Types of Cellular Damage due to Radiation

Faculty of Applied Science- Department of Radiology

Course Name: Radiobiology Course Code: MTR 211

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Outlines

- Levels of Radiation Effects.
- Concept of Radiosensitivity.
- Law of Bergonié and Tribondeau.
- Classification of Tissues by Radiosensitivity.
- Factors Affecting Tissue Response to Radiation.
- Early vs Late Radiation Effects.
- Radiation Effects on Skin, Bone Marrow, Blood, Immune System, Gastrointestinal Tract, Reproductive Organs, Lens of The Eye, Lung, Kidney, Liver, Nervous System, Bone, Thyroid Gland.
- Whole-Body Radiation Effects.
- Acute Radiation Syndrome (ARS) Types.
- Pediatric Tissue Radiosensitivity.
- Pregnancy and Radiation Exposure.
- Tissue Weighting Factors (ICRP Concept).
- Radiation Protection of Organs.

Learning Outcomes

By the end of the lecture, students should be able to:

- Define tissue and organ radiosensitivity
- Explain factors affecting radiation response
- Describe radiation effects on major tissues and organs
- Differentiate early and late radiation effects
- Understand clinical relevance in radiology practice

Levels of Radiation Effects

Molecular level

- Damage to DNA and proteins
- Includes strand breaks and base damage

Cellular level

- Impaired cell division and function
- Cell death or mutation may occur

Tissue level

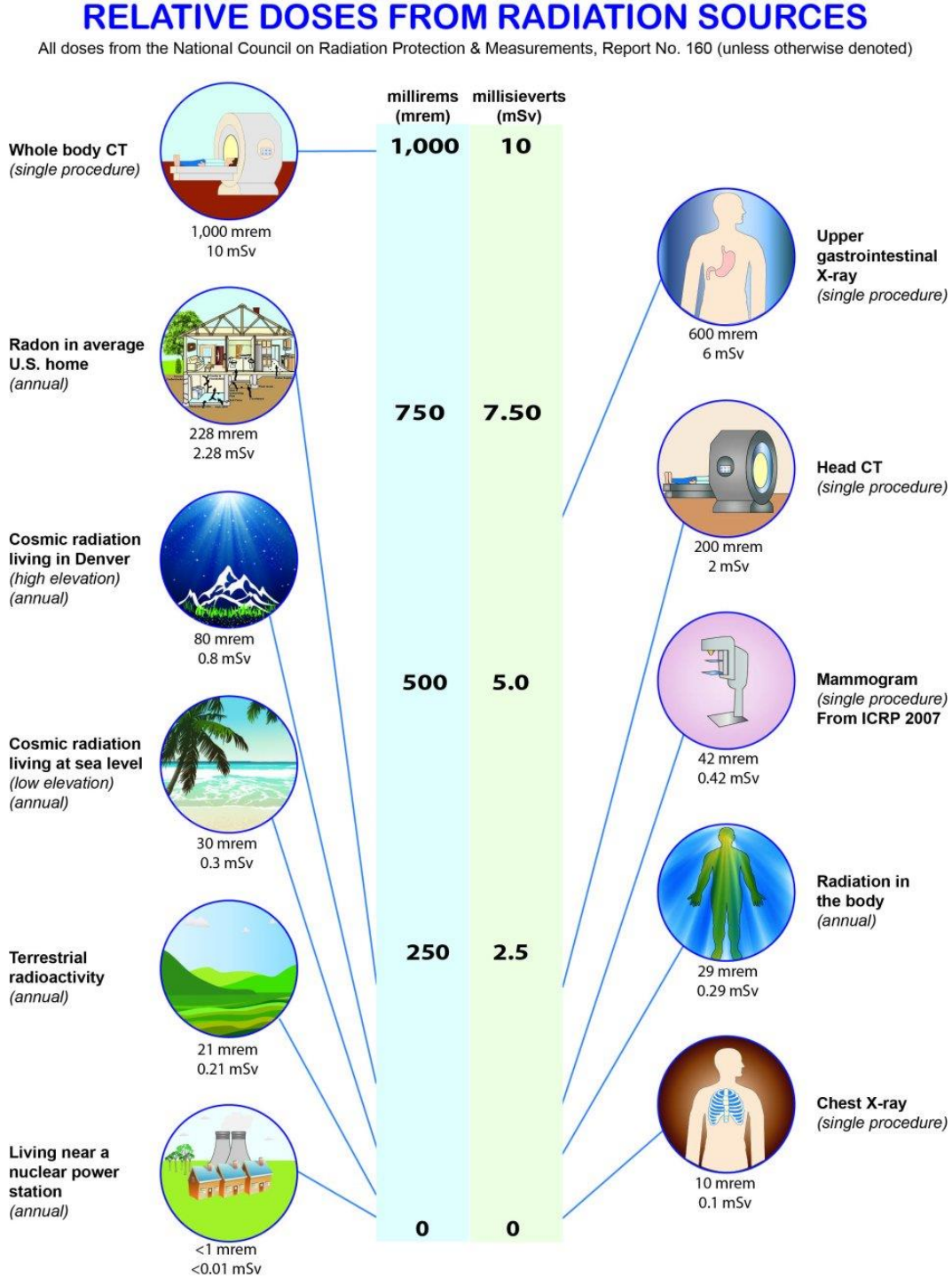
- Loss of large numbers of cells
- Rapidly dividing tissues are most affected

Organ level

- Tissue damage leads to organ dysfunction
- Example: lung fibrosis, kidney damage

Whole-body level

- Multiple organs affected at high doses
- May result in acute radiation syndrome



Concept of Radiosensitivity

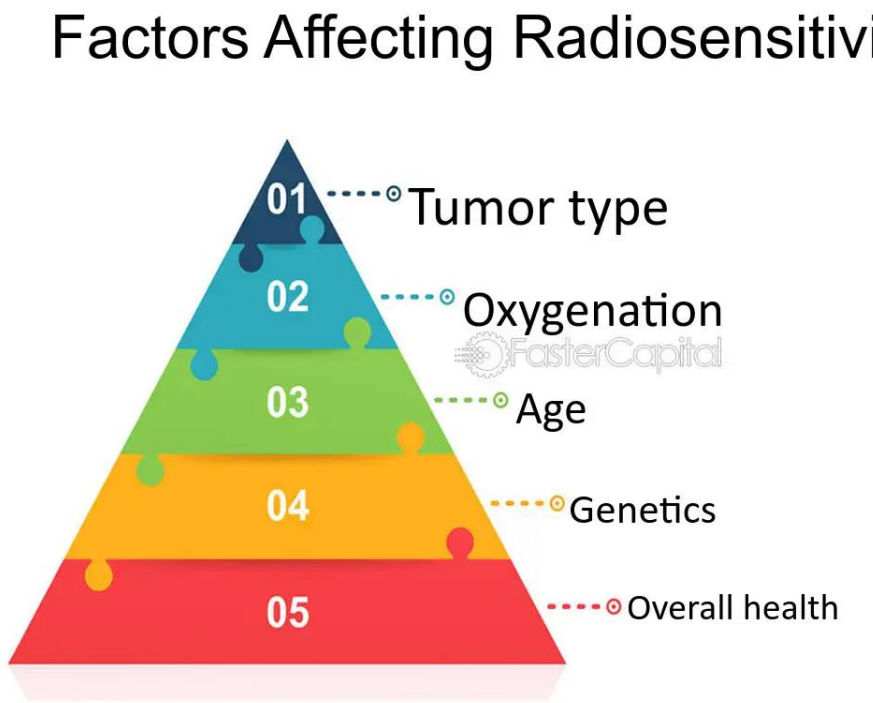
- **Radiosensitivity:** refers to how easily cells or tissues are damaged by radiation
- Different tissues respond differently to the **same radiation dose.**

Radiosensitivity depends on:

1. Rate of cell division
2. Degree of cell differentiation
3. Ability to repair DNA damage
4. Rapidly dividing, less differentiated cells are more radiosensitive
5. Highly differentiated cells are generally more radioresistant

Examples:

- High radiosensitivity: bone marrow, lymphoid tissue
- Low radiosensitivity: muscle, nerve tissue



Law of Bergonié and Tribondeau

- Describes the relationship between **cell characteristics** and **radiosensitivity**

States that cells are more **radiosensitive** if they:

- **Divide rapidly**
- **Are poorly differentiated**
- **Have a long future of cell division**

- Cells are more **radioresistant** if they:
- **Divide slowly or do not divide**
- **Are highly differentiated**

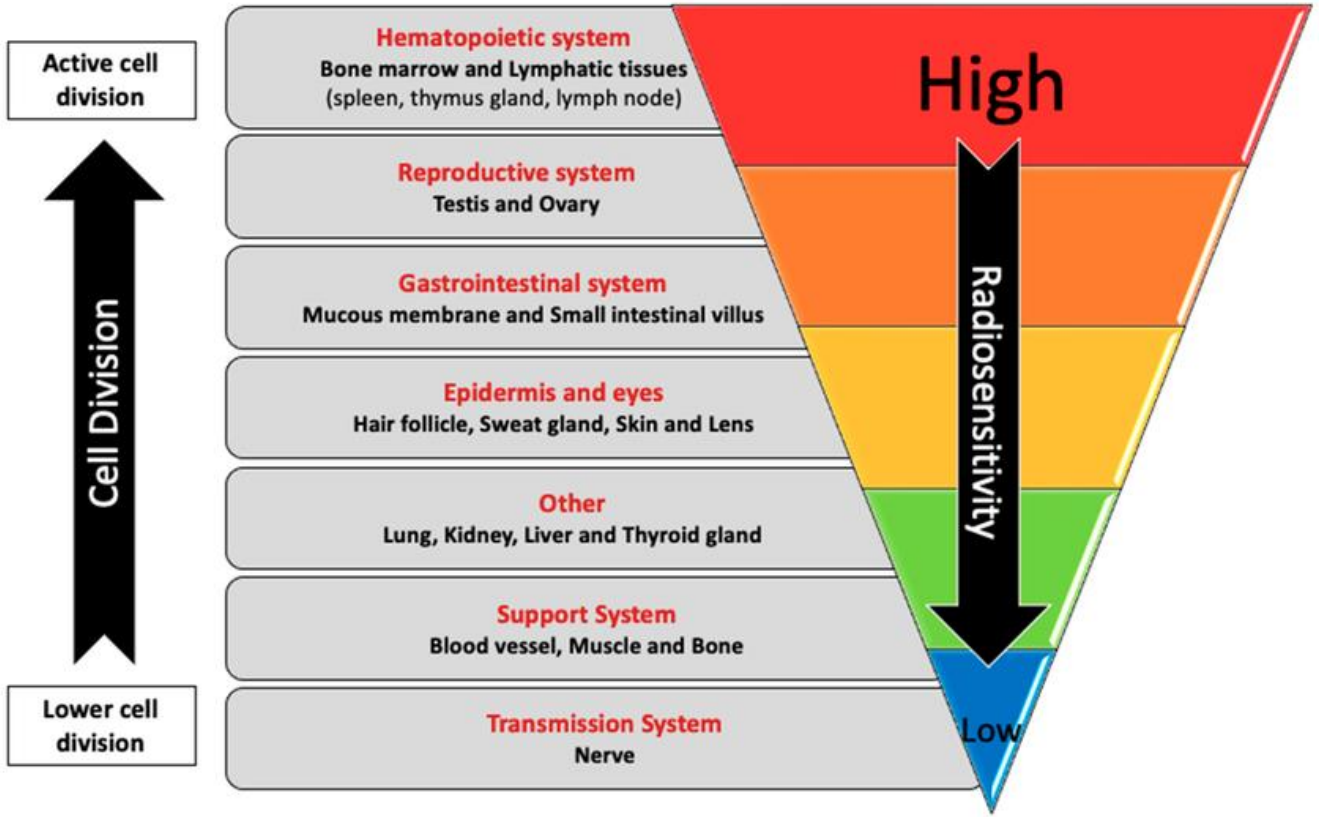
Jean Alban BERGONIE
(1857-1925)

Louis TRIBONDEAU
(1872-1918)

Claudius REGAUD
(1870-1940)

Classification of Tissues by Radiosensitivity

- **Highly radiosensitive tissues:** Bone marrow, Lymphoid tissue, Gonads, Intestinal epithelium.
- **Moderately radiosensitive tissues**: Skin, Lung, Liver, Kidney.
- **Radioresistant tissues:** Muscle, Nervous tissue, Bone and cartilage.



Factors Affecting Tissue Response to Radiation

- **Radiation dose**

Higher dose → greater biological damage

- **Dose rate**

Rapid exposure causes more severe effects

- **Fractionation**

Dividing the dose allows tissue repair

- **Oxygenation**

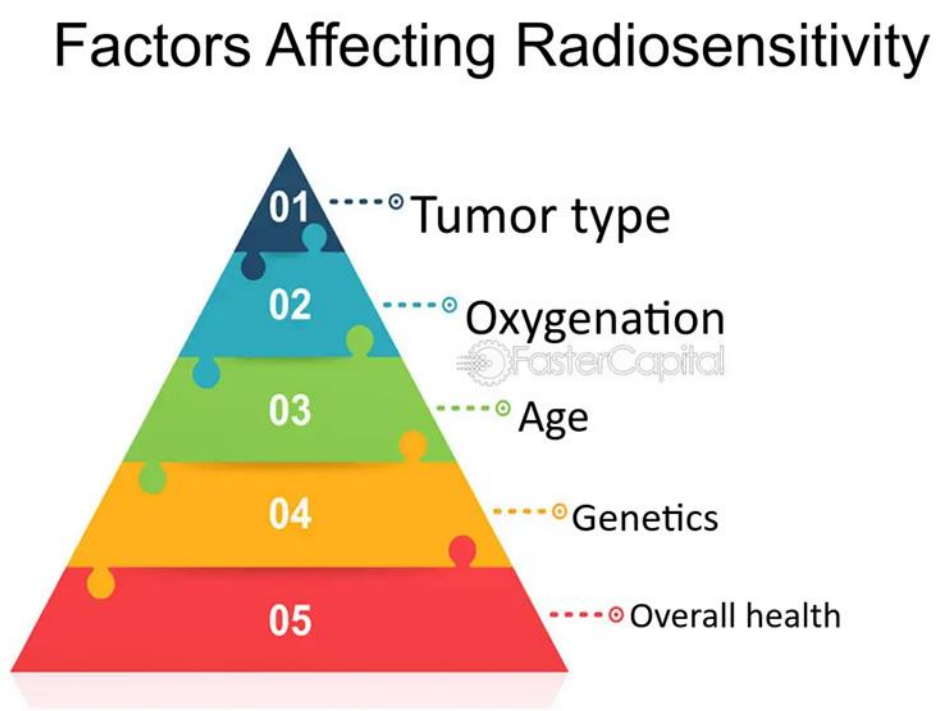
Well-oxygenated tissues are more radiosensitive

- **Age**

Children are more sensitive than adults

- **Volume of tissue irradiated**

Larger exposed area → increased tissue damage



Early vs Late Radiation Effects

Early (acute) radiation effects

- Appear **days to weeks** after exposure
- Occur in **rapidly dividing tissues**
- Usually temporary and reversible

Examples:

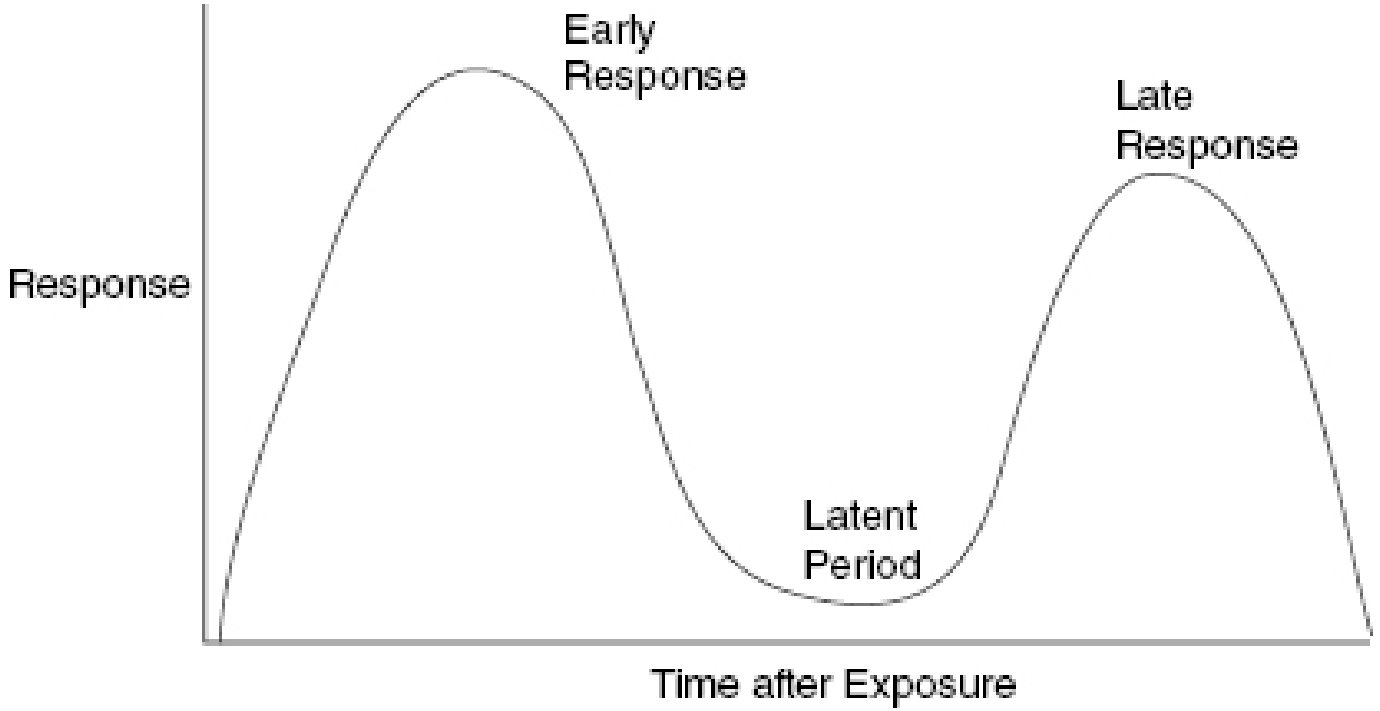
1. Skin erythema
2. Hair loss
3. Nausea and vomiting

Late radiation effects

- Appear **months to years** after exposure
- Occur in **slowly dividing tissues**
- Often permanent and irreversible

Examples:

1. Fibrosis
2. Cataract
3. Secondary cancers



Radiation Effects on Skin

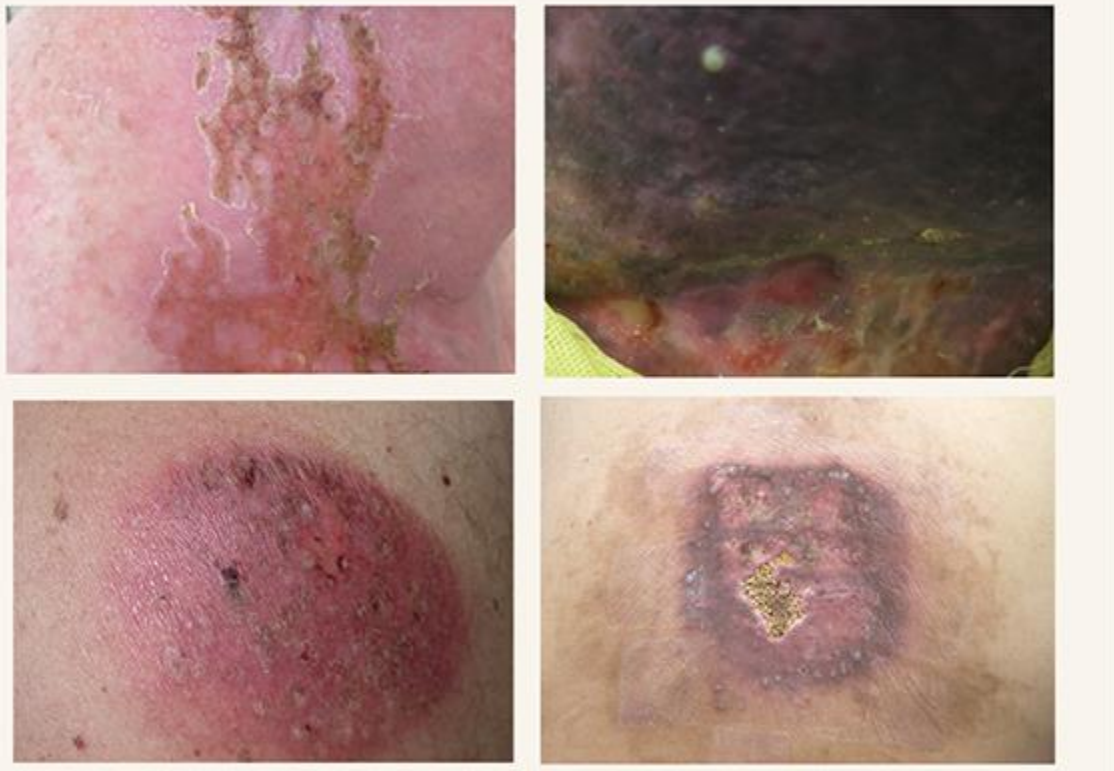
Early (acute) effects:

- **Erythema:** redness due to inflammation
- **Epilation:** temporary hair loss
- **Dry or moist desquamation:** peeling of skin

Late (chronic) effects:

- **Skin atrophy:** thinning of the skin
- **Fibrosis:** stiffening due to scar tissue
- **Telangiectasia:** dilated blood vessels

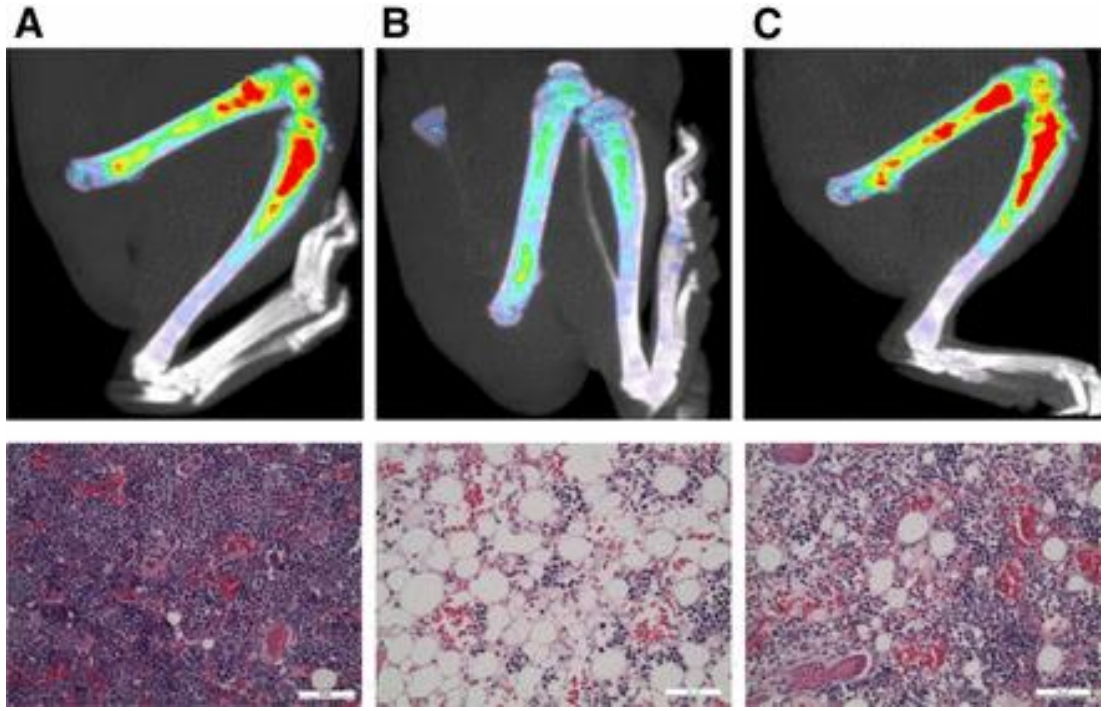
Figure 1. Clinical presentation of radiation dermatitis across multiple skin tones.



Radiation Effects on Bone Marrow

- **Highly radiosensitive tissue**
- Damage leads to **suppression of blood cell production.**

1. **Anemia:** low red blood cells.
2. **Leukopenia:** low white blood cells → increased infection risk.
3. **Thrombocytopenia:** low platelets → bleeding risk.



Clinical relevance

- Critical in whole-body or repeated exposure.
- Limits radiation dose in diagnostic and therapeutic procedures.

Radiation Effects on Blood and Immune System

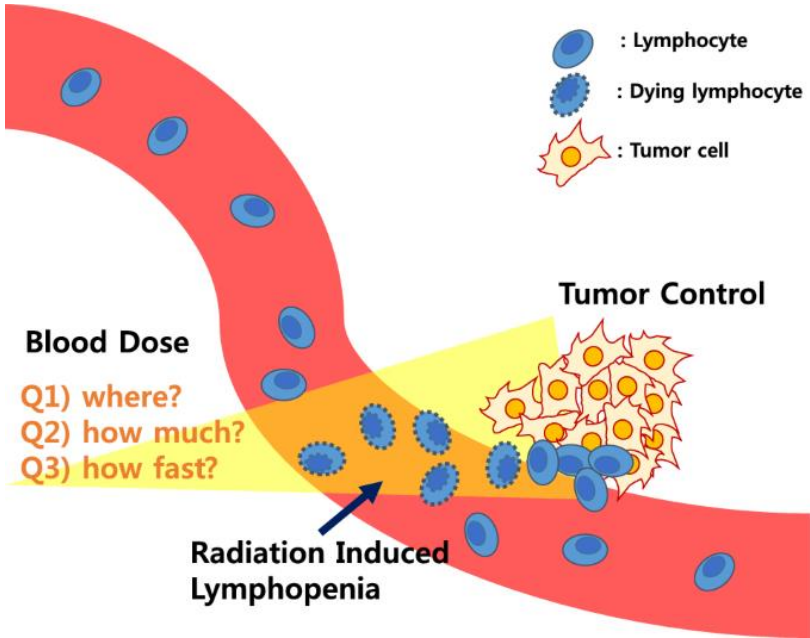
- **Lymphocytes are extremely radiosensitive**
- Rapidly decreases even at low doses.

Effects of radiation

- Reduced immune response → higher risk of infections.
- Temporary or permanent depletion of blood cells, depending on the dose.

Clinical relevance

- Important in radiation therapy and diagnostic imaging.
- Guides dose limitation and monitoring.



Radiation Effects on Gastrointestinal (GI) Tract

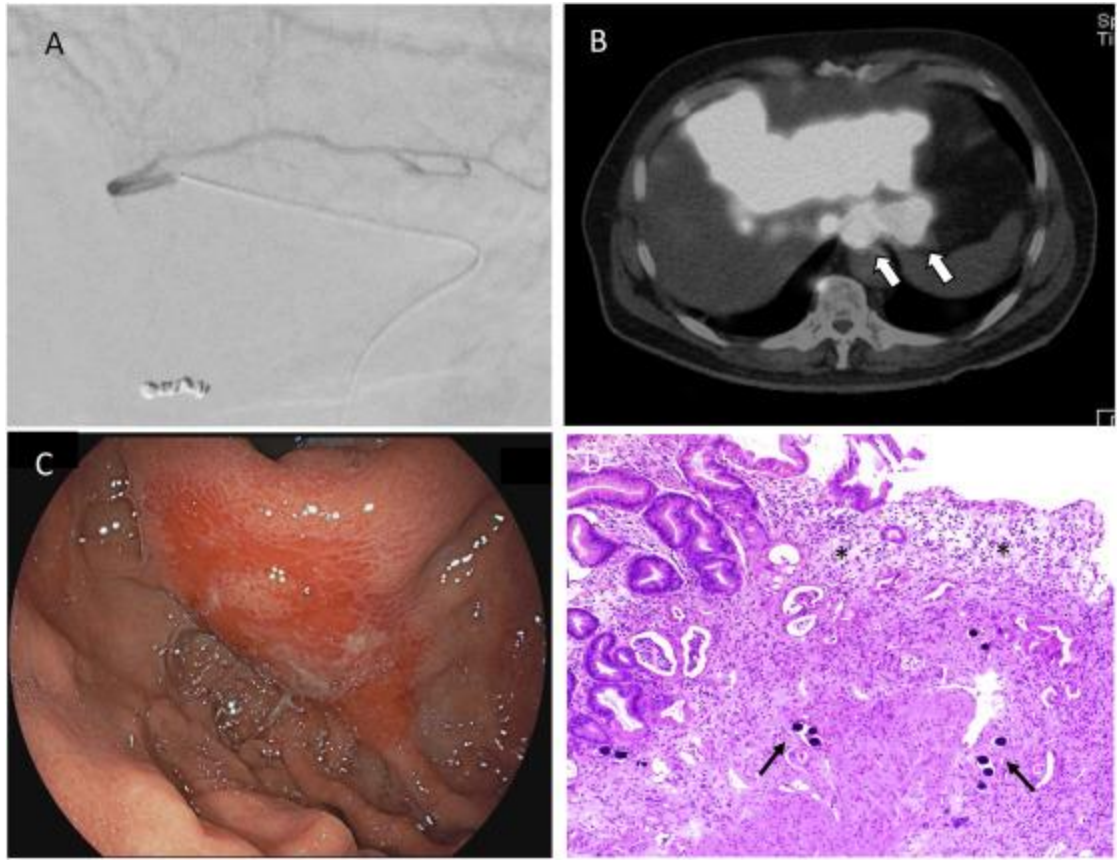
- Highly radiosensitive tissue due to **rapid cell turnover.**

Early (acute) effects

1. Nausea and vomiting
2. Diarrhea
3. Loss of appetite
4. Severe damage
5. Ulceration of the mucosa
6. Malabsorption and dehydration

Clinical relevance

- Limits radiation dose to abdominal imaging or therapy.



Radiation Effects on Reproductive Organs

- Gonads **are highly radiosensitive.**

Testes

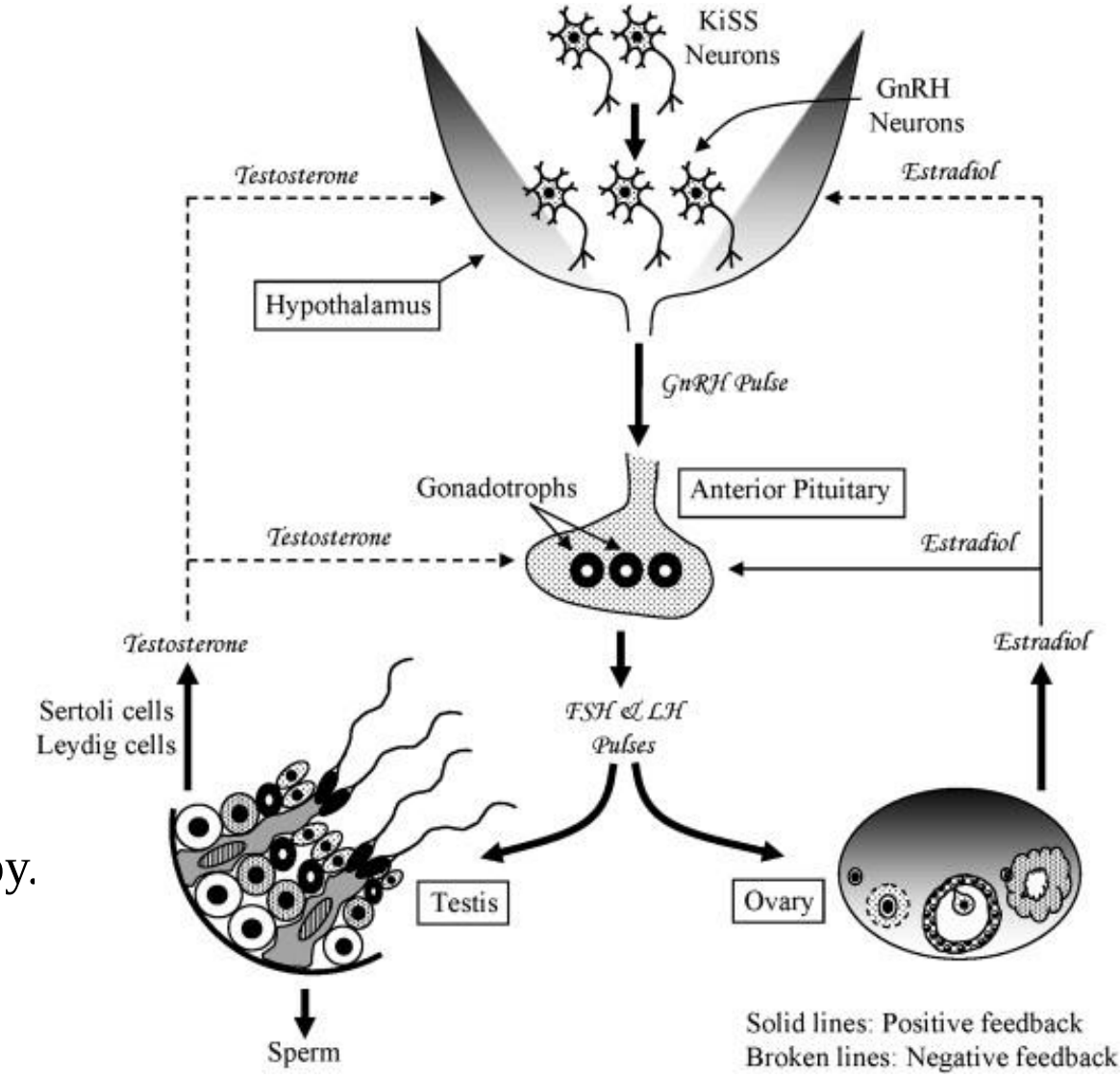
- Temporary or permanent sterility, depending on dose.

Ovaries

- Reduced fertility.
- Risk of premature menopause.

Clinical relevance

- Protect reproductive organs during radiology and therapy.
- Use shielding whenever possible.



Radiation Effects on the Lens of the Eye

- The lens is **highly sensitive** to radiation
- **Deterministic effect** – has a threshold dose

Damage results in:

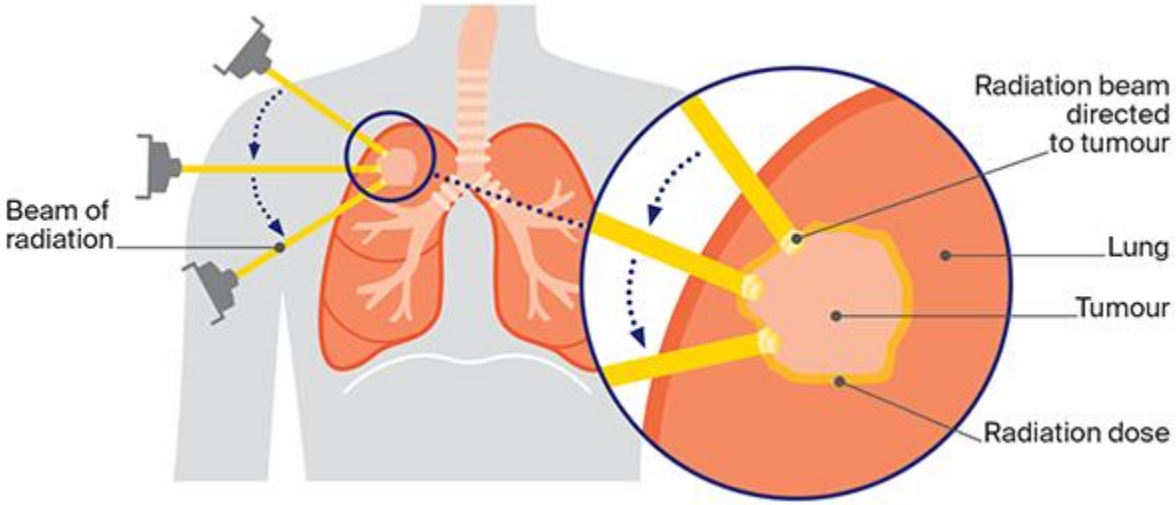
- Radiation-induced cataracts
- Gradual clouding of the lens, leading to vision impairment

Clinical relevance

- Important in interventional radiology and CT procedures
- Eye protection is recommended for staff and patients

Radiation Effects on the Lung

- **Moderately radiosensitive** tissue



Early effects (acute)

- Radiation pneumonitis – inflammation of lung tissue
- **Symptoms:** cough, shortness of breath, fever

Late effects (chronic)

- Pulmonary fibrosis – permanent scarring of lung tissue
- Reduced lung capacity and respiratory function

Clinical relevance

Dose and volume of lung irradiated must be carefully controlled in radiotherapy

Radiation Effects on the Kidney

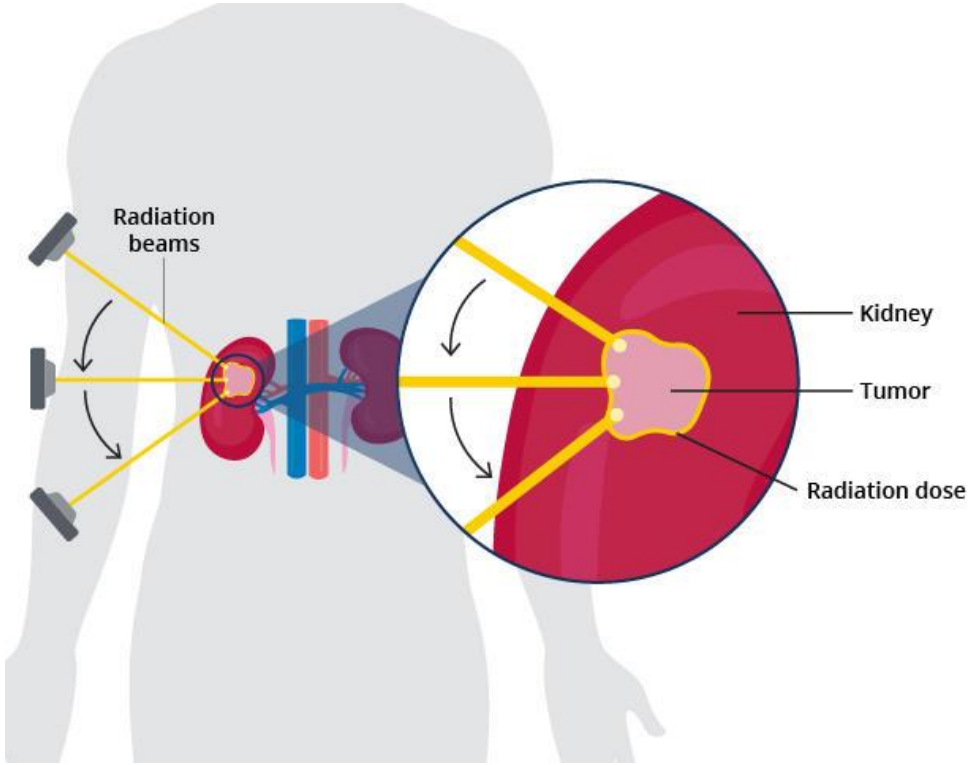
- **Late-responding tissue:** effects appear months to years after exposure

Radiation-induced kidney damage may cause:

- Radiation nephritis
- Hypertension
- Chronic renal failure

Clinical relevance

Kidneys are **moderately sensitive**; careful dose planning is essential in abdominal and pelvic radiotherapy



Radiation Effects on the Liver

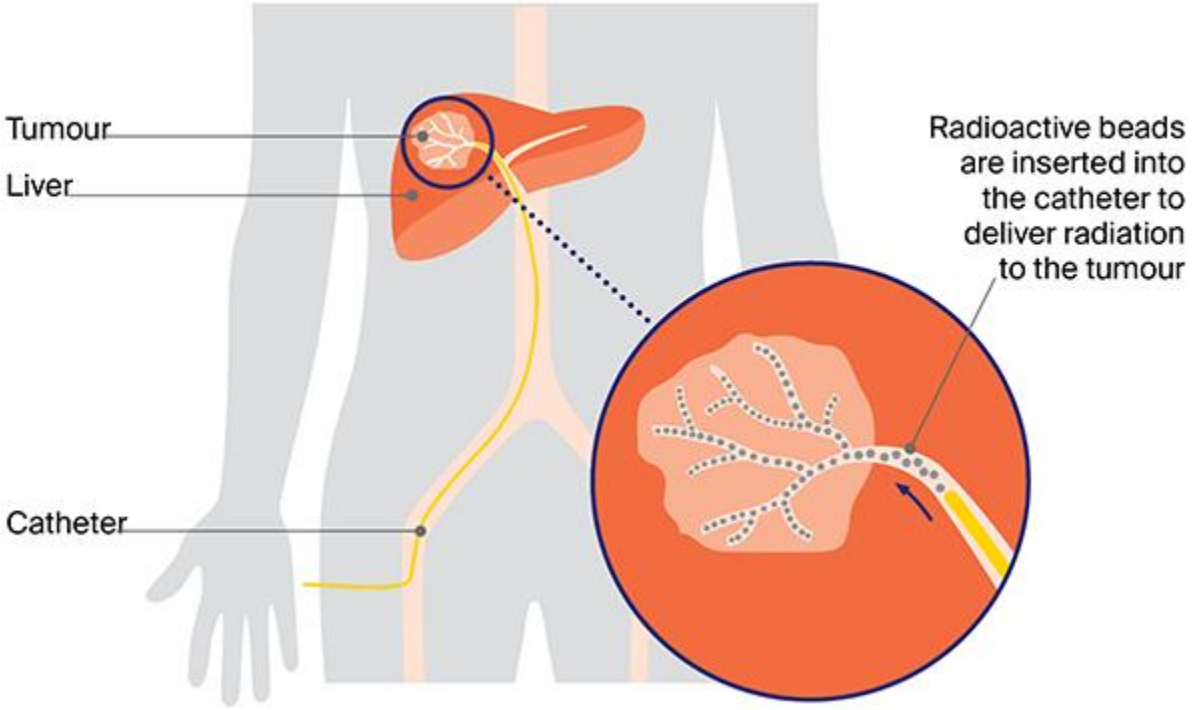
- **Relatively radioresistant**, but high doses can cause damage

Possible effects

- Radiation-induced liver disease (RILD)
- Hepatic dysfunction
- Fibrosis in severe cases

Clinical relevance

- Important in liver radiotherapy and abdominal imaging
- Dose limitation and careful planning are essential

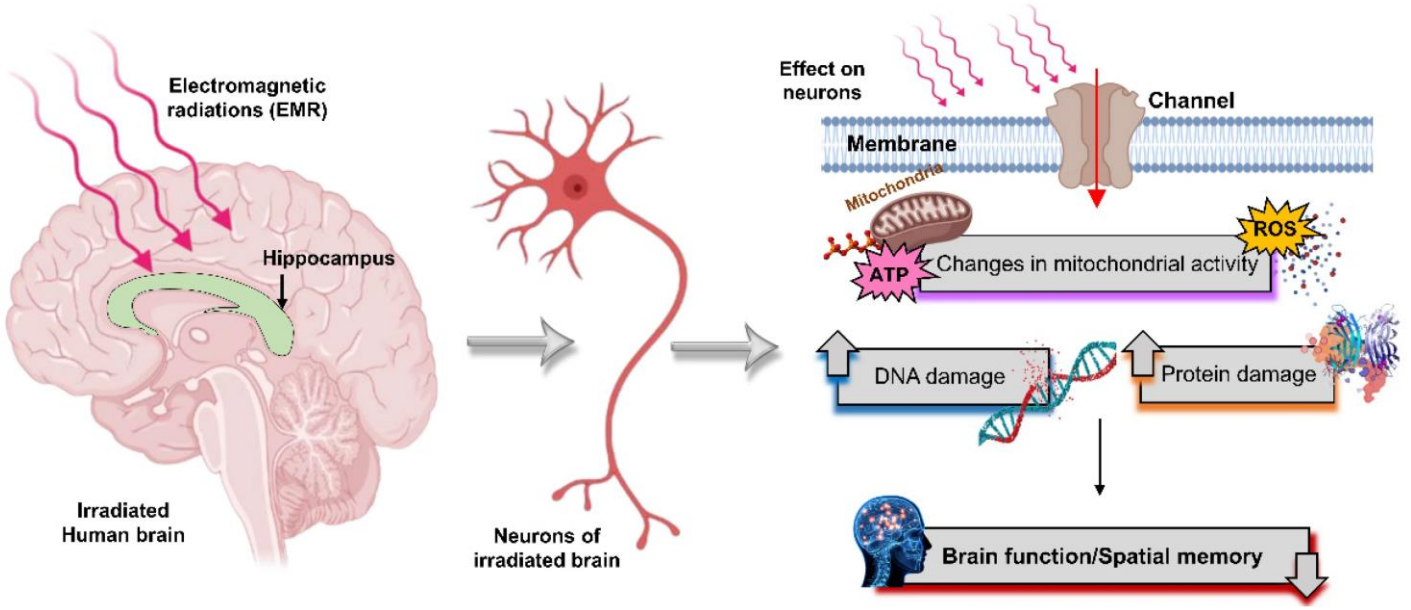


Radiation Effects on the Nervous System

- Highly differentiated tissue → **radioresistant**

Early effects:

- Rare at diagnostic doses
- May occur only at very high exposures



Late effects:

- Demyelination
- Necrosis of nervous tissue
- Cognitive or motor deficits in severe cases

Clinical relevance:

- Nervous tissue generally tolerates standard diagnostic radiation
- Critical to monitor during high-dose radiotherapy

Radiation Effects on Bone

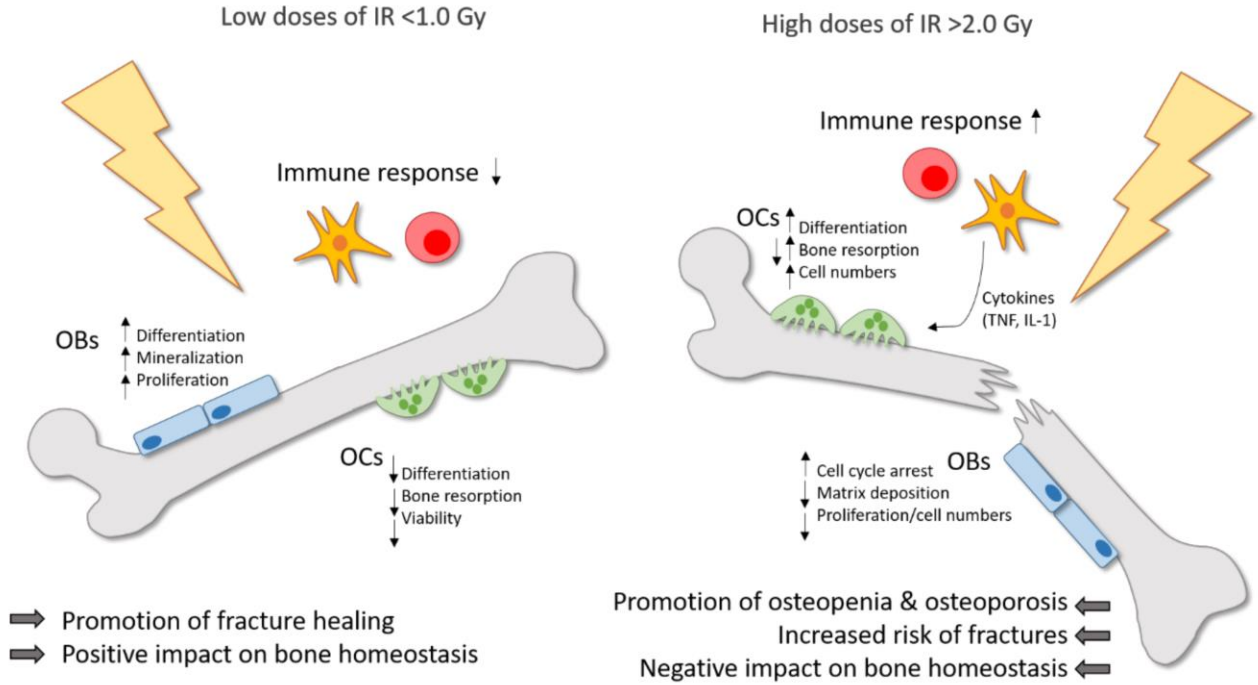
- Bone tissue is generally **radioresistant**
- **Bone marrow** inside bones is highly **radiosensitive**
- Damage can lead to **hematopoietic suppression**

High-dose effects on bone:

- Growth retardation in children
- Osteoradionecrosis (bone death due to radiation)

Clinical relevance:

- Important in radiotherapy near skeletal structures
- Protect growing bones in pediatric patients



Radiation Effects on the Thyroid Gland

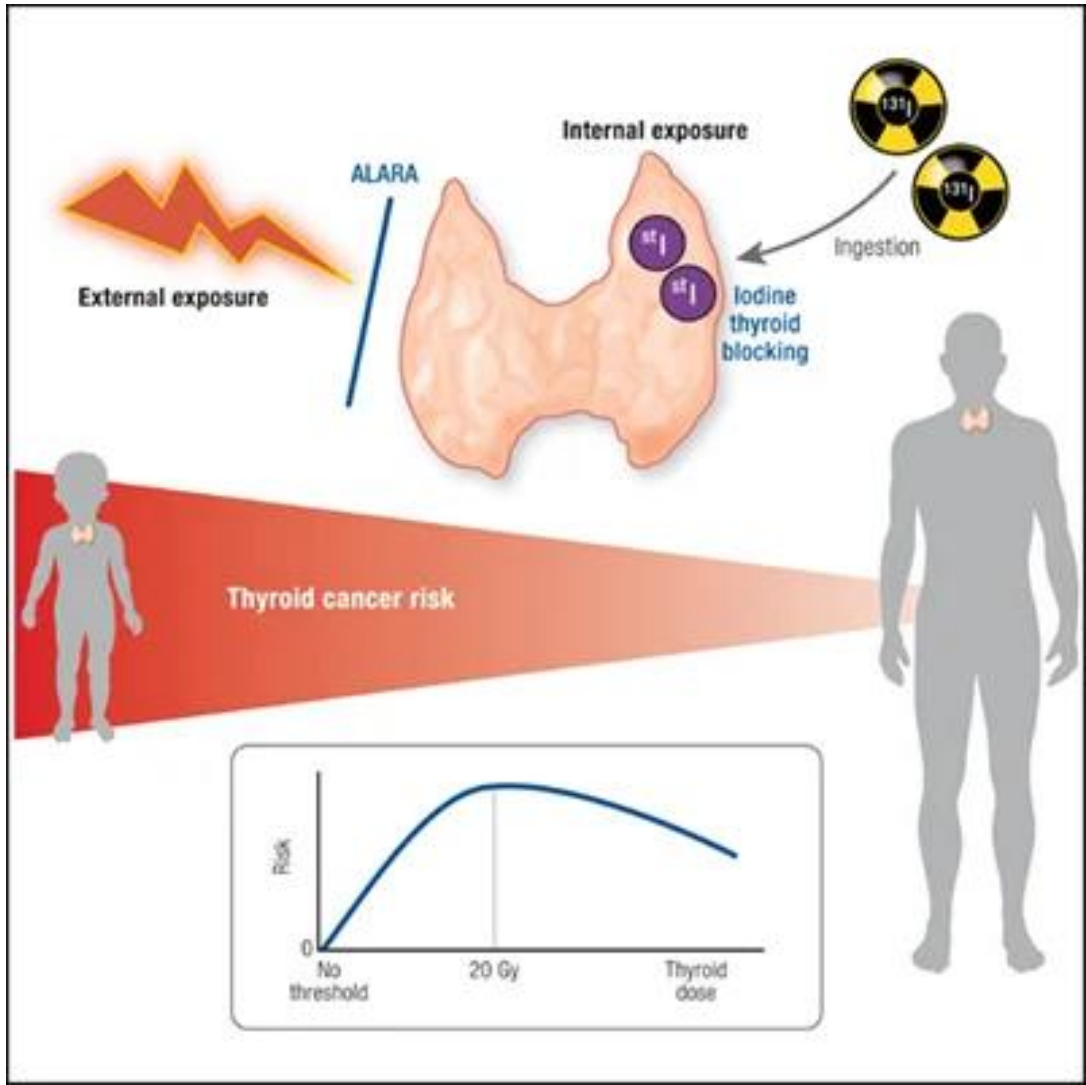
- Thyroid is **sensitive to radiation**, especially in children

Potential effects:

- Increased risk of thyroid cancer
- Hypothyroidism in some cases

Clinical relevance:

- Important to use thyroid shielding during neck and chest imaging
- Minimize radiation exposure, particularly in pediatric patients



Whole-Body Radiation Effects

- Occur after **high-dose exposure**
- Can affect multiple **organs and systems** simultaneously
- Leads to **Acute Radiation Syndrome** (ARS)

Stages of ARS:

1. **Prodromal phase:** nausea, vomiting, fatigue
2. **Latent phase:** apparent recovery, symptom-free period
3. **Manifest illness:** organ-specific symptoms depending on dose

Clinical relevance:

- Seen in accidental or occupational radiation overexposure
- Requires urgent medical management

Acute Radiation Syndrome (ARS) Types

Hematopoietic syndrome

- Dose: 1–8 Gy
- Affects bone marrow → anemia, infection, bleeding

Gastrointestinal (GI) syndrome

- Dose: 8–30 Gy
- Affects intestinal lining → nausea, vomiting, diarrhea, dehydration

Central Nervous System (CNS) syndrome

- Dose: >30 Gy
- Affects brain and spinal cord → neurological symptoms, rapid death

Pediatric Tissue Radiosensitivity

- **Children are more radiosensitive than adults**

Reasons:

- Rapidly dividing cells
- Longer expected lifespan → more time for stochastic effects to develop

Implications:

- Higher risk of radiation-induced cancer
- Careful dose optimization in pediatric imaging and therapy

Pregnancy and Radiation Exposure

- The embryo and fetus are **highly radiosensitive**

Effects depend on:

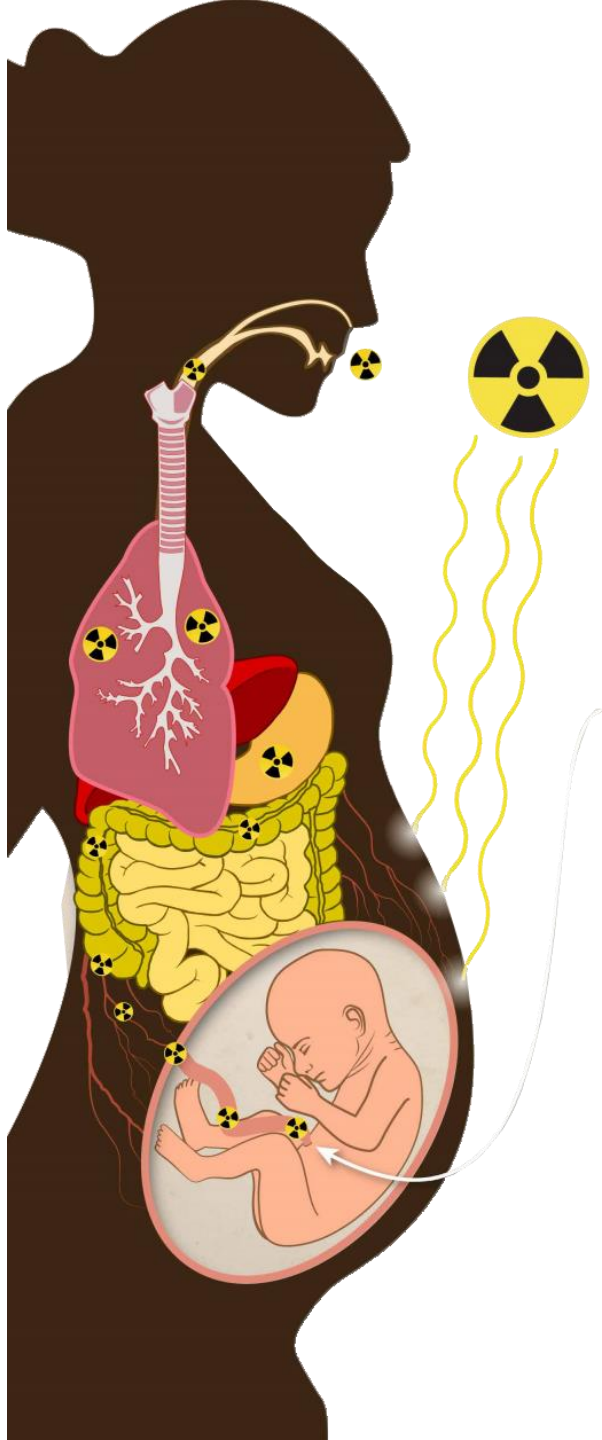
- Gestational age – early stages are most vulnerable
- Radiation dose

Possible outcomes:

- Birth defects and malformations
- Growth retardation
- Increased risk of childhood cancer

Clinical relevance:

- Minimize radiation exposure in pregnant patients
- Use shielding and alternative imaging methods



Tissue Weighting Factors (ICRP Concept)

- **Different tissues contribute differently to radiation risk**

Tissue weighting factor (wT):

- Reflects the **radiosensitivity** of each organ
- Used to calculate **effective dose** in radiology

Examples of weighting factors:

- Bone marrow, gonads, breast → higher wT (more sensitive)
- Muscle, skin → lower wT (less sensitive)

Clinical relevance:

- Guides **dose planning** and **radiation protection**
- Helps prioritize protection of sensitive or

Radiation Protection of Organs

- **Time:** Minimize exposure duration
- **Distance:** Maximize distance from the radiation source
- **Shielding:** Use lead aprons, thyroid collars, gonad shields
- **Collimation:** Limit the beam to the target area only
- **Monitoring:** Use dosimeters for staff exposure

Questions? Comments?

Thank you!