Radiobiology (also known as radiation biology), as a field of clinical and basic medical sciences, originated from Leopold Freund's 1896 demonstration of the therapeutic treatment of a hairy mole using a new type of electromagnetic radiation called x-rays, which was discovered 1 year previously by the German physicist, Wilhelm Röntgen. At the same time, Pierre and Marie Curie discovered the radioactive polonium and radium later used to treat cancer. In simplest terms, radiobiology is the study of the action of ionizing radiation on living things.

(Figure 1) Radiation Biology – Mechanism

The absorption of radiation energy initiates a large number of processes in a cell. It may take some time (weeks, months and years) before the biological result can be observed. This situation must not lead us to believe that nothing takes place in this latent period.
The starting point is the absorption process (Figure 2). Radiation energy is deposited in the system and a number of “primary” products are formed. These products (ions, excited molecules, and free radicals) are very reactive with lifetimes in an ordinary cell of the order of a fraction of a second. Their reactions with molecules in the cell result in secondary processes which finally yield a macroscopic result such as cell death, cancer or genetic change.

(Figure 2) The radiation-induced processes in a biological system.

1-1 Molecular theory of Radiation Biology

A theory that can be used to explain the biological effects of ionizing radiation to low doses, many different LET particles, and to interactions between radiation and chemical agents for end points such as cytotoxicity, mutation, chromosome aberrations, and DNA damage. The theory is based on the assumption that DNA is the target and that double-strand breaks in it are the molecular lesions responsible for the biological effects of radiation.
1-2 Radiation Damage to Proteins and DNA

Protein consists of amino acids bonded together in long chains called polypeptide chains. Altogether, 20 different amino acids can be combined in a large number of ways. Radiation damage and changes to the different amino acids, as well as to shorter or longer peptide chains. Many proteins are enzymes, the “workhorses” in the cell operating as catalysts for a number of biochemical processes. (Figure 3)

1-3 Radiation damage to DNA

There are four types of DNA Damage as Follow:

1-3-1 Single strand breaks
A single strand break is simply a break in one of the sugar-phosphate chains. This damage is usually simple to repair and, in experiments, it has been shown that approximately 90% of the single strand breaks are repaired in the course of one hour at 37°C.

1-3-2 Double strand breaks
This type of damage involves both strands of the DNA helix, which are broken opposite to each other or within a distance of a few base pairs. If you look at Figure 4, you may imagine that this damage would kill the cell and in experiments with bacteria a correlation is found between double strand breaks and cell death.

1-3-3 Base damage
Experiments indicate that radiation sensitivity varies from one base to another. After an initial ionization, rapid electronic reorganizations take
place with the result that the damage is transported to certain regions of the macromolecule. The base guanine is particularly sensitive.

1-3-4 Clustered damage

Clustered damage is what makes ionizing radiation quite different from other agents that cause DNA damage.

(Figure 3 The DNA molecule with 4 common types of radiation damage)

1-4 Radiation Damage to Cells

Cell death induced by radiation can be divided into two groups:

1. If a cell dies after the first mitosis it is called mitotic death or reproductive death.
2. If the cell dies before reaching the first mitosis it is called interphase death.

1-5 Radiation and Chromosomal Aberrations

The mechanisms for the formation of aberrations are not yet fully understood. To some degree, they involve strand breaks in the DNA-molecule. While the biological effects connected with chromosome changes are also not fully understood, there is a correlation between cancer induction and the incidence of aberrations. Moreover, the formation of chromosomal changes can be used to attain information on the radiation dose. Attempts have been made to find chromosomal aberrations in groups of people exposed in the Chernobyl accident and after the atmospheric nuclear tests in the 1950s and 1960s (figure 5).

(Figure 4) Type of Chromosomal aberration induced by Radiation.
1-6 Repair Processes

Cells have repair systems. This is a necessity for survival. The crew working on repair in our cells are enzymes. It is the job of some enzymes to detect DNA damage while others are called upon to repair the damage. The repair processes can be divided into three types:

A • The specific site of damage is repaired. In this case the enzymes work right at the damaged site. The original base sequence is preserved.

B • The whole stretch of DNA containing a damaged site (or sites) is removed and replaced, preserving the native sequence.

C • The damage is ignored during replication; it is by-passed. With luck the correct base will be inserted or, if incorrect, it won’t matter. Because this type of repair is error prone, it is held in reserve in case the higher fidelity repair systems miss, or cannot cope with, the damage. For this reason, it is aptly called “SOS” repair. (Figure 6)

(Figure 5) Repair of pyrimidine dimers in DNA. The process includes several steps and altogether four enzyme groups
The repair mechanism the following steps:

1. Recognition. It is important to have enzymes that can recognize the damage and signal for help.

2. Cutting of the DNA-strand. It is a requirement that specific enzymes, like the endonucleases, can cut the DNA-strand in the neighborhood of the damage.

3. The damaged part is removed and rebuilt. Exonuclease and polymerase are key enzymes. The former cuts out the damaged part and the later replaces it with a new undamaged part.

4. Joining. The repair is finished when the ligase enzyme joins the cut DNA-strand back together.

The biological effects on the whole body from exposure to radiation will depend upon several factors. Some of these are listed below. For example, a person, already susceptible to infection, who receives a large dose of radiation may be affected by the radiation more than a healthy person.

1. Total Dose
2. Type of Cell
3. Type of Radiation
4. Age of Individual
5. Stage of Cell Division
6. Part of Body Exposed
7. General State of Health
8. Tissue Volume Exposed
9. Time Interval over which Dose is received