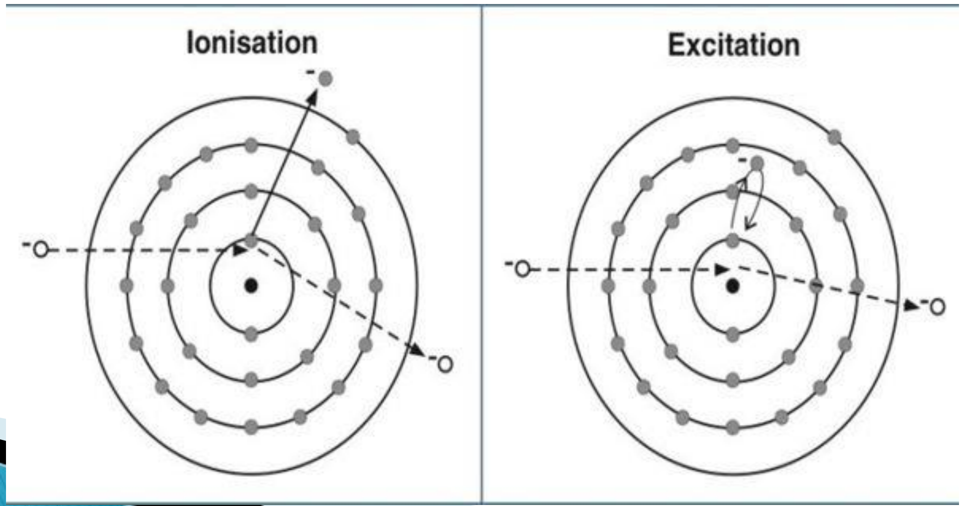
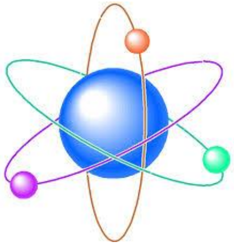
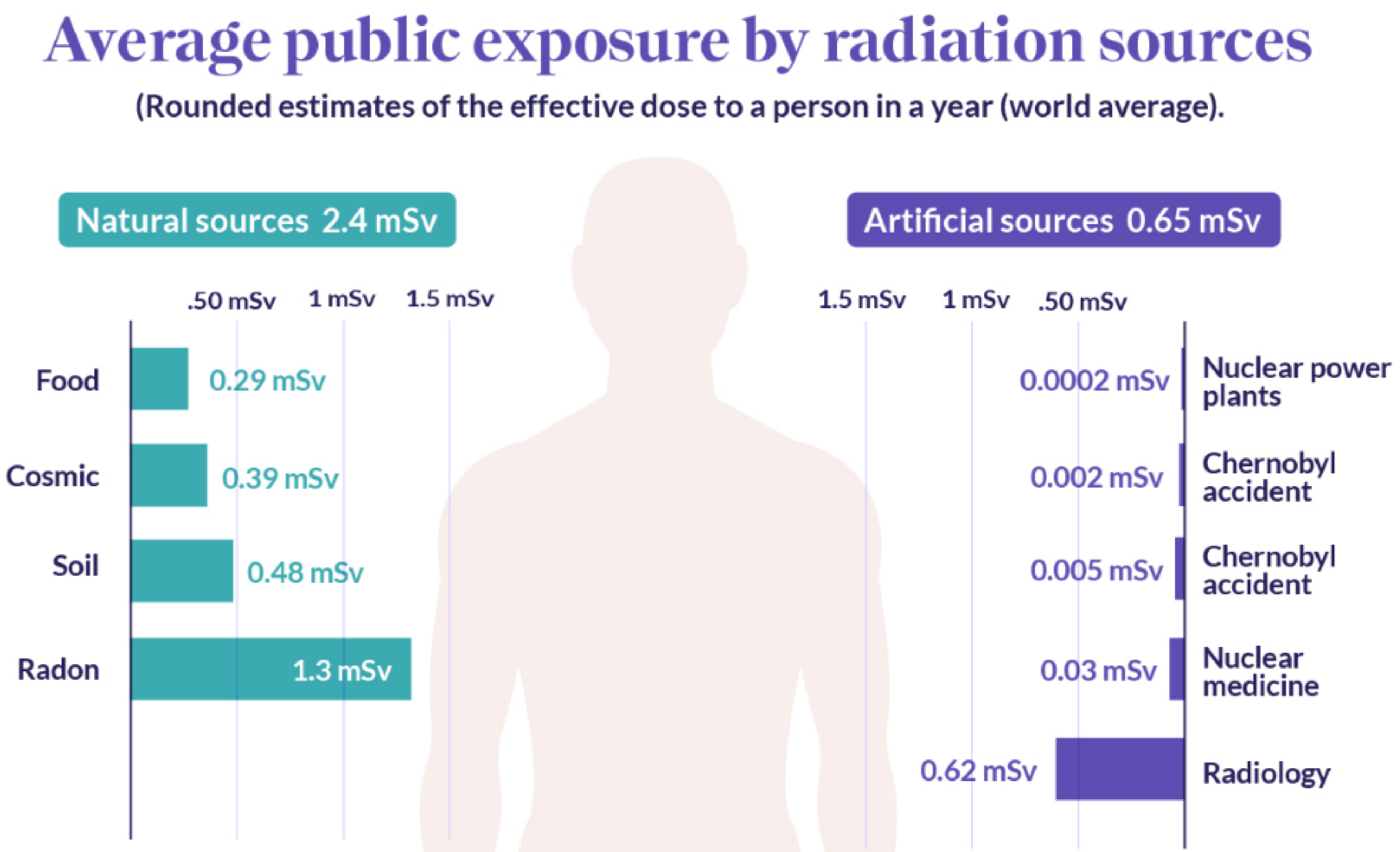
Biological
Effects of Ionizing Radiation
Radiation Protection
Dosimetry

- Ionization is the process of ion production by ejection of electrons from atoms and molecules after exposure to radiation.
- Ionizing radiation is subdivided into electromagnetic radiation (X-rays and gamma rays) and particulate radiation including neutrons and charged particles (alpha and beta particles).
- When radiation interacts with target atoms, energy is deposited, resulting in ionization or excitation



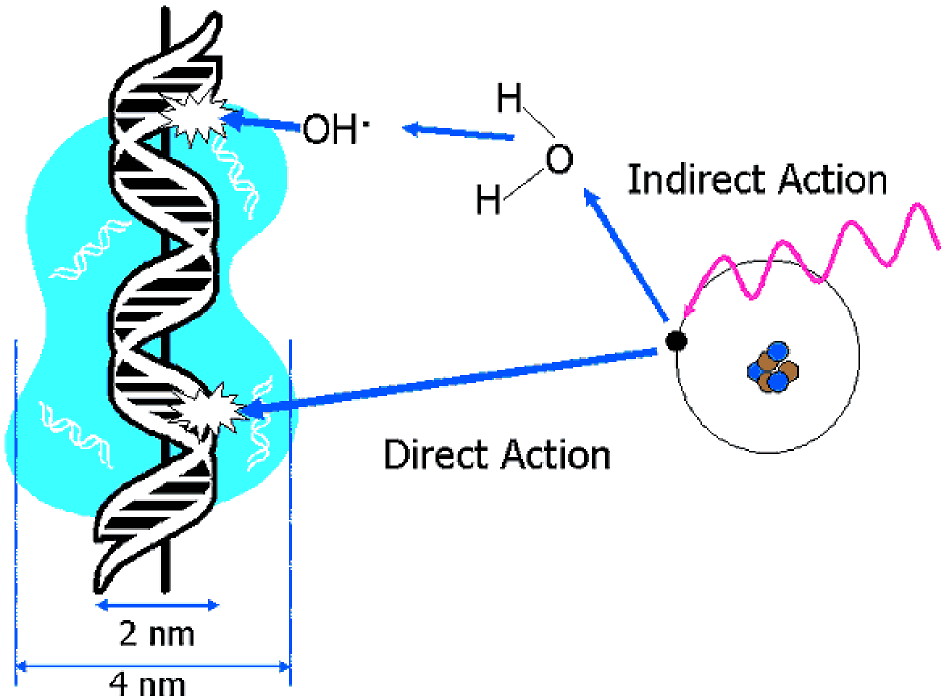


Sources of ionizing radiation



Average annual radiation dose (expressed as dose equivalent and effective dose equivalent) ≈3,6 mSv.
~80% of this exposure, is natural background radiation, and about 2/3 of that is from radon .

Mechanisms of Radiation Damage



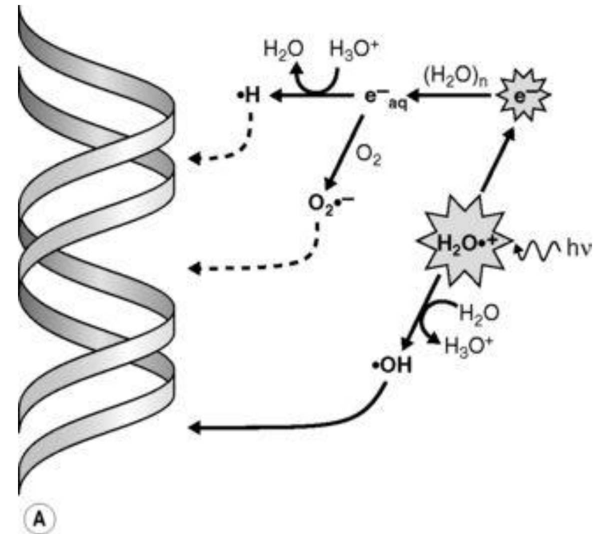
- Radiation damage occurs via one of two ways.
- **indirect action**–it has been estimated that about two-thirds of biological damage caused by low linear energy transfer (LET) radiation
- **direct action**–biological damage by high linear energy transfer (LET) radiation is primarily by direct damage

Direct Action

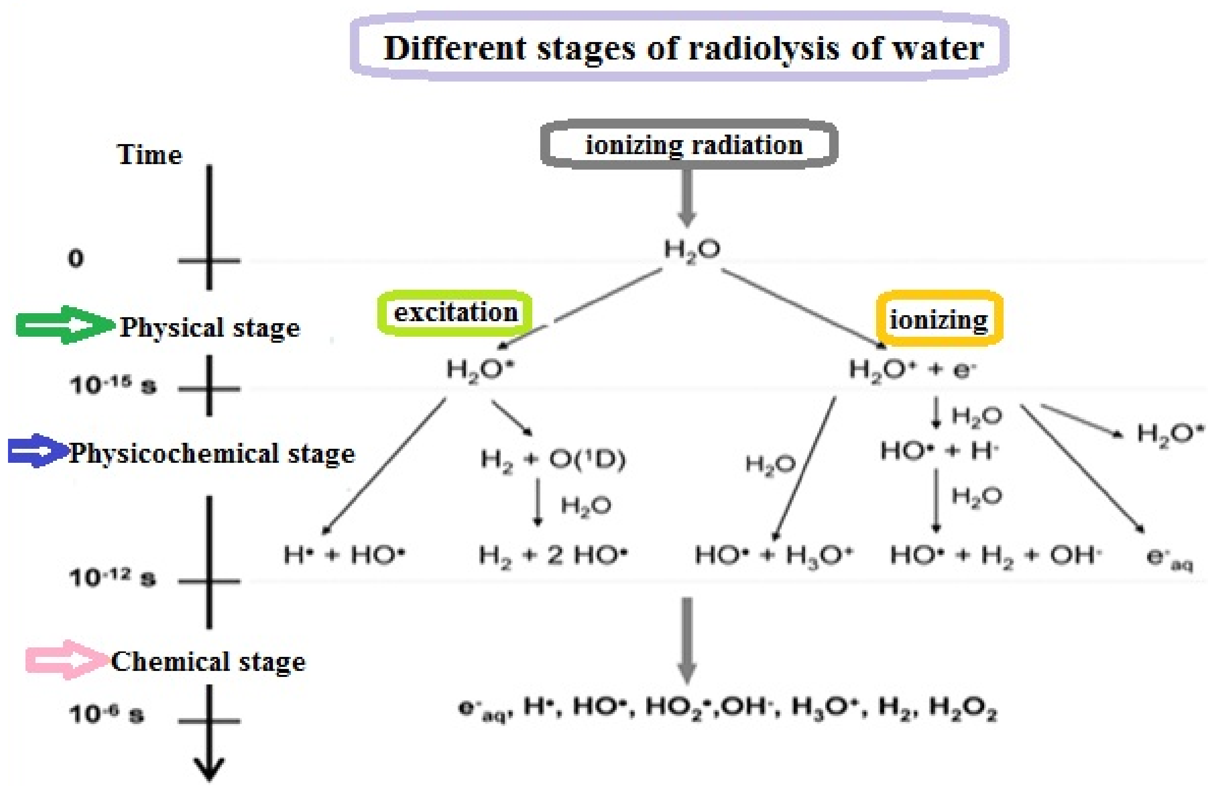
- The direct effect theory or target theory proposes that ionizing radiation acts by direct hits on target atoms. All atoms or molecules **within** the cells, such as enzymatic and **structural** proteins and RNA, are vulnerable to radiation injury.
- DNA, however, is the principal target, in which ionizing radiation produces single- or double-**stranded** chromosomal breaks.

Indirect Action

- occurs when radiation interacts with non-critical target atoms or molecules, usually water. This results in the production of free radicals.
- Free radicals are atoms or molecules that have an unpaired electron and are highly reactive. These free radicals can then attack other parts of the cell and critical targets such as the DNA.
- When ionizing radiation interacts with water two types of free radicals are formed: hydrogen and **hydroxyl.**
- The presence of an excess of oxygen during irradiation of cells **allows** the formation of additional free radicals: **hydroperoxyl** free radicals.

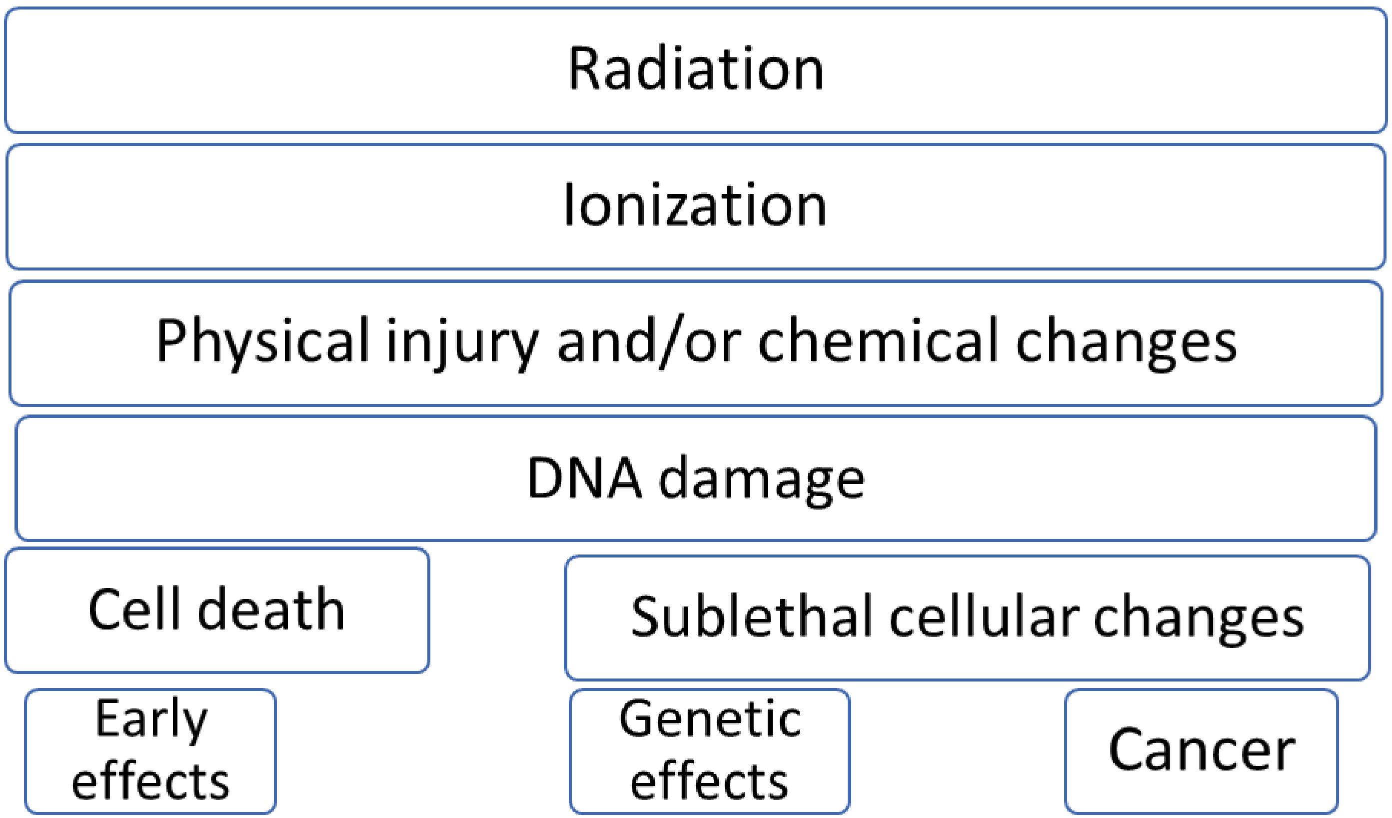


Indirect Action– Radiolysis of Water



The lifetimes of simple free radicals (H0 or OH) are very short, on the order of 10–10 sec. While generally highly reactive they do not exist long enough to migrate from the site of formation to the cell nucleus. However, the oxygen derived species such as hydroperoxyl free radical does not readily recombine into neutral forms. These more stable forms have a lifetime long enough to migrate to the nucleus where serious damage can occur.

Mechanisms of Radiation Damage

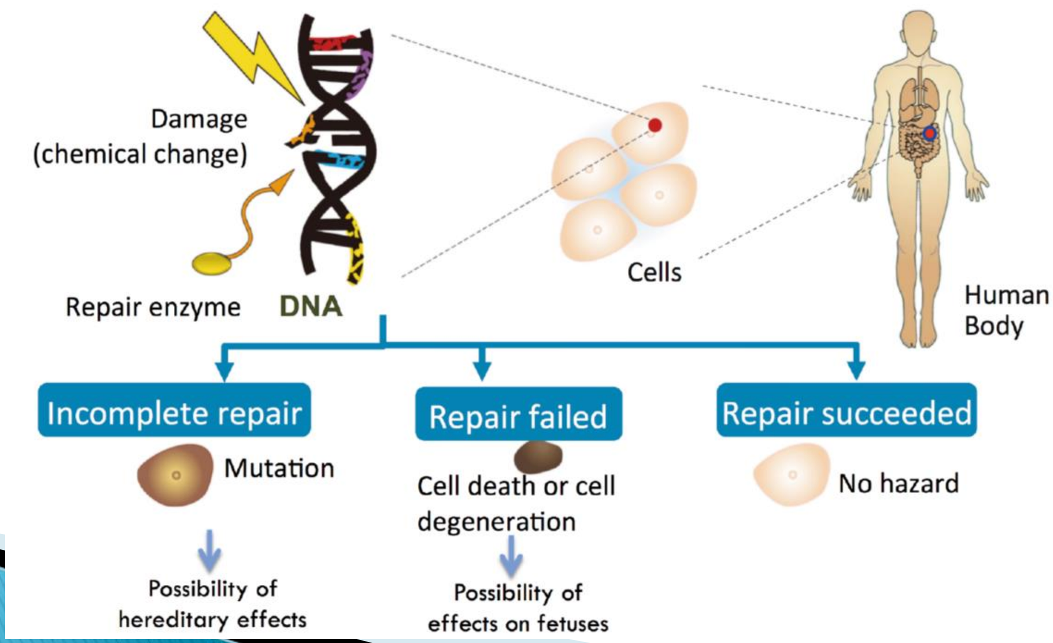


Radiation-Induced Cell Injury

- The nucleus is relatively more radiosensitive than the cytoplasmic structures.
- Nuclear changes after radiation include swelling of the nuclear membrane and disruption of chromatin materials
- Cytoplasmic changes include swelling, vacuolization, disintegration of mitochondria and endoplasmic reticulum, and reduction in the number of polysomes
- Radiation induced **apoptosis** is highly related to the type of involved cell. **Lymphocytes**, for example, are highly **susceptible** to radiation by this mechanism

Radiation effect on cells

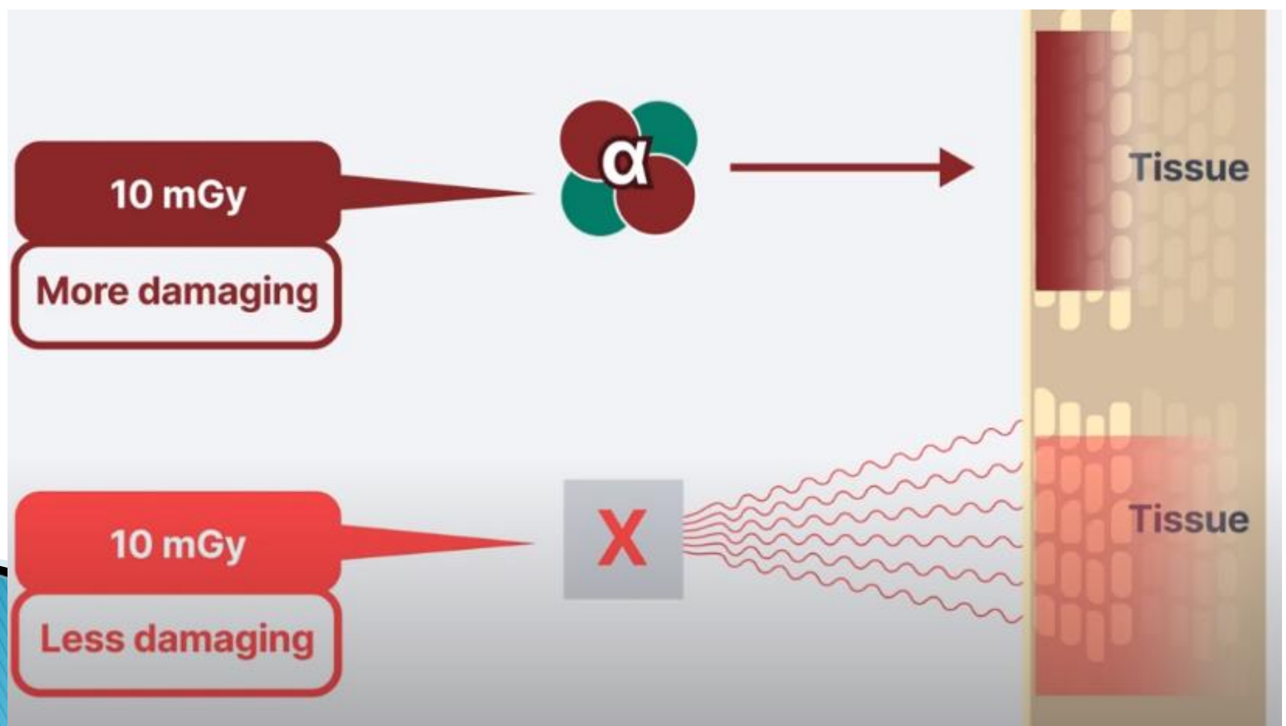
- Cell may be undamaged
- Cell may die
- Cell may repair and work normally
- Cell may be repaired but abnormally
- Cells that sustain non-lethal DNA damage show increased mutation rate in descendent cells several generations after the initial exposure



Factors Affecting Radiation Hazards

1. Factors Related to Ionizing Radiation

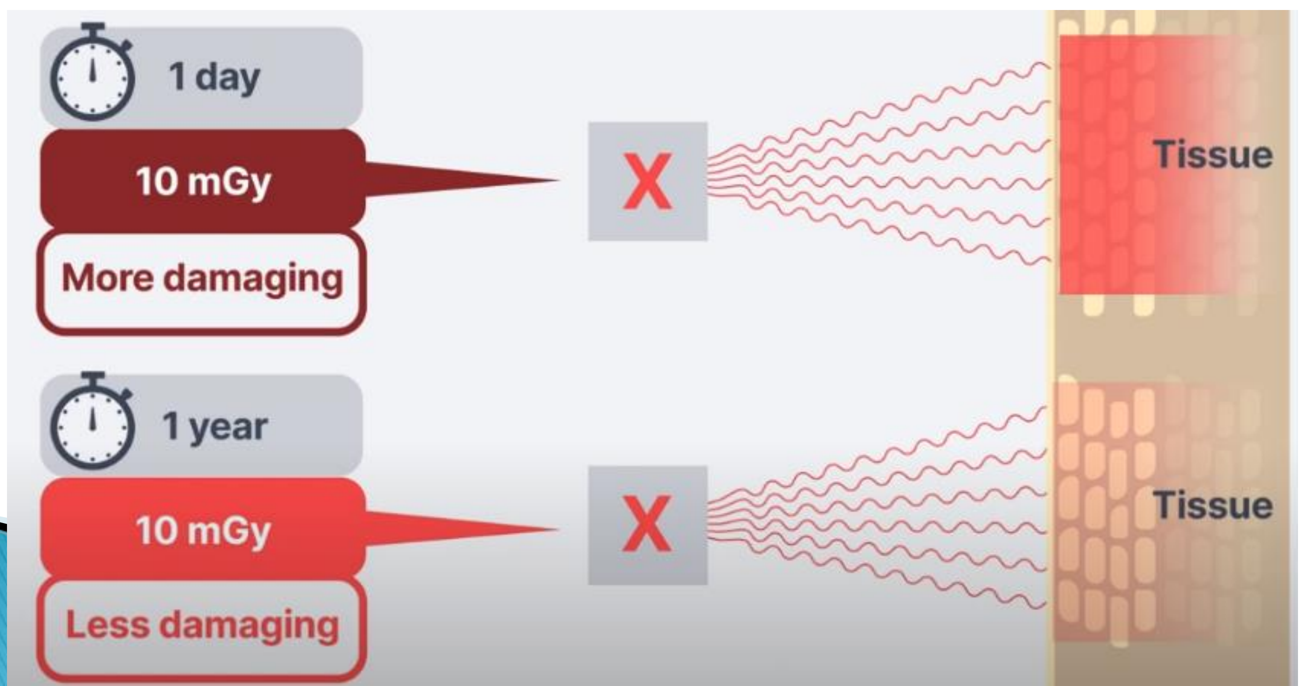
- **Type of Radiation** : differ in penetrability based on LET (Thus alpha particles penetrate a short distance but induce heavy damage, whereas beta particles travel a longer distance but much shorter than gamma rays)



Factors Affecting Radiation Hazards

1. Factors Related to Ionizing Radiation

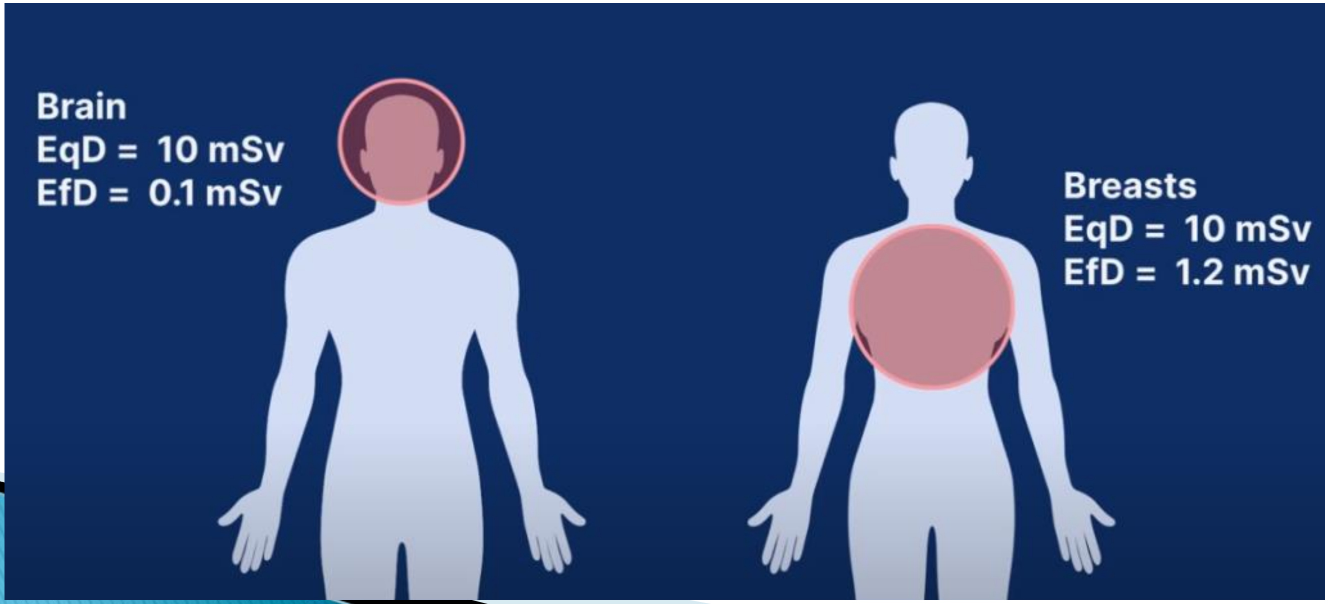
- **<u>Dose Rate</u>**: expresses the time for which dose is administered. The longer the duration for the same total dose, the better the chance of cellular repair and the smaller the damage.
- **<u>Mode of Administration :</u>** single dose of radiation causes more damage than the same dose being divided (fractionated)



Factors Affecting Radiation Hazards

2. Factors Related to Biological Target

- **Radiosensitivity:** normal cells and their tumors vary in their sensitivity to radiation. Radiosensitivity varies with the rate of mitosis and cellular maturity. Blood-forming cells are very radiosensitive, while neurons, muscle and parathyroid cells are highly radioresistant



Factors Affecting Radiation Hazards

2. Factors Related to Biological Target

- **Repair Capacity of Cells**: Some cells are known to have a higher capacity than others to repair the damage caused by ionizing radiation; consequently, the biological effects of the same radiation dose are different.
- **Cell-Cycle Phase**: Radiosensitivity appears to be greatest in G2 phase
- **Degree of Tissue Oxygenation**: the amount of molecular oxygen **rather** than the rate of oxygen utilization by the cells is the most important factor for increasing the sensitivity of cells to radiation. The probable mechanism is the allowance of additional free radicals, which enhance the damage of cells

The effective half-life

- The physical half-life (Tp or T1/2) is the time it takes for half of the nuclide atoms to become stable.
- The biologic half-life (Tb) reflects the half-time for excretion of the material from the organ or whole body. *For instance, the biologic half-life of 99mTc-MDP is the time it takes for one half of this radiopharmaceutical to be filtered and excreted by the kidneys and bladder.*
- The effective half-life (Te) is a measurement that combines the above two values; it is the time required for one half of the initial radioactivity to disappear from an organ or the body both by excretion and physical decay. The effective half-life is always shorter than **either** the physical or biologic half-life and is calculated using the formulas.

$$\frac{1}{T_E} = \frac{1}{T_P} + \frac{1}{T_B}$$

Acute vs Chronic exposure

Acute

- High doses
- Immediate effects

Chronic

- Low radiation doses
- Long term effects

- The biological effect of low-level radiation is extremely difficult to study in a controlled environment. At low doses, radiation can trigger only partially understood effects that can lead to cancer or genetic damage. These effects take years or generations to appear.
- The effects of high radiation exposure to populations during accidents or nuclear war have been the main source of information. At high doses, the effect may become evident within minutes, hours, or days.

Acute Whole-Body Exposure Syndromes

Following exposure to a large, single, short-term whole-body dose of ionizing radiation, the resulting injury is expressed as a **series** of clinical symptoms. The sequence of events can be generally divided into four clinical periods.

time →

prodromal period	latent period	manifest phase	recovery period or death
• up to 48h, anorexia, nausea, vomiting, diarrhea	• 48 h to 2-3 weeks after exposure, patient becomes asymptomatic	• 6-8 weeks after exposure, variable symptoms appear based on the radiation dose	• based on the radiation dose

Exposure Levels and Symptoms

- 0.05 – 0.2Sv No symptoms
- 0.2 – 0.5Sv No noticeable symptoms
- 0.5 – 1Sv Mild radiation Sickness
- 1 – 2Sv Light radiation poisoning, 10% Fatality after 30 days
- 2 – 3Sv Moderate radiation poisoning, 35% fatality after 30 days
- 3 – 4Sv Severe radiation poisoning, 50% Fatality after 30 days
- 4 – 6Sv Acute Radiation Poisoning, 60% Fatality after 30 days
- 6 – 10Sv Acute radiation poisoning, Near 100% Fatality after 14 days
- 10 – 50Sv Acute radiation poisoning, 100% Fatality after 7 days

- **Radiation Sickness**: The symptoms can be mild, such as **loss** of appetite and mild **fatigue**, or evident only on laboratory tests with mild lymphopenia (subclinical), or may be **severe**, appearing as early as 5 min after exposure to very high doses of 10 Gy or more. Lower doses delay the onset of symptoms and produce less severe symptoms
- **Acute Regional Effects:** When enough radiation is delivered locally to a certain part of the body, as in the case of radiation therapy, acute effects can appear in the exposed area (skin **erythema** and gastrointestinal edema and ulceration).

Delayed Radiation Effects

- **Cancer:** The only stochastic somatic effect is cancer. Tissues with a high rate of cell proliferation are more **prone** to radiation tumor induction. Cancer becomes evident, following a period of latency-lejtenci. Leukemia first appears at least 2-5 years after exposure while solid tumors appear after at least 10 years, often several decades later.

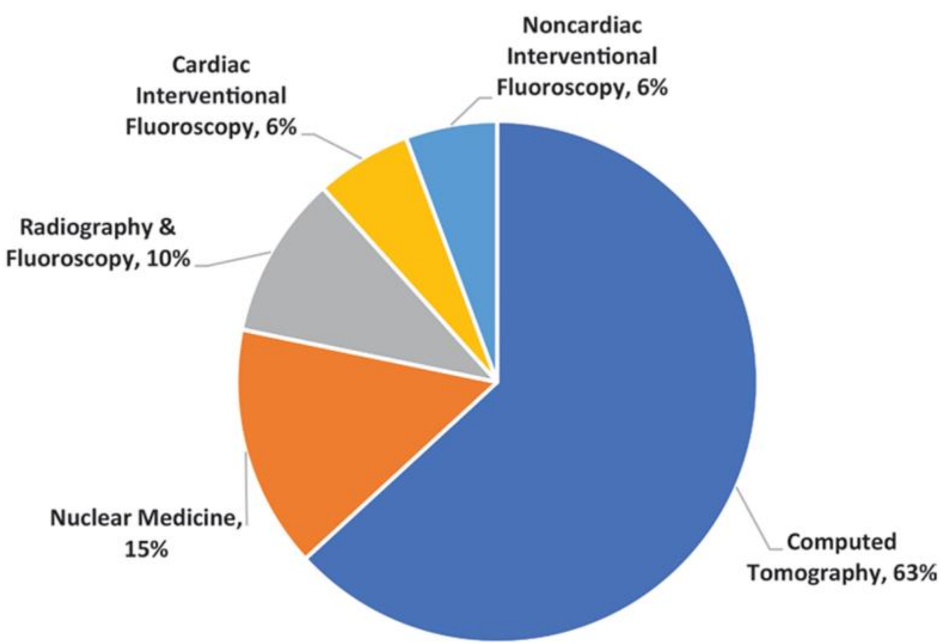
- There is no clear evidence that low-level radiation causes cancer. The incidences of thyroid cancer and leukemia in patients treated with iodine-131 in doses of up to several hundreds of MBq with 20 years follow-up were identical to those among patients treated surgically for the same conditions.

Delayed Radiation Effects

- **Genetic effects** may include changes in the number and structure of chromosomes and gene mutations, dominant or recessive.
- **Effects on the Unborn Child:** The embryonic stage is one of the most radiosensitive stages in the life of any organism. The classical triad of effects of radiation on the embryo is growth retardation, embryonic, fetal, or neonatal death, and congenital malformation. The probability of finding one or more of these effects is dependent **upon** radiation dose, the dose rate, and the stage of gestation at exposure.
- ICRP: exposure of embryos and fetuses-fituses to doses of less than 100 mGy incurs no risk of malformation.

- *During the first 2 weeks of conception the effect of radiation is an all or none effect, where the embryo is aborted. Following this period and up to 8 weeks the embryo is very vulnerable to congenital malformations.*

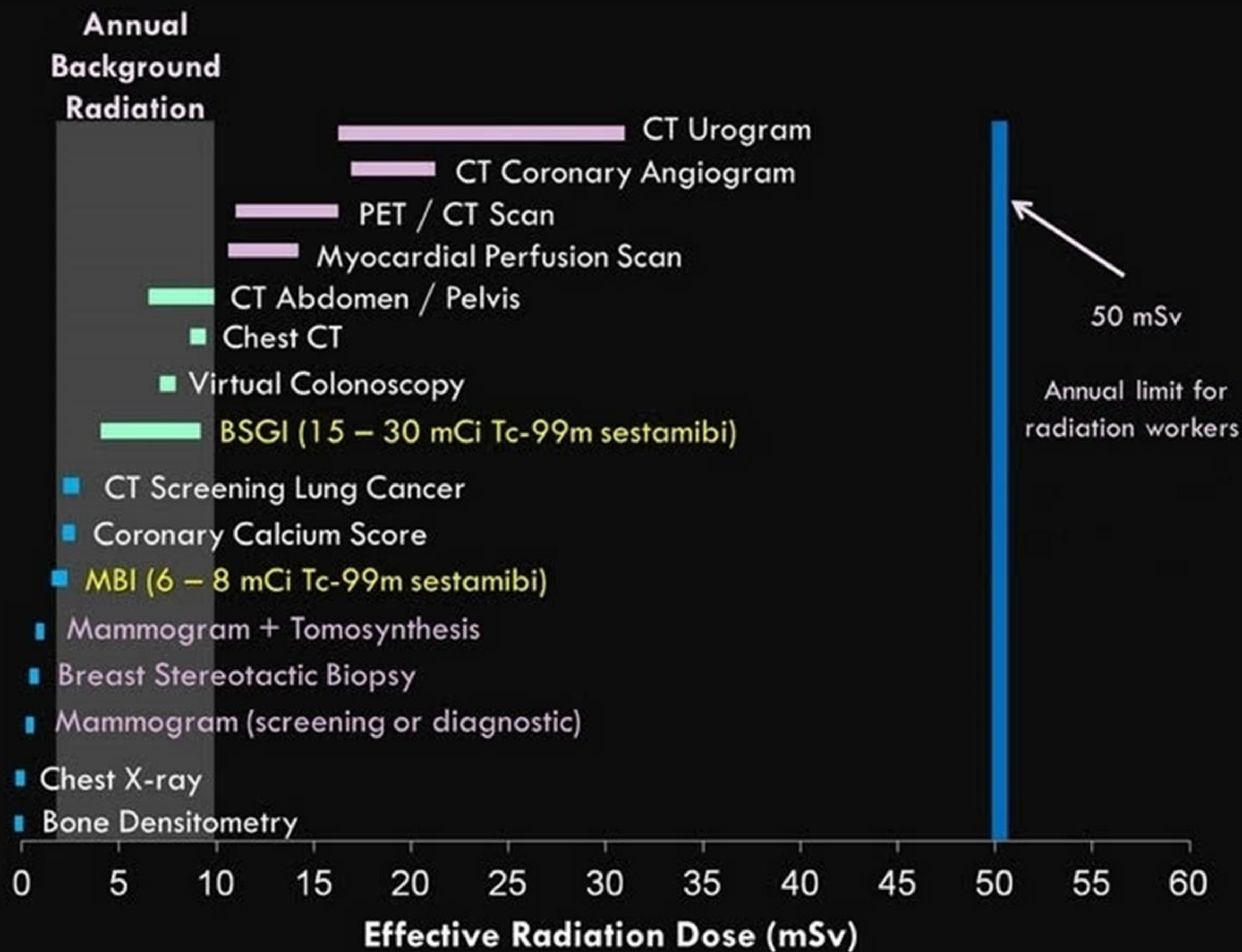
Exposure from Medical Procedures



- These levels of exposure from diagnostic medical procedures have no detectable biological effects. It is estimated that less than 0.006% of those undergoing nuclear medicine procedures in the USA might be affected annually.

Example: the chest X-ray delivers 0.1-0.2 mSv to the chest wall
The average nuclear medicine procedure delivers 3 mSv to the whole body.

The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP 2007;37(2-4):1-332.



Annual Background Radiation
CT Urogram
CT Coronary Angiogram
PET / CT Scan
Myocardial Perfusion Scan
CT Abdomen / Pelvis
Chest CT
Virtual Colonoscopy
BSGI (15 – 30 mCi Tc-99m sestamibi)
CT Screening Lung Cancer
Coronary Calcium Score
MBI (6 – 8 mCi Tc-99m sestamibi)
Mammogram + Tomosynthesis
Breast Stereotactic Biopsy
Mammogram (screening or diagnostic)
Chest X-ray
Bone Densitometry
50 mSv
Annual limit for radiation workers
0 5 10 15 20 25 30 35 40 45 50 55 60
Effective Radiation Dose (mSv)

Radiation effects

stochastic

Late effects

Carcinogenesis,
hereditary effects

deterministic

Early effects

Local or
common

Late effects

Cataract,
radiodermatitis
Teratogenic effects

Deterministic Effects

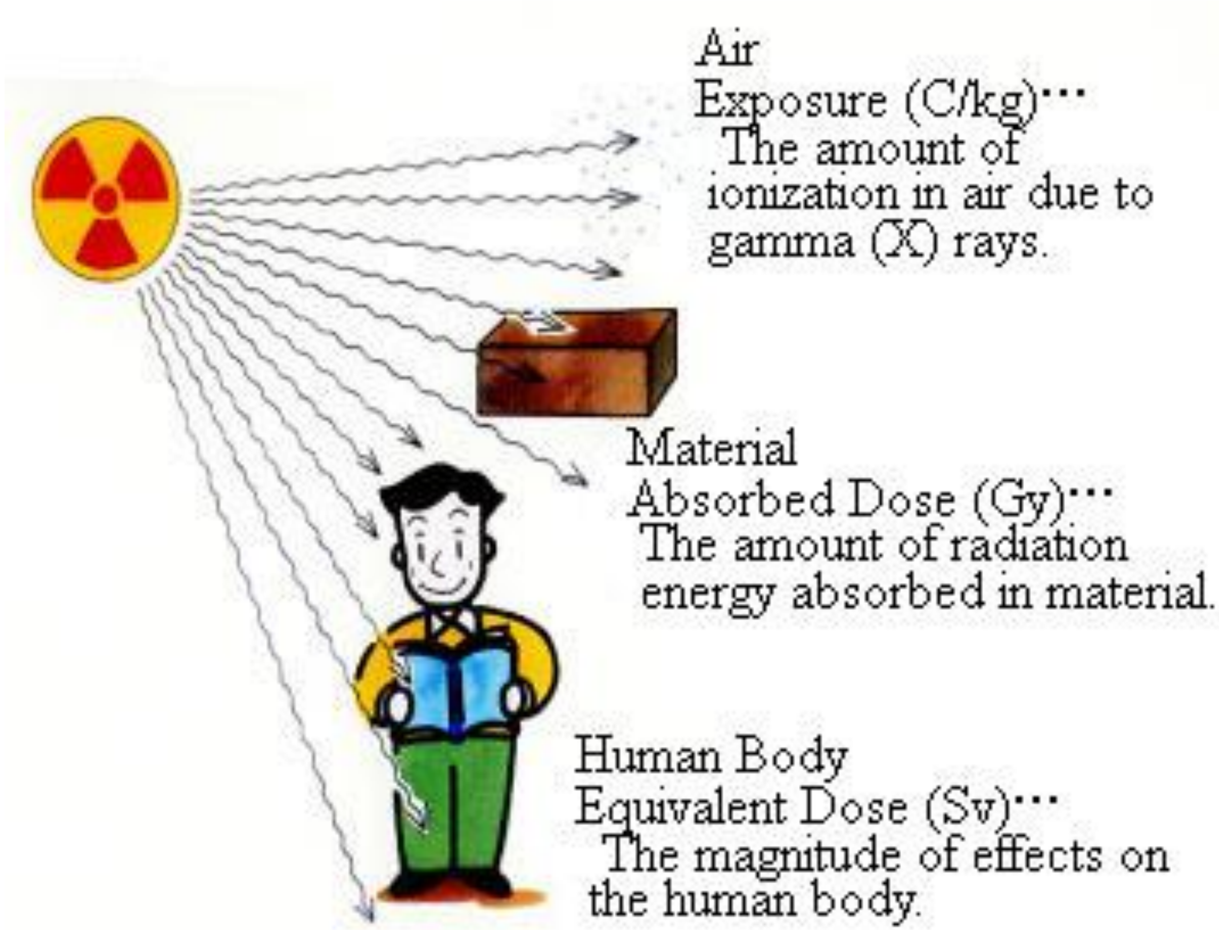
- The harmful effects of ionizing radiation has on human tissue can be divided into two types: **Deterministic and Stochastic.**
- **Deterministic effects** only occur once a threshold of exposure has been exceeded. The severity of deterministic effects increases as the dose of exposure increases. Radiation doses involved here are usually substantial and delivered over a short space of time and there is a threshold dose below which no clinical effect is observed.
- **Cataracts** are one of the most important of the deterministic effects.

- *Cataracts induced by radiation tend to develop on the posterior surface of the lens of the eye while the cataracts associated with old age, diabetes, etc., tend to occur on the anterior surface.*

Stochastic Effects

- stochastic effects are not assumed to have thresholds, i.e. doses below which the effects will not occur
- There is only a probability of effect occurring. This means that although there is no threshold level for these effects, the risk of an effect occurring increases linearly as the dose increases.
- For the purpose of radiation protection, stochastic effects are assumed to be possible at the smallest of doses.

Quantities and Units



Quantities and Units Used in Nuclear Medicine

Quantity	SI Unit	Conventional unit	Equivalence Meaning	Equivalence Meaning
Activity	Becquerel (Bq)	curie (Ci)	1 Bq=2.7×10^{-11} Ci	Number of disintegrations of radioactive material per second
Absorbed dose ionizing	gray (Gy) J/kg	rad	1 Gy=100 rad	Energy absorbed from radiation per unit mass of absorber
Exposure by	coulombs per kilogram (C/kg)	roentgen (R)	1 C/kg=3.9 ×103 R	Amount of charge liberated ionizing radiation per unit mass of air
Dose equivalent	Sievert (Sv)	rem	1 Sv = 100 rem	Absorbed dose times the quality factor (Dose × QF)

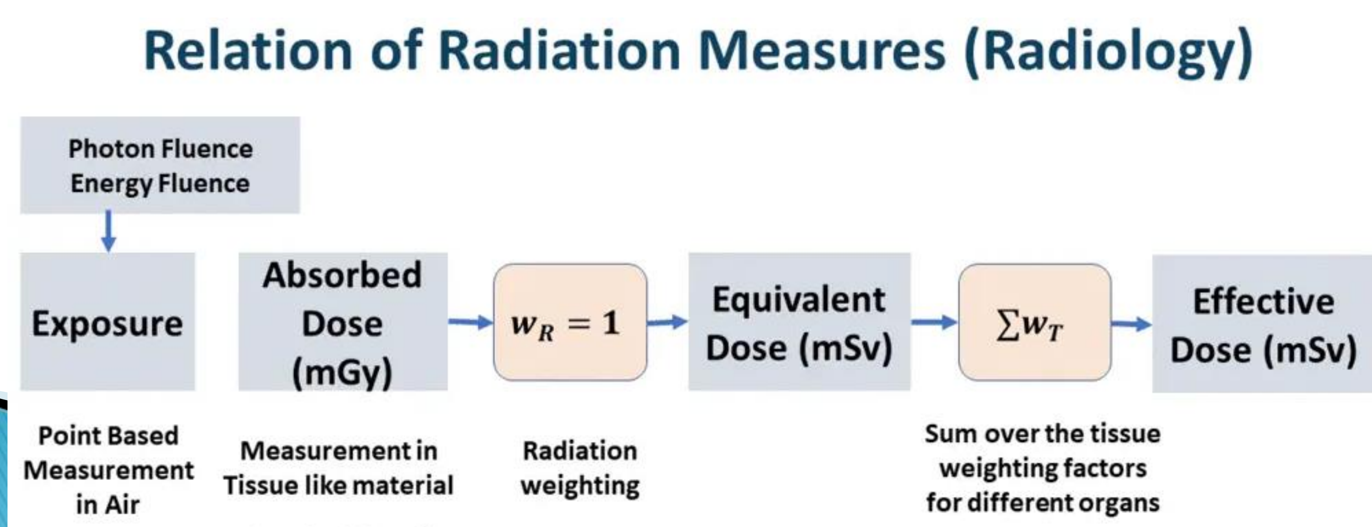
Radiation exposure

- is a measure of the ionization of air due to ionizing radiation from photons
- It is defined as the electric charge free by such radiation in a specified volume of air divided by the mass of that air
- The SI unit of exposure is C/Kg (Roentgen).

Absorbed dose

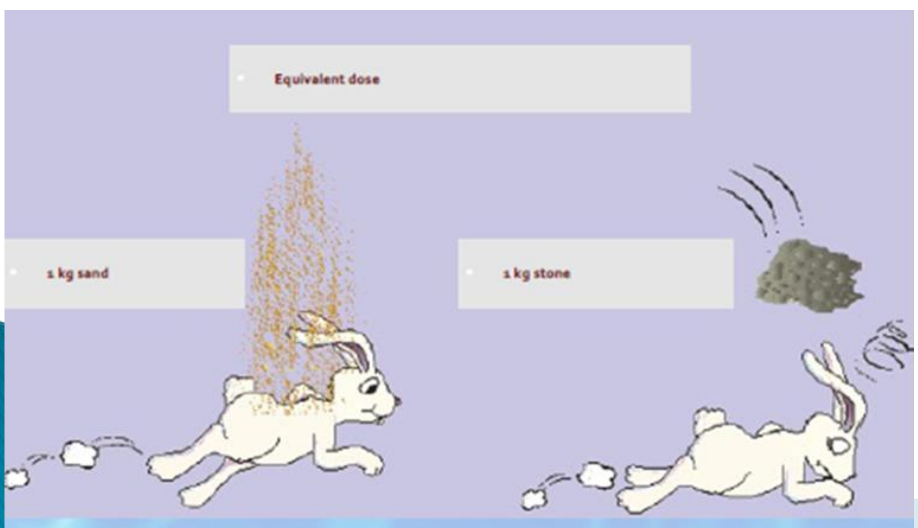
- total amount of ionizing radiation energy absorbed by an object.
- describe how much energy that radiation deposits in a material
- $D = \Delta ED/m$.

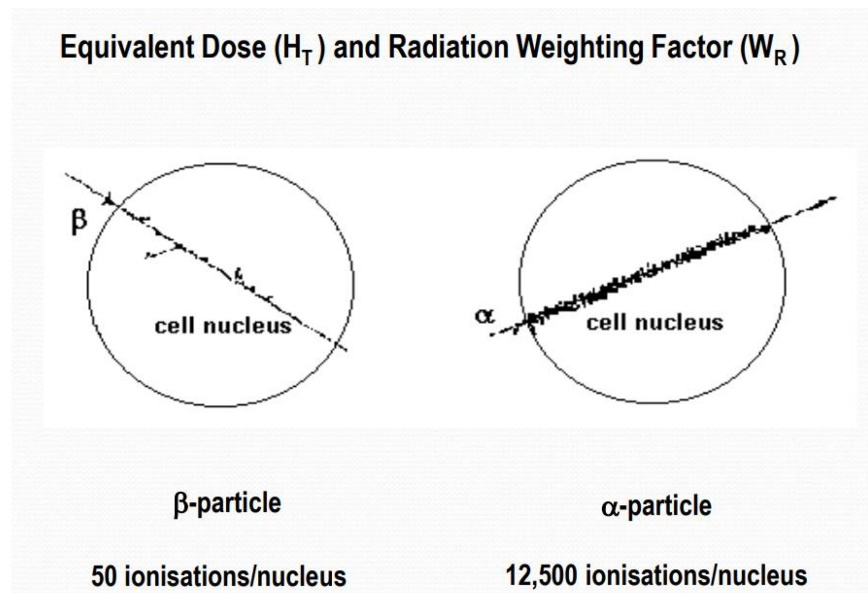
The SI unit is the gray 1 Gy = 1 J/kg and the conventional unit the rad;
1 Gy=100 rad and 1 rad =10mGy



Radiation Weighting Factor (WR)

- Importantly, for the same absorbed dose, the frequency and severity of biological effects are generally less for low-LET radiation than for high-LET radiations. The radiation weighting factor (wR), was invented for purposes of radiation protection:
- **Alpha Particles 20**
- **Beta Particles 1**
- **Photons 1**
- **Neutrons 5 – 20**





Equivalent Dose

- is a measure of the biological damage. The equivalent dose (H_T), in tissue or organ (T), is related to the radiation weighting factors (W_r) and the mean absorbed doses ($D_{T,R}$) to tissue or organ (T) due to radiations (R)

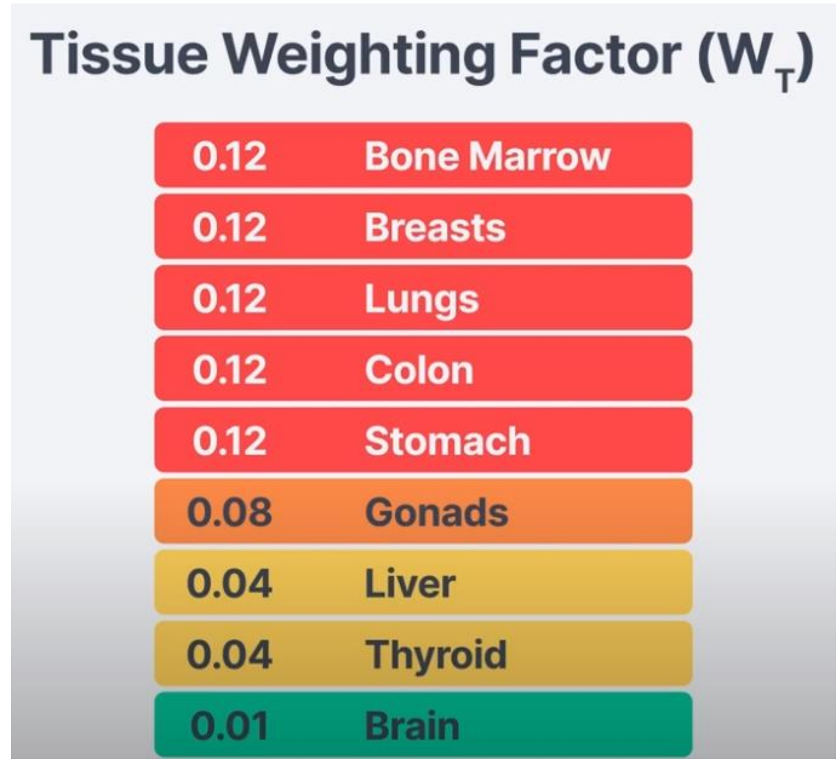
$$H_T = \sum_R W_R D_{T,R}$$

- For equivalent dose, the SI unit is the sievert (1 Sv=1 J/kg) and the conventional unit the rem 1 Sv=100 rem; 1 rem=10mSv

Tissue Weighting Factor

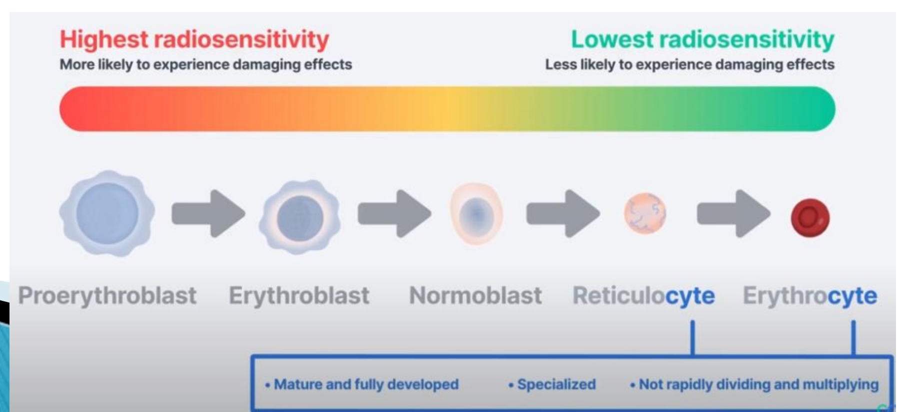
Not only that the different types of radiation produce different biological effects, but they also vary according to the sensitivity organ or tissue for the radiation.

For that ICRP 60 introduced the tissue weighting factors for different organs and tissues



Tissue Weighting Factor (W_T)

0.12	Bone Marrow
0.12	Breasts
0.12	Lungs
0.12	Colon
0.12	Stomach
0.08	Gonads
0.04	Liver
0.04	Thyroid
0.01	Brain



Effective Dose and Tissue Weighting Factor

- The effective dose (E) is intended to provide a single- value estimate of the overall stochastic risk (the total risk of cancer and genetic effects) of a given irradiation .
- Effective dose is defined as the product of Equivalent Dose and Tissue weighting factors (W_T)

$E = W_T H_T$

E – Effective Dose

W_T – Tissue Weighting Factor

H_T – Equivalent dose

If more than one organ is involved –

$$E = \sum_T W_T \sum_R W_R D_{T,R}$$

Dose Limit For Radiation Staff

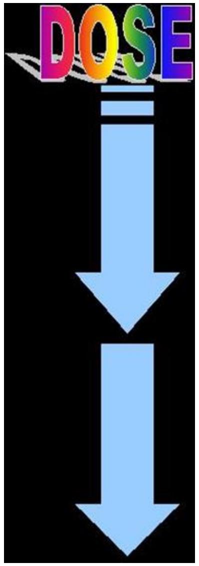
- The annual dose limit for radiation staff recommended by the ICRP has a 5-years mean of 20 mSv/year with a maximum dose in 1 year of 50 mSv.
- Annual equivalent doses for the skin, hands and feet are 500 mSv (ICRP 2007).
- The mean annual equivalent dose to the lens (averaged over a 5-years period) was recommended to be within the limit of 20 mSv with a maximum dose of 50 mSv in a year (ICRP, 2012).

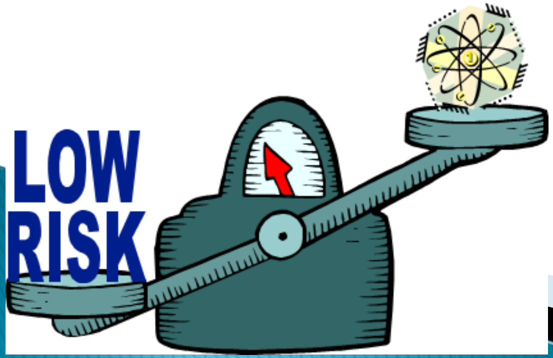
APPLICATION	OCCUPATIONAL DOSE LIMIT	PUBLIC DOSE LIMIT
Effective Dose	* 20 mSv per year, averaged over 5 years, and not more than 50 mSv in any 1 year.	** 1 mSv per year
Annual Equivalent Dose to:		
Lens of the eye	20 mSv	1 mSv
skin	500 mSv	50 mSv
hands and feet	500 mSv	-

International Commission on Radiological Protection-ICRP

Radiation Protection Standards

- for occupationally exposed individuals (such as nuclear medicine technologists and physicians) as well as for non-occupationally exposed **individuals/ididvidjuals**, radiation protection standards are based on the assumption – the no-threshold hypothesis – that any radiation dose above natural background may create some additional risk of damage – hereditary efects, potential life-span shortening, and, in particular, cancer.
- radiation safety program maintains radiation doses to workers and the public not just below the regulatory limit but as low as reasonably achievable (ALARA)





Personnel Dosimetry

- personnel monitors provide estimates of external exposure. Personnel dosimeters are generally changed monthly. Most radiation workers wear a single dosimeter on the trunk of the body. Certain /**serten/** workers such as radiopharmacists wear additional dosimeters (ring and eye glass dosimeters).

Personnel Dosimetry

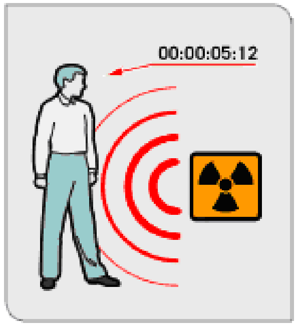
- "film badges" consisted of plastic holders containing a small piece of X ray film in a light-tight seal. The optical density, or opacity ("blackening"), of film is directly related to its exposure.

- Thermoluminescent dosimeters (TLDs) have now largely replaced film in personnel monitors. TLDs are composed of lithium fluoride, most commonly. When TLDs absorb radiation energy and are subsequently heated to sufficiently high temperatures, they emit visible light in an amount directly related to the radiation energy absorbed. Desirable characteristics of TLDs are sensitivity, linear, energy-independent response, and insensitivity to heat, light, and humidity, re-usability.

- Both film and TLDs are "integrating" detectors and thus yield the total dose up to the time the film is developed or the TLD is read. /**red**/

Limiting External Exposure

- **Time:** Minimize the time spent in the vicinity of a source of radiation. Work efficiently, but do not rush.

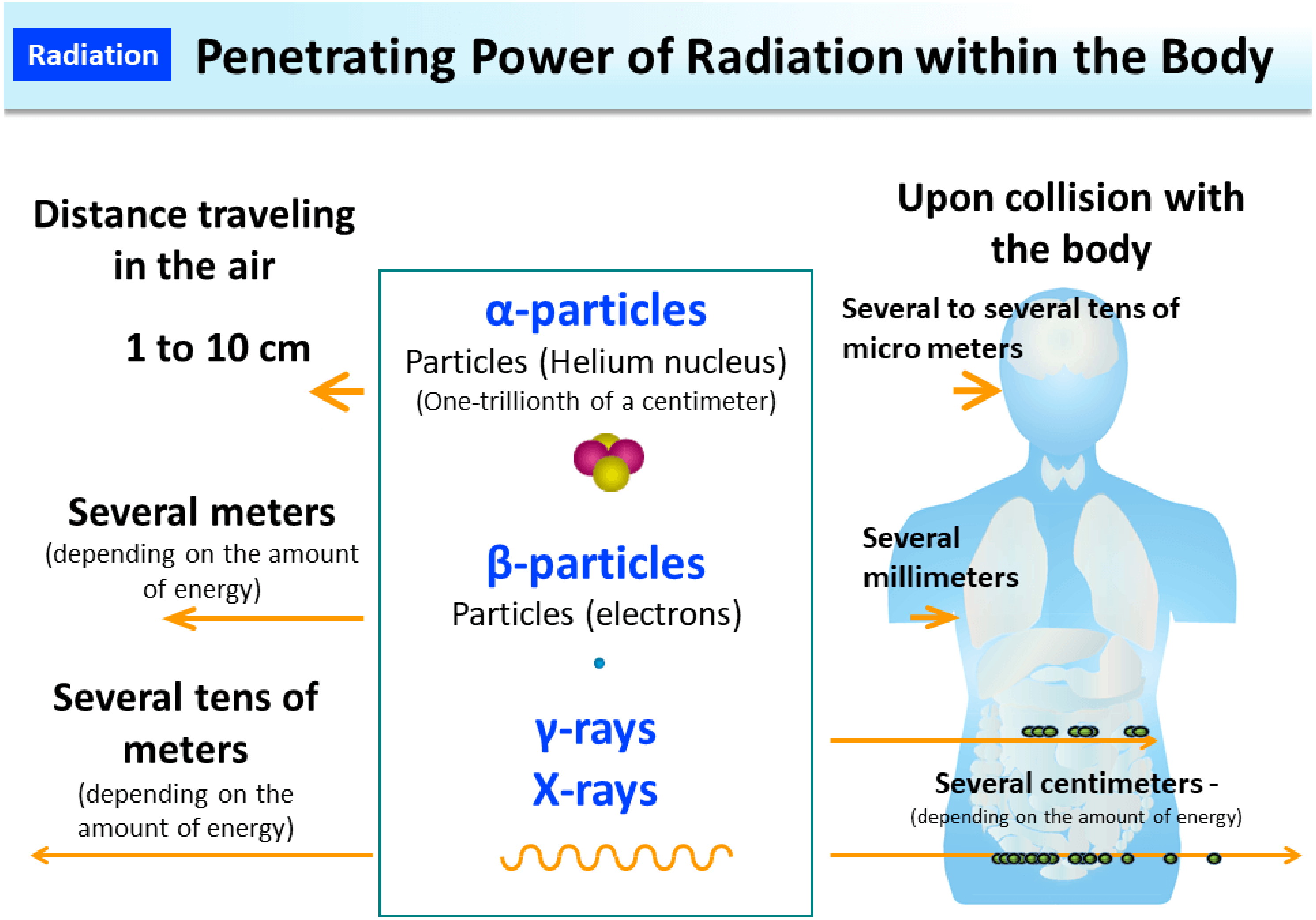


- **Distance:** Maintain as large distance from the source as practical. The radiation intensity from a source (patient or dose) diminishes rapidly as the distance from the source is increased. The radiation dose decreases as the inverse square of the distance from the source.

- **Shielding:** Shields take many forms: lead aprons /ejprons/, syringe shields, vial shields, countertop shields (often with leaded /leded/ glass), fixed and portable lead barriers, as well as thinner shields of plastic that may be used for beta-emitting and low-energy gamma emitting sources. The use of lead or other dense materials as shielding for beta particles is discouraged because the dose will be increased owing to the bremsstrahlung effect.

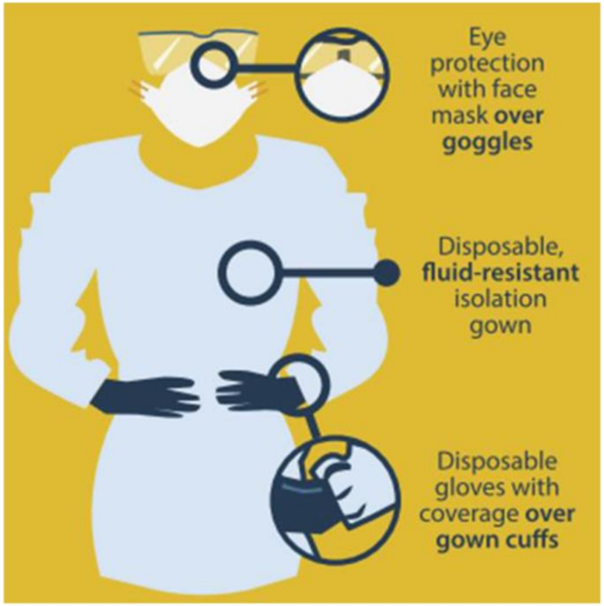

LEMER PAX

Shielding


Radiation
Penetrating Power of Radiation within the Body
Distance traveling in the air
1 to 10 cm
α-particles
Particles (Helium nucleus)
(One-trillionth of a centimeter)
Upon collision with the body
Several to several tens of micro meters
Several meters
(depending on the amount of energy)
β-particles
Particles (electrons)
Several millimeters
Several tens of meters
(depending on the amount of energy)
γ-rays
X-rays
Several centimeters -
(depending on the amount of energy)

Limiting Internal Exposure

- Protection techniques are oriented mainly toward preventing the radioactive material from entering the body. Entrance is most commonly by inhalation, but ingestion, absorption through intact skin, and intake through skin puncture is also possible.
- Limiting inhalation: Adequate air replacement and good airflow patterns
- Limiting ingestion: wearing protective gloves and coats when preparing doses or handling body fluids from a radioactive patient, hands be washed after the removal of gloves,
- eating, drinking, and smoking in radiation areas is strictly prohibited.



Limiting Exposure to Patients and Family Members

- Patient doses are calculated with the intention of reducing the exposure to as low a value as possible while performing a clinically useful diagnostic test.
- Education of patients and their family members is important particularly following the administration of beta emitters which excreted through bodily fluids, predominantly via urine.
- Hygienic /hajdzinik/* precautions, such as flushing the toilet twice after use, hand washing, and separate laundering of clothes and linen are necessary to prevent contact with radioactive urine/**jurine**/, sweat /svet/, and **saliva./salajva/**

Summary and Conclusions

1. Ionizing radiation is potentially harmful, the most important long-term risk is radiation-induced carcinogenesis.
2. All radiation exposures to staff, patients, and members of the public must be as low as reasonably achievable.
3. The safety of both patients and staff must be considered and the importance of staff education and training cannot be **overemphasized**.
4. Legislation has now been introduced to cover most aspects of work with radioactive materials.

Thank you for your attention

A radiographic exposure results in 0.015 joules of energy absorbed by the liver. If the liver weighs 0.9 kilograms, what is the total absorbed dose to the liver?

A. 0.0167 Gy
B. 0.0135 Gy
C. 60 Gy
D. 0.07 C

The thyroid of a radiation worker is exposed to an absorbed dose of 10 mGy from an alpha-emitting radionuclide. Calculate the effective dose.

A. 7 mGy
B. 8 mSv
C. 0.4 mSv
D. 10 mGy

D= J/kg=0,015 J/0,9 kg=0.0167

EqD=DxWr

Wr(X-ray)=1

EqD= 25mGy x 1= 25mSv

A radiation worker received a gonadal dose of 25 mGy over the course of a year. If 100% of this dose was from x-rays, what is the equivalent dose?

A. 25 mGy
B. 25 mSv
C. 3 mSv
D. 3 mGy

During an AP scoliosis x-ray, the breast, gonads, and stomach of a patient receive a dose of 3 mGy. What is the total effective dose?

A. 0.32 mSv
B. 0.0035 mSv
C. 0.96 mSv
D. I have no idea

EfD=D x Wr x Wt

Wr (alpha)=20

Wt (thyroid)=0.04

EfD= 10x20x0.04=8mSv

D=3 mGy

Wr (X-ray)=1

Wt (breast) =0.12

Wt (gonads) =0.08

Wt (stomach)=0.12

0.12+0.8+0.12=0.32

EfD =D x Wr x Wt=3x1x0.32

EfD =0.96 mSv

- Efective doze for thyroid after Thyroid examination (99mTc–pertehnetate scan)

Absorbed dose = 10 mGy

Wr=1

Wt=0.04

Efective dose=10 x0.04x1=0,4 mSv

1. During a surgical procedure the x-ray technologist stands at 1 meter from the c-arm for 1 hour and acquires an equivalent dose of 0.1 mSv. If the technologist had stood at a distance of 5 meters, what would their dose have been?

A. 0.5 mSv
B. 0.02 mSv
C. 0.004 mSv
D. 2.5 mSv

2. A radiograph is made with a 72 inch SID resulting in a receptor exposure of 0.01 mGy. What will the receptor exposure be if the SID is changed to 36 inches?

A. 0.0025 mGy
B. 0.04 mGy
C. 0.02 mGy
D. 0.005 mGy

2. When distance increase

3. Which of the following are referred to as nonpenetrating radiation?
(a) Positrons.
(b) Gamma photons.
(c) X-rays.
(d) Alpha particles.
(e) Beta particles.

3. (a), (d), (e).

4. Which term refers to the loss of energy or weakening of a beam of radiation as it passes through matter?
(a) Attenuation. (b) Absorption.

4. (a).

5. Which term is used to describe the transfer of energy from radiation to surrounding matter?
(a) Attenuation. (b) Absorption. (c) Annihilation reaction.

5. (b).

6. **Which of the following is true of the interaction of charged particles with matter?**

(a) Alpha particles have a higher LET than beta particles.

(b) The range of alpha particles is generally greater than beta particles.

(c) Alpha particles have a higher specific ionization than beta particles.

a and c are true, b is false; alpha particles have a shorter range than beta particles.

11 True or false: Gas filled detectors are highly efficient for detection of high-energy gamma photons and x-rays as well as low-energy beta particles.

12 . **Which of the following radiation detectors are classified as ionization chambers?**

(a) Pen dosimeter (b) Geiger counter (c) Dose calibrator.

13. True or false: Because of the near-maximal ionization of the gas molecules in a Geiger counter in response to each radiation interacting with a gas molecule in the detector, Geiger counters cannot be used to distinguish between types or energies of radiation.

.14.

- **True or false:** The film badge, unlike the pen dosimeter, can provide some information about the type and energy of the radiation an individual has **received.**
  True.
  The film badge is a detector that is commonly used to measure the cumulative exposure received by personnel working with radioactivity. It is simply a plastic holder containing film that is radiosensitive. Strips of materials of different densities (such as aluminum, cadmium, and lead) are placed within the badge in the space in front of the film. These strips attenuate the incoming radiation and reduce the degree of exposure of the film located immediately behind the strip. the amount of attenuation is dependent on the type of radiation (alpha, beta, gamma,or x-ray), the energy of the radiation, and the density of the absorber. By comparing the amount of exposure of film behind each strip (including a fourth uncovered area), some estimate as to the type and energy of the radiation can be determined. Unlike the pen dosimeter, which can be read by the user, the film badge must be sent to an outside laboratory for interpretation.

15. **True or false: The roentgen (C/kg) is a measure of radiation exposure in tissue.**

False: It is a measure of radiation exposure in air only.

16. **Pocket dosimeters are useful because**

(1) They do not need charging.

(2) They can differentiate between different types of radiation.

(3**) They can be used for immediate readings of radiation exposure.**

Select the three most effective ways to reduce exposure when working with radioactivity.

(a) Reduce the time spent in the vicinity of a radioactive source.

(b) Use soap when washing your hands.

(c) Maintain the maximum possible distance from the source.

(d) Shield the radioactive source.

(e) Wear a face mask.

23. The survey meter, also known as the Geiger-Mueller detector or Geiger counter, is a radiation detector filled with:

(A) Water

(B) Gas

(C) Lead

(D) Scintillation crystals

24. Popular radiation safety acronym ALARA stands for:

(A) As Low as Radiologist Approve

(B) As Low as Radiation Accepted

(C) As Low as Reasonably Achievable

(D) As Low as Reasonably Accepted

25. The radionuclides emitting b- particles should be stored in containers of low Z material to prevent:

(A) Compton scatter

(B) Bremsstrahlung radiation

(C) Back injuries

(D) Extra expenditures

26. All of the following are recommended means of reducing radiation exposure EXCEPT:

(A) Use of remote handling devices

(B) Applying shielding

(C) Wearing film badge

(D) Limitation of time

27. The diagnostic and therapeutic uses of radiopharmaceuticals are dependent on the accumulation of the material in the “organ of interest.” According to the Nuclear Regulatory Commission (NRC) definition, the part of the body that is most susceptible to radiation damage under the specific conditions under consideration is called:

(A) The critical organ

(B) The paired organ

(C) The target organ

(D) The internal organ