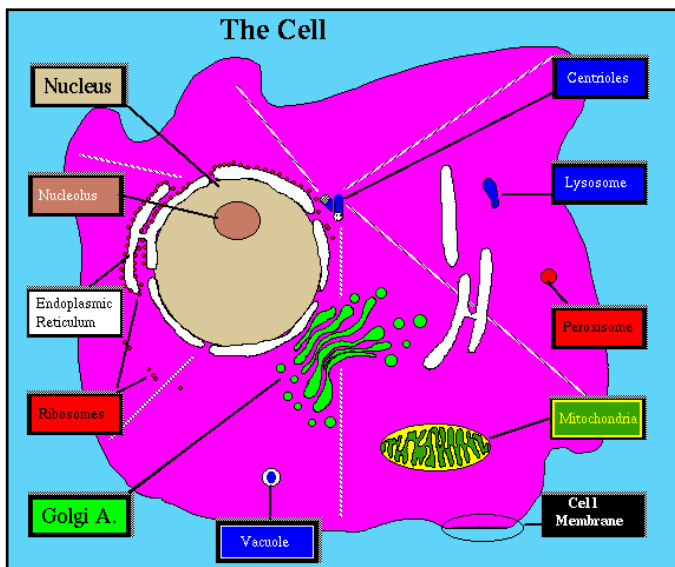


CHAPTER 3 – RADIOBIOLOGICAL CONCEPTS

Injury due to irradiation is caused mainly by ionization within the tissues of the body. When radiation interacts with a cell, ionizations and excitations are produced in either biological macromolecules or in the medium in which the cellular organelles are suspended, predominantly water. Based on the site of interaction, the radiation-cellular interactions may be termed as either direct or indirect. The term, “radiosensitivity,” is used to describe the relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation. The term, “radiotoxicity,” is used to refer to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.



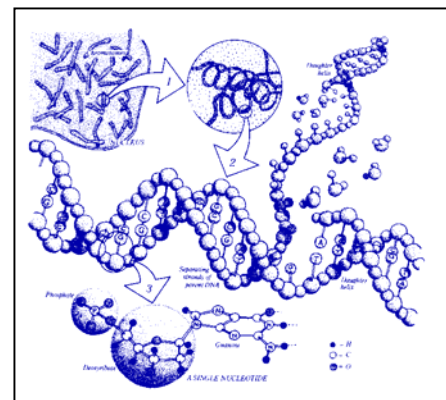
Direct action occurs when an ionizing particle interacts with and is absorbed by a macromolecule in a cell (DNA, RNA, protein, enzymes, etc.). These macromolecules become abnormal. The abnormalities initiate the events that lead to biological changes.

Indirect action involves the absorption of ionizing radiation in the water medium in which the macromolecules are suspended. Through a

complex set of reactions, the ionized water molecules form free radicals that can cause damage to the macromolecules.

The most important target for radiation in the cell is DNA in the nucleus. Biological effects result when DNA damage is not repaired or is improperly repaired. Extensive damage to DNA can lead to cell death. Large numbers of cells dying can lead to organ failure and death for the individual. Damaged or improperly repaired DNA may develop into lymphoma and cancers in somatic cells. Two kinds of effects may result.

Acute, or non-stochastic, effects are health effects,



the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a non-stochastic effect (also known as a deterministic effect).

Delayed, or stochastic, effects, are health effects that occur randomly and for which the probability of the effect occurring, rather than the severity, is assumed to be a linear function of the dose without threshold. Genetic effects and cancer incidence are examples of stochastic effects.

Radiation causes ionizations in the molecules of living cells. These ionizations result in the removal of electrons from the atoms, forming ions or charged atoms. The ions formed then can go on to react with other atoms in the cell, causing damage. An example of this would be if a gamma ray passes through a cell, the water molecules near the DNA might be ionized and the ions might react with the DNA causing it to break.

The absorbed dose is the amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the rad, which is 100 ergs/gram. The quality factor is a modifying factor that is used to derive dose equivalent from absorbed dose. It corrects for varying risk potential due to the type of radiation. The dose equivalent is the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and the sievert (Sv). The rem is the special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and any other necessary modifying factors. The sievert is the international unit (SI) of dose equivalent. The sievert is equal to 100 rem.

At low doses, such as what we receive every day from background radiation, the cells repair the damage rapidly. Background radiation is ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

At higher doses (up to 100 rem), the cells might not be able to repair the damage, and the cells may either be changed permanently or die. Most cells that die are of little consequence, the body can just replace them. Cells changed permanently may go on to produce abnormal cells when they divide. In the right circumstance, these cells may become cancerous. This is the origin of our increased risk in cancer, as a result of radiation exposure.

At even higher doses, the cells cannot be replaced fast enough and tissues fail to function. An example of this would be "radiation sickness." This is a condition that results after high doses to the whole body (>100 rem), where the intestinal

lining is damaged to the point that it cannot perform its functions of intake of water and nutrients, and protecting the body against infection. This leads to nausea, diarrhea and general weakness. With higher whole body doses (>300 rem), the body's immune system is damaged and cannot fight off infection and disease. At whole body doses near 400 rem, if no medical attention is given, about 50% of the people are expected to die within 60 days of the exposure, due mostly to infections.

If someone receives a whole body dose more than 1,000 rem, he/she will suffer vascular damage of vital blood providing systems for nervous tissue, such as the brain. It is likely at doses this high, 100% of the people will die, from a combination of all the reasons associated with lower doses and the vascular damage.

Since these doses are much greater than anyone experiences occupationally, you should know the risks for lower doses. According to the BEIR¹ V Report, the risk of cancer death is 0.08% per rem for doses received rapidly (acute) and might be 2-4 times (0.04% per rem) less than that for doses received over a long period of time (chronic). These risk estimates are an average for all ages, males and females, and all forms of cancer. There is a great deal of uncertainty associated with the estimate.

Radiation induced genetic effects have not been observed to date in humans. The largest source of material for genetic studies involves the survivors of Hiroshima and Nagasaki, but the 77,000 births that occurred among the survivors showed no evidence of genetic effects.

If cells are dividing very rapidly and are undifferentiated in their structure and function, they are generally more sensitive to radiation. In the embryo stage, cells meet both these criteria and would be expected to be highly sensitive to radiation. The embryo is an early stage of development, before the individual limbs and organs are recognizable. In humans, this development takes about eight weeks. The organism is considered a fetus from that stage until birth.

There is direct evidence that the human embryo/fetus is more radiosensitive than an adult. There is also evidence that it is especially sensitive to certain radiation effects during the first 2 to 3 months after conception when a woman may not be aware that she is pregnant. Those radiation effects include childhood cancer and certain growth and development abnormalities.

URI limits the exposure to an unborn child to 500 millirems or less during pregnancy. This protection is offered to any woman who declares her pregnancy in accordance with state regulations. You should contact the Radiation Safety Office if you wish to declare a pregnancy or want additional information regarding such a declaration.

¹ Biological Effects of Ionizing Radiation Committee V