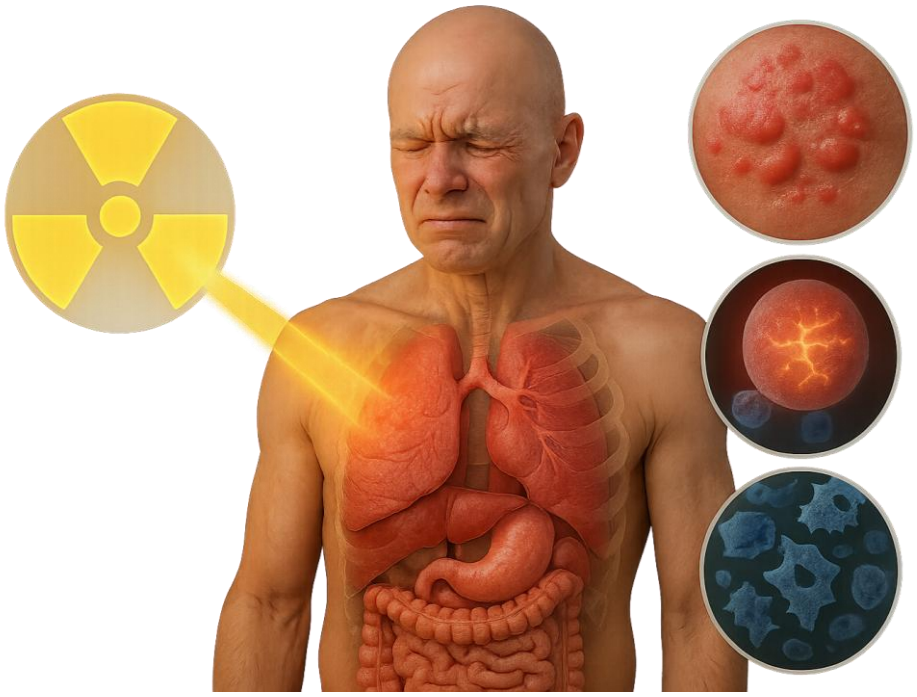
Biological effects of radiation

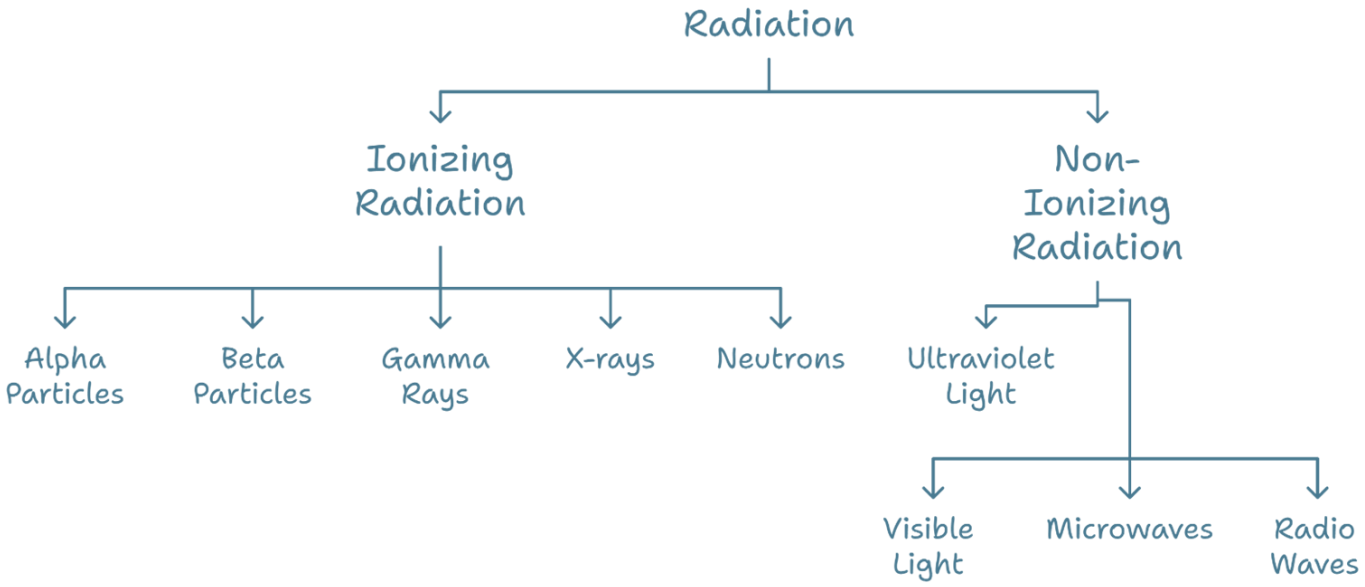
Introduction to Radiation

What is Radiation?

- Radiation refers to the **emission and propagation of energy** in the form of waves or particles through space or a material medium.



Types of Radiation



A. Ionizing Radiation

- This has enough energy to remove tightly bound electrons from atoms, thus ionizing them.
  - **Examples**: Alpha particles, beta particles, gamma rays, X-rays, neutrons

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- **Sources**: Radioactive materials (e.g., uranium, radon), nuclear reactors, cosmic rays, medical imaging (CT, X-rays)

B. Non-Ionizing Radiation

- Does not carry enough energy to ionize atoms.
  - **Examples**: Ultraviolet (UV) light (partially ionizing), visible light, microwaves, radio waves
  - **Sources**: Sunlight, cell phones, microwaves, lasers

Mechanisms of Damage (Primarily Ionizing Radiation)

Ionizing radiation causes cellular damage through two primary mechanisms:

A. Direct Action

- Radiation interacts directly with critical biomolecules (e.g., DNA), leading to:
  - Ionization
  - Excitation
  - Molecular bond breakage
  - DNA damage:
    - Single-strand breaks
    - Double-strand breaks (more lethal)
    - Base damage and cross-linking

B. Indirect Action

- Radiation ionizes water molecules (~70% of cell content), producing highly reactive free radicals:
  - Hydroxyl radical (•OH)
  - Hydrogen peroxide (H_2O_2)
- These free radicals can damage:
  - DNA
  - Proteins
  - Cell membranes
- This contributes to:
  - Oxidative stress
  - Damage to cellular macromolecules (proteins, lipids, DNA)

Ionizing Radiation: Types and Characteristics

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A. Alpha Particles (α)

- **Composition**: 2 protons + 2 neutrons (helium nucleus).
- **Charge**: +2
- **Penetration**: Very low (stopped by paper or skin).
- **Danger**: Only dangerous **internally** (e.g., inhaled or ingested).

B. Beta Particles (β)

- **Composition**: High-energy, high-speed electrons or positrons.
- **Charge**: -1 (electron) or +1 (positron).
- **Penetration**: Moderate (can penetrate skin but stopped by plastic or aluminum).
- **Danger**: External and internal exposure can be harmful.

C. Gamma Rays (γ) and X-rays

- **Nature**: Electromagnetic radiation.
- **Penetration**: Very high (can penetrate deep into tissues; requires dense shielding like lead).
- **Danger**: External and internal exposure both hazardous.

D. Neutrons

- **Nature**: Uncharged particles.
- **Penetration**: Very high; requires hydrogen-rich materials like water or concrete to slow them down.
- **Danger**: Highly penetrating and biologically damaging due to inducing secondary radiation.

Cellular and Molecular Effects of Radiation

A. DNA Damage

1. Single-Strand Breaks (SSBs):

- Easier for the cell to repair.

2. Double-Strand Breaks (DSBs):

- More dangerous; may lead to mutations, chromosomal aberrations, or cell death.

3. Base Modifications & Cross-Linking:

- Disrupt gene expression and replication.

B. Cellular Outcomes

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1. **Successful DNA Repair**: Cell survives with normal function.
2. **Misrepair**: Can lead to **mutations**, cancer.
3. **Apoptosis (Programmed Cell Death)**: Cell detects damage and self-destructs.
4. **Necrosis**: Uncontrolled cell death due to overwhelming damage.
5. **Senescence**: Cell stops dividing but remains metabolically active.

C. Tissue and Organ Effects

A. Deterministic Effects (Non-Stochastic)

- **Severity increases with dose**
- There is a **threshold dose** below which the effect doesn't occur.
- Examples:
  - Skin burns (erythema)
  - Hair loss (epilation)
  - Cataracts
  - Radiation sickness
  - Sterility
  - Organ failure (at very high doses)

B. Stochastic Effects

- **Probability increases with dose**, but **severity is independent** of dose.
- **No threshold** – any exposure has a chance to cause the effect.
- Examples:
  - **Cancer** (e.g., leukemia, thyroid cancer, breast cancer)
  - **Genetic mutations** passed to offspring

Radiation Exposure and Biological Effects

Acute Radiation Syndrome (ARS)

- At high doses, ionizing radiation causes ARS. Severity depends on the dose:

Dose (Gy)	Symptoms	Timeframe
0.1–0.5	No immediate symptoms; increased long-term cancer risk	Years
0.5–1.0	Mild nausea, temporary blood count changes	Days

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