

6. BIOLOGICAL EFFECTS OF RADIATION

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“Radiation biology is the branch of biology concerned with the effects of ionizing radiation on living systems.”

Radiations having adequate energy to ionize atoms, dissociate molecules, or alter nuclear structures. The adult body is composed of 70% water. Radiation interacts by either ionizing or exciting the atoms or molecules in the body (water). Energy is deposited and absorbed as a result of these interactions.

➤ TYPES OF RADIATION:

1) Ionization Radiation

a) **Electromagnetic Radiation:** X-ray and Gamma ray

b) **Corpuscular Radiation:** alpha particle, beta particles, and protons.

2) **Non ionizing radiation:** Ultraviolet radiation, visible, infrared, microwave and radio frequency radiation.

1) Ionization Radiation:

- The term ionization is applied to radiation which has the ability to penetrate tissues and deposit its energy in to the tissues.
- Here, alpha particles are 10 times as harmful as X-ray, beta or gamma rays. But alpha particles have little penetrating power. While it is dangerous if it is enter by inhalation or through wound in to body.
- Gamma ray and X-ray have shorter wave length but have deeper penetrating power.
- X-rays are man made while gamma rays are emitted spontaneously by radioactive elements during their disintegration.

2) Non ionizing radiation:

- These types of radiation rays have longer wave length than ionizing radiation rays.
- As wavelength elongated, the value of electromagnetic radiation decreases. So all non ionizing forms of radiation have less energy than ionizing form.

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Some common environmental radiations			
	Approximate penetrating ability		
Types of radiation	Air	Tissue	Lead
Alpha particles	4 cm	0.05 mm	0
Beta particles	6-300 cm	0.06-4.0 mm	0.005-0.3 mm
Gamma rays	400 meters	50 mm	40 mm
X-rays	120-240 meters	15-30 mm	0.3 mm

➤ RADIATION UNITS:

The potency of radiation is mainly measured in three way:

- 1) Roentgen: Roentgen is the unit of exposure. It is the amount of absorbance in air at a given point.
- 2) Rad: It is the unit of absorbed dose. It is the amount of radioactive energy absorbed per gram of tissue or any material.
- 3) Rem: It is the product of absorbed dose and modifying factors. It indicates the degree of potential danger to health.

Now a day, the radiation unit roentgen is replaced by coulomb per kilogram, rad is replaced by gray (Gy) and Sievert (Sv) replacing the rem.

➤ THE ACTION OF RADIATION ON THE CELL IS CLASSIFIED AS EITHER: DIRECT OR INDIRECT.

Direct Attack:

- Incident radiation directly attacks the DNA of the water molecule and ionizes water molecules; electrons are released.
- The ionized water molecules can react further - forming highly reactive molecules such as hydrogen peroxide, or radicals such as hydroperoxyl.
- Biologic chain reaction occurring.

Indirect Attack:

- These are effects mediated by free radicals.

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- A free radical is an electrically neutral atom with an unshared electron in the orbital position. The radical is electrophilic and highly reactive.
- Since the predominant molecule in biological systems is water, it is usually the intermediary of the radical formation and propagation.

➤ **BIOLOGICAL EFFECTS OF RADIATION:**

- Tissue damage may be by deterministic or stochastic.
 - The low dose or “stochastic” effects (statistical), which could be seen, are: Carcinogenesis (i.e. induction of cancer) and Genetic effects (i.e. damage seen in offspring).
 - In case of very high doses, the types of biological effects seen are called “Deterministic” Effects (Definite). Effects include: Cataracts, Reddening of the skin, Burns, Hair loss, Blood changes, Temporary or permanent sterility, Nausea, CNS damage, Death.
 - To prevent the occurrence of deterministic effects and to protect against unacceptable risk of stochastic effects it is essential to show the limit of dose.
 - **Deterministic Effect become visible in different doses is;**
 - 20 Sv:** Death within hours due to CNS failure.
 - 5-10 Sv:** Death within days due to destruction of cells in gut lining.
 - 2-5 Sv:** Death within weeks due to bone marrow failure.
- But limit for occupational exposure is 20 msv.

● **1) Radiation Effects on DNA:**

- The biological effects of ionizing radiation originate primarily from damage to the DNA of a cell or cells.
- Cells that divide more rapidly are more sensitive to the effects of radiation. So it is essential to know that the type of effect the radiation can have on the DNA is determined by whether it is a low dose which mainly damages cells, or a high dose which mainly kills cells.

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Basically, there are four things that can happen:

1. The radiation may pass through the cell without doing any damage.
2. The radiation may damage the cell, but cell repairs damage.
3. The radiation may damage the cell so that the cell not only fails to repair itself but reproduces itself in the damaged form – Biological Response.
4. The radiation may cause so much damage, cell dies.

2) Somatic effects of radiation:

- A dose of 400-500 roentgens is fatal for whole body in about 50 percent of cases.
- A dose of 600-700 roentgens are harmful in every case.

Mainly two types of effects are seen in affected person;

- A. Acute:** In which mainly white blood cells are affected and produce mild lassitude and softening of the muscles.
- B. Chronic:** These effects mainly seen after some weeks to years. It produces mainly three kinds of effects Leukemia, Malignant tumors and Shortening of life.

3) Genetics Effects:

- It is mainly due to injury in to the chromosomes. Chromosomes produce chromosome mutation and point mutation.
- Chromosome mutation is associated with sterility.
- Point mutation affects the genes.

Eg: Japanese atom bomb survivor of the twin city Hiroshima and Nagasaki after World War II have increase frequency of malignant tumors, acute and chronic myeloid leukemias and various solid tumors of breast, colon, thyroid and lungs due to genetic mutation.

SOURCES OF RADIATION:

1. Natural Background Radiation
2. Man-Made Radiation

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1. Natural Background Radiation:

a) Cosmic Radiation:

- The earth, and all living things on it, is constantly bombarded by radiation from outer space.
- Charged particles from the sun and stars interact with the earth's atmosphere and magnetic field to produce a shower of radiation.

b) Terrestrial Radiation

- Radioactive elements are found in soil, water, and vegetation.
- Important radioactive elements include uranium and thorium and their radioactive decay products which have been present since the earth was formed billions of years ago.
- Some radioactive material is ingested with food and water. Radon gas, a radioactive decay product of uranium is inhaled.

c) Internal Radiation:

- People are exposed to radiation from radioactive material inside their bodies. Besides radon, the most important internal radioactive element is naturally occurring potassium-40 but uranium and thorium are also present.
- On average, in the United States radon contributes 55% or all radiation exposure from natural and man-made sources. Another 11% comes from the other radioactive materials inside the body

2) Man-Made Radiation:

a) Machines:

- Medicine: Diagnostic (x ray, fluoroscopes, CAT scans), therapeutic (accelerators)
- Industry and Research (x ray, accelerators)

b) Radioactive Material:

- Medicine: diagnostic (thyroid scans, stress tests), therapeutic (cobalt irradiation [cancer], hyperthyroid treatment)
- Biological and Medical Research (tracers, radio-pharmaceuticals, drug development)
- Industry - (thickness/density gauges, well logging)