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Types of Ionizing Radiation

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Radiation, the transport of energy by electromagnetic waves or atomic particles, can be classified into two main categories depending on its ability to ionize matter. For example, the minimum energy required to ionize an atom, ranges from a few electron volts for alkali elements to 24.6 eV for helium which are in the group of noble gases.

Uses of radiation

- Hospitals use radiation in a wide range of ways. X-Ray, CT, and PET machines use X-ray (X-ray and CT) and Gamma radiation (PET) to produce detailed images of the human body, which provide valuable diagnostic information for doctors and their patients. Radionuclides are also used to directly treat illnesses, such as radioactive iodine, which is taken up almost exclusively by the thyroid, to treat cancer or hyperthyroidism. Radioactive tracers and dyes are also used to be able to accurately map a specific area or system, such as in a cardiac stress test, which may use a radioactive isotope like Technetium-99 to identify areas of the heart and surrounding arteries with diminished blood flow.

- Food irradiation is the process of using radioactive sources to sterilize foodstuffs. The radiation works by killing bacteria and viruses or eliminating their ability to reproduce by severely damaging their DNA or RNA. Since neutron radiation is not used, the remaining food doesn't become radioactive itself, leaving it safe to eat. This method is also used to sterilize food packaging, medical devices, and manufacturing parts.

- Some smoke detectors also use radioactive elements as part of their detection mechanism, usually americium-241, which use the ionizing radiation of the alpha particles to cause and then measure changes in the ionization of the air immediately around the detector. A change due to smoke in the air will cause the alarm to sound.

—**Non-ionizing radiation** cannot ionize matter because its energy is below the ionization potential of atoms such as Near ultraviolet radiation, visible light, infrared photons, microwaves and radio waves.

— **Ionizing radiation** takes a few forms: Alpha, beta, and neutron particles, and gamma and X-rays. All types are caused by unstable atoms, which have either an excess of energy or mass (or both). In order to reach a stable state, they must release that extra energy or mass in the form of radiation.

Ionizing radiation is radiation that have enough energy to remove an electron from an atom or a molecule, this will lead to create ions that may be a damaging into the environment of the irradiated medium.

Ionizing radiation can ionize matter either directly or indirectly because its energy is greater than the ionization potential of atoms.

Ionizing radiation can be categorized into two types:

1- directly ionizing radiation

2-indirectly ionizing radiation .

Both directly and indirectly ionizing radiation can passing through human tissue, thereby enabling the use of ionizing radiation in medicine for both imaging and therapeutic procedures .

Type of Ionization

- **Directly ionizing radiation** consists of charged particles, such as electrons, protons, α particles and heavy ions. It deposits energy in the medium through direct Coulomb interactions (It is force of attraction between positive and negative charge) between the charged particle and electrons of atoms in the absorber.

- **Indirectly ionizing radiation** consists of uncharged (neutral) particles which deposit energy in the absorber through a two-step process. In the first step, the neutral particle releases or produces a charged particle in the absorber which, in the second step, deposits at least part of its kinetic energy in the absorber through Coulomb interactions with electrons of the absorber.

Biological Effects of Ionizing Radiation

1-Mechanisms of Radiation Damage

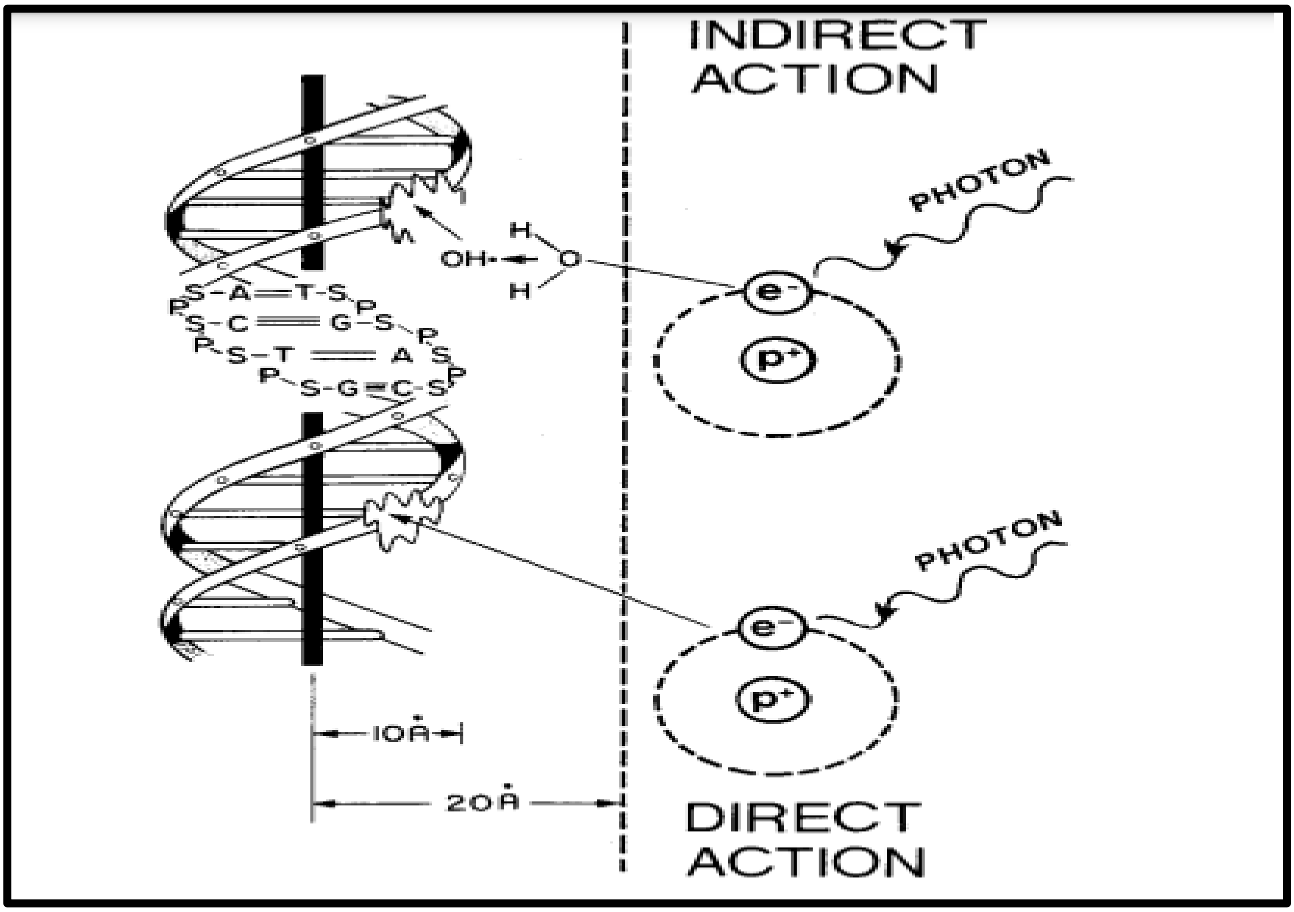
Radiation damage starts at the cellular level. Radiation that is absorbed in a cell has the potential to impact a variety of critical targets in the cell, the most important of which is the DNA. Evidence indicates that damage to the DNA is what causes cell death, mutation, and carcinogenesis. The mechanism by which the damage occurs can happen in one of two ways.

A. Direct Action

In a first way, radiation may impact the DNA directly, causing ionization of the atoms in the DNA molecule. This can be visualized as a “direct hit” by the radiation on the DNA, and this is a fairly uncommon occurrence due to the small size of the target; the diameter of the DNA helix is only about 2 nm. It is estimated that the radiation must produce ionization within a few nanometers of the DNA molecule in order for this action to occur.

B. Indirect Action

In a second way, the radiation interacts with non-critical target atoms or molecules, usually water. This results in the production of free radicals, which are atoms or molecules that have an unpaired electron and thus are highly reactive. These free radicals can then attack critical targets such as DNA below (Figure). Because they are able to diffuse some distance in the cell, the initial ionization event does not have to occur so close to the DNA in order to cause damage. Thus, damage from indirect action is much more common than damage from direct action, especially for radiation that has a low specific ionization.



Mechanisms of Radiation Damage

When the DNA is attacked, either via direct or indirect action, the damage is caused to the strands of molecules that make up the double-helix structure. Most of this damage consists of breaks in only one of the two strands and is easily repaired by the cell, using the opposing strand as a template. If, however, a double-strand break occurs, the cell has much more difficulty repairing the damage and may make mistakes. This can result in mutations, or changes to the DNA code, which can result in consequences such as cancer or cell death. Double-strand breaks occur at a rate of about one double-strand break to 25 single-strand breaks. Thus, most radiation damage to DNA is reparable.

2-Determinants of Biological Effects

A. Rate of Absorption

The rate at which the radiation is administered or absorbed is most important in the determination of what effects will occur. Since a considerable degree of recovery occurs from the radiation damage, a given dose will produce less effect if divided (thus allowing time for recovery between dose increments) than if it were given in a single exposure organ.

B-Area Exposed

The portion of the body irradiated is an important exposure parameter because the larger the area exposed, other factors being equal, the greater the overall damage to the organism. This is because more cells have been impacted and there is a greater probability of affecting large portions of tissues or organs. Even partial shielding of the highly radiosensitive blood-forming organs such as the spleen and bone marrow can mitigate the total effect considerably. An example of this phenomenon is in radiation therapy, in which doses that would be lethal if delivered to the whole body are commonly delivered to very limited areas, e.g., to tumor sites. Generally, when expressing external radiation exposure without qualifying the area of the body involved, whole-body irradiation is assumed.

C. Variation in Species and Individual Sensitivity

There is a wide variation in the radiosensitivity of various species. Within the same species, individuals vary insensitivity. For this reason, the lethal dose for each species is expressed in statistical terms, usually for animals as the LD50/30 for that species, For humans, the LD50/60 (the dose required to kill 50 percent of the population in 60 days).

D. Variation in Cell Sensitivity

Within the same individual, a wide variation in susceptibility to radiation damage exists among different types of cells and tissues. In general, those cells which are rapidly dividing or have a potential for rapid division are more sensitive than those which do not divide. Further, cells which are non-differentiated (i.e., primitive, or non-specialized) are more sensitive than those which are highly specialized. Within the same cell families, then, the immature forms, which are generally primitive and rapidly dividing, are more radiosensitive than the older, mature cells which have specialized in function and have ceased to divide. This radiosensitivity is defined as the "Law of Bergoniè and Tribondeau". One exception to this law is mature lymphocytes, which are highly radiosensitive. Based upon these factors, it is possible to rank various kinds of cells in descending order of radiosensitivity. Most sensitive are the white blood cells called lymphocytes, followed by immature red blood cells. Epithelial cells, which line and cover the body.