敏), Skin burn

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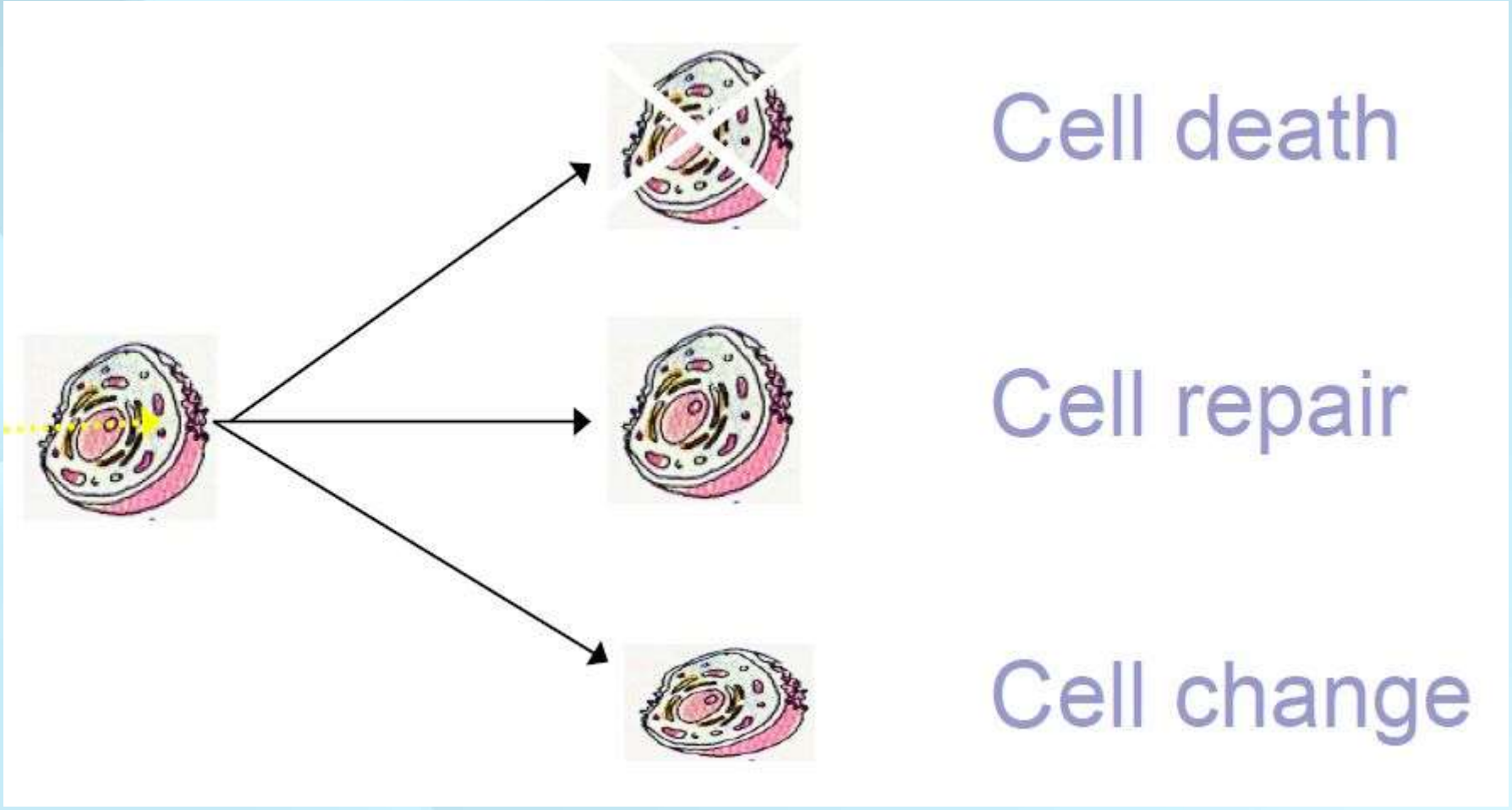
Cellular Effects



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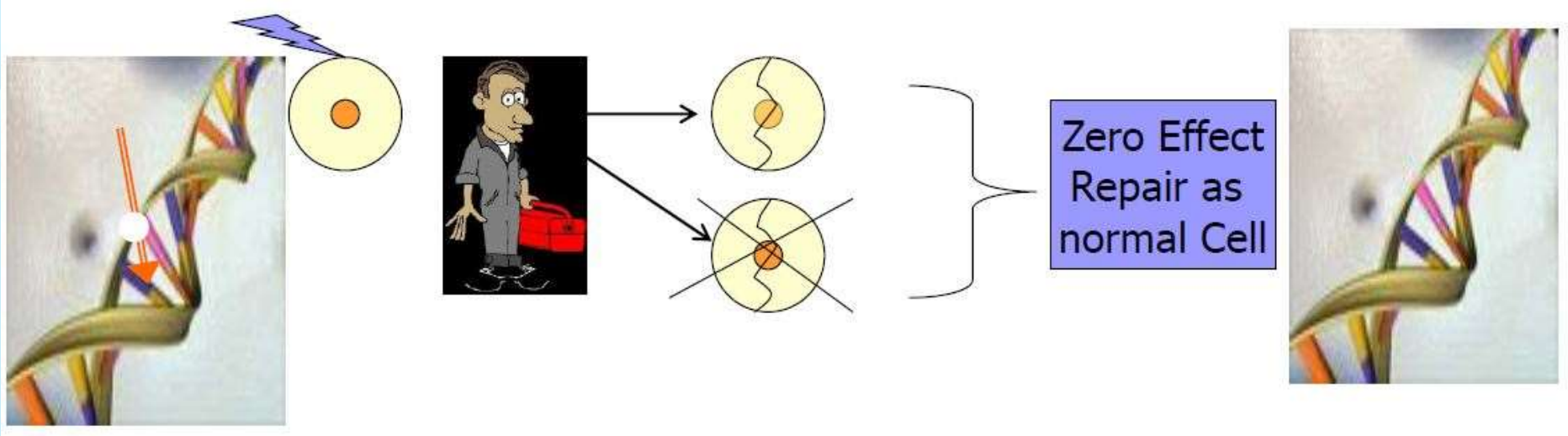
Cellular Repair (No Health Effect)

- Cell damaged, but repaired itself before producing new cell. 細胞損壞，但在生產新細胞之前自行修復。
- Cell destroyed by the immune system. 損壞了的細胞被免疫系統破壞。



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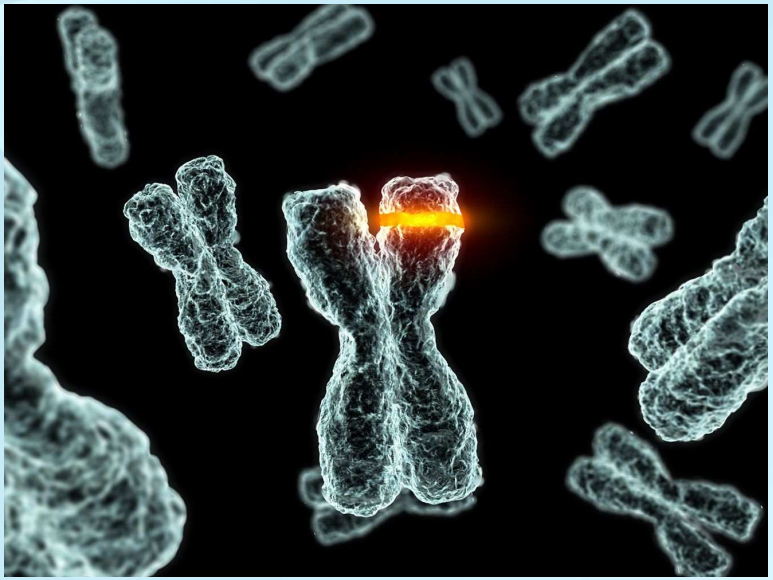
Cellular Mutation

- Cells Damaged, Irreparable & Producing new abnormal cell
- Irradiation alters genetic coding, or DNA

Possible cancer,
Genetic effect



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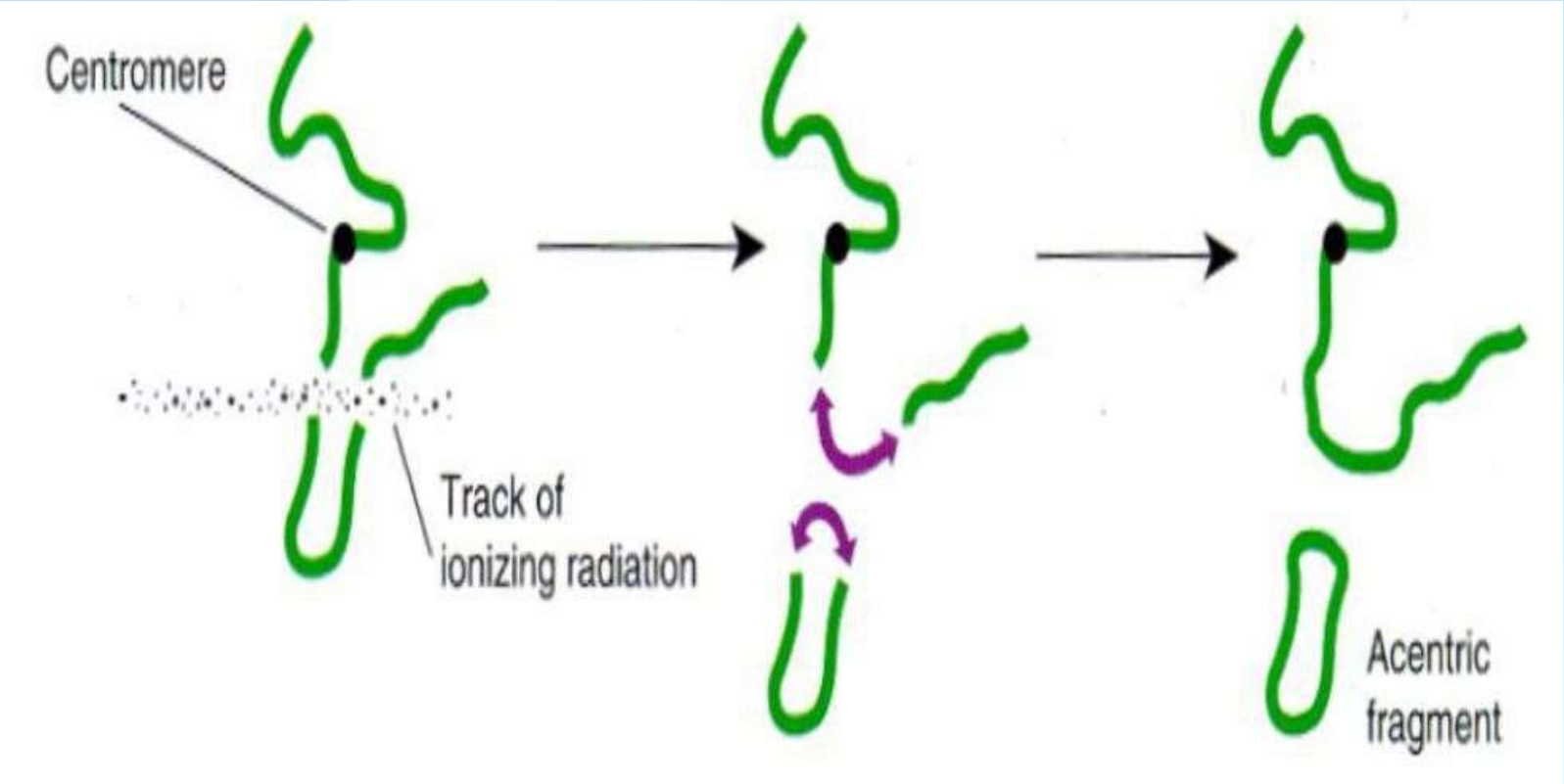
Cell Change

- Chromosomal deletions (染色體缺失)



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Dose Limits

- Annual Dose Limit of Radiation worker
  輻射工作者的年度劑量限值

20 mSv/year for Radiation Worker

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Measures for Radiation Work

- TLC Badge (Thermoluminescent Dosimeter)

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Safety Measures for MXRVSS

- Light & Siren Alert
- Announcement Alert
- CCTV Monitoring
- Radiation Safety Area
- Annual Radiation Measurement

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End of
Introduction of Radiation and X-ray

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