College of Health and Medical Techniques

Department of Radiological Techniques

Radiobiology

The first stage

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Introduction to Radiobiology

Radiobiology, a branch of science that deals with the action of ionizing radiation on biological tissues and living organisms, is a combination of two disciplines: radiation physics and biology.

All living organisms are composed of protoplasm which consists of organic and inorganic compounds dissolved or suspended in water.

Cells contain inorganic compounds (water and minerals) as well as organic compounds (proteins, carbohydrates, nucleic acids, lipids).

• The two main constituents of a cell are the cytoplasm, which supports all metabolic functions within the cell, and the nucleus, which contains the genetic information (DNA).

• Human cells are **somatic** cells and **germ** cells.

• Cells propagate through division; division of somatic cells is called **mitosis**, division of germ cells meiosis.

• When a **somatic cell** divides, two cells are produced, each carrying a chromosome complement identical to that of the original cell.

Somatic cells are classified as: -

1. **Stem cells**: exist to self-perpetuate and produce cells for a differentiated cell population (e.g., stem cells of the hematopoietic system, epidermis, mucosal lining of the intestine).
2. **Transit cells:** cells in movement to another population (e.g., a reticulocyte which is differentiating to become an erythrocyte).
3. **Mature cells:** cells that are fully differentiated and do not exhibit mitotic activity (e.g., muscle cells, nervous tissue).
   - ✓ A group of cells that together perform one or more functions is referred to as tissue.
   - ✓ A group of tissues that together perform one or more functions is called an organ.
   - ✓ A group of organs that perform one or more functions is a system of organs or an organism.

Linear energy transfer (LET) determines the beam quality of ionizing radiation.

LET focuses attention on the linear rate of energy absorption by the absorbing medium as a charged particle traverses the medium.

Typical LET values for commonly used radiations are:

a. **250 kVp x ray : 2 keV /µ m**
b. **cobalt-60 gamma ray : 0.3 keV/µ m**
c. **3 MeV x ray : 0.3 keV/µ m**
d. **1 MeV electron : 0.25 keV/µ m**

X rays and gamma rays are considered low LET (sparsely ionizing) radiations, while energetic neutrons, protons and heavy charged particles are high LET (densely ionizing) radiations.

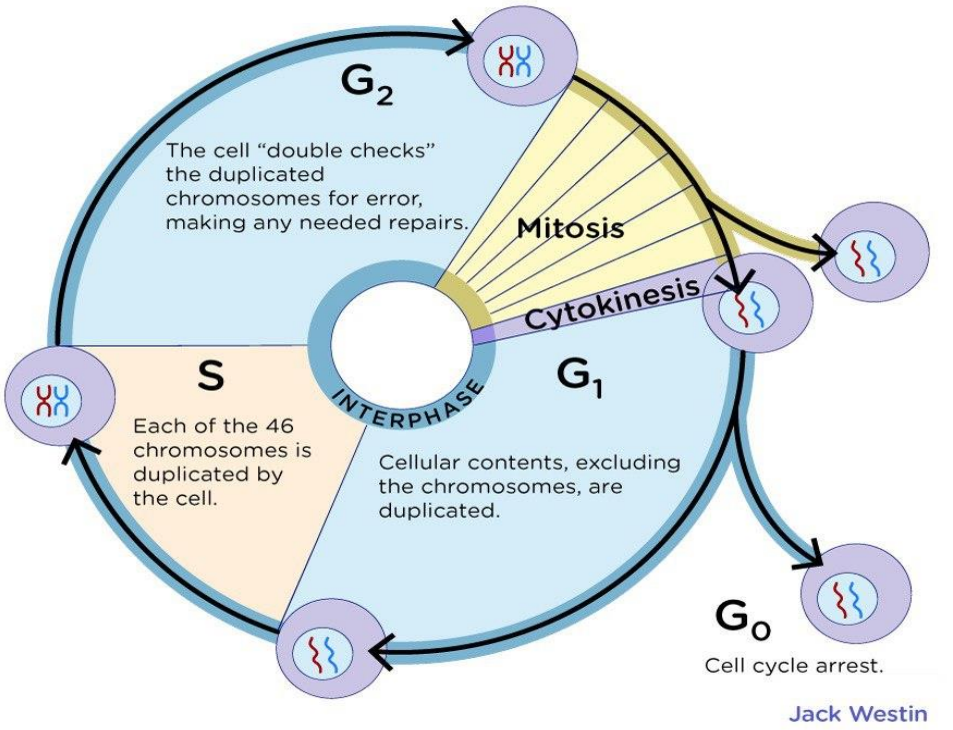
The demarcation value between low and high LET is at about 10 keV/µ m.

CELL CYCLE AND CELL DEATH

The cell proliferation cycle is defined by two well-defined time periods:

(1) Mitosis M where division takes place, and

(2) the period of DNA synthesis S.



The S and M portions of the cell cycle are separated by two periods (gaps) G1 and G2 when DNA is not yet synthesized but other metabolic processes take place.

The time between successive divisions (mitoses) is called **cell cycle time**.

For mammalian cells growing in culture :

- the S phase is usually in the range of 6-8 hours
- M less than an hour
- G2 in the range of 2-4 hours.
- G1 from 1-8 hours

making the total cell cycle in the order of 10-20 hours. In contrast, the cell cycle for stem cells in certain tissues is up to about 10 days.

In general, cells are most radiosensitive in the M and G2 phases, and most resistant in the late S phase.

The cell cycle time of **malignant cells** is shorter than that of some normal **tissue cells**, but during regeneration after injury normal cells can proliferate faster.

Cell death for non-proliferating (static) cells is defined as the loss of a specific function,

while for stem cells it is defined as the loss of reproductive integrity (reproductive death).

A surviving cell that maintains its reproductive integrity and proliferates indefinitely is said to be **clonogenic**.

IRRADIATION OF CELLS

The biological effects of radiation result mainly from damage to the DNA which is the most critical target within the cell.

however, there are also other sites in the cell which, when damaged, may lead to cell death.

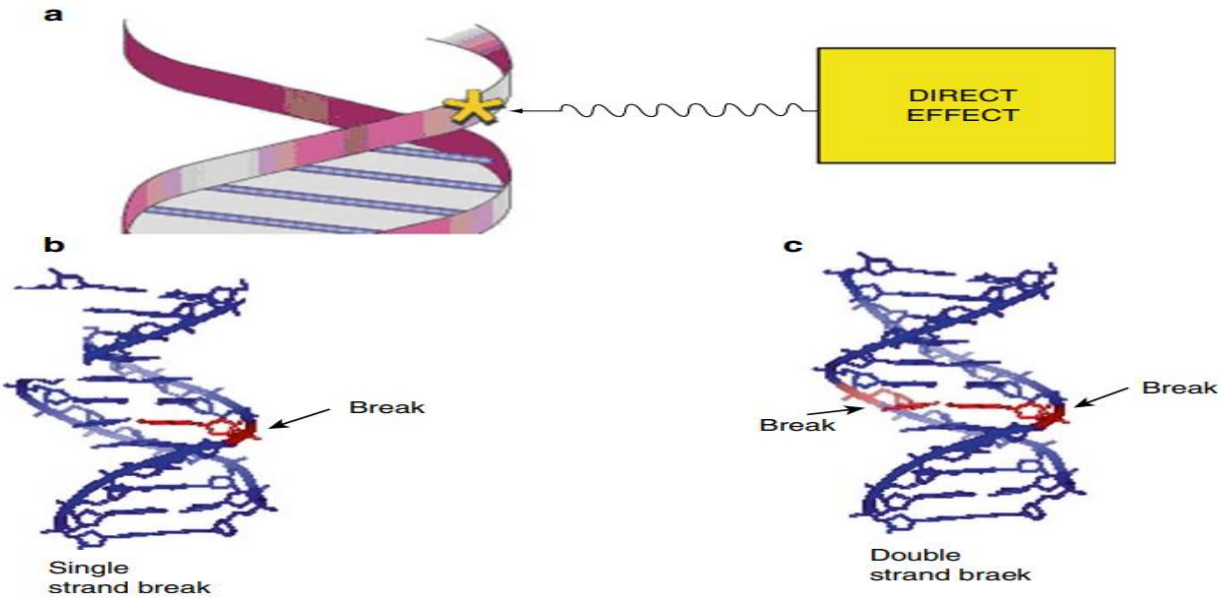
When directly ionizing radiation is absorbed in biological material, the damage to the cell may occur in one of two ways: **direct** or **indirect** action.

1. Direct action in cell damage by radiation

In direct action the radiation interacts directly with the critical target in the cell.

Direct action is the dominant process in interaction of high LET particles with biological materials.

The direct ionization of atoms in DNA molecules is the result of energy absorption via the photoelectric effect and Compton interactions. If this absorbed energy is sufficient to remove electrons from the molecule, bonds are broken, which can break one DNA strand or both . A single broken strand can usually be repaired by the cell, while two broken strands commonly result in cell death.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