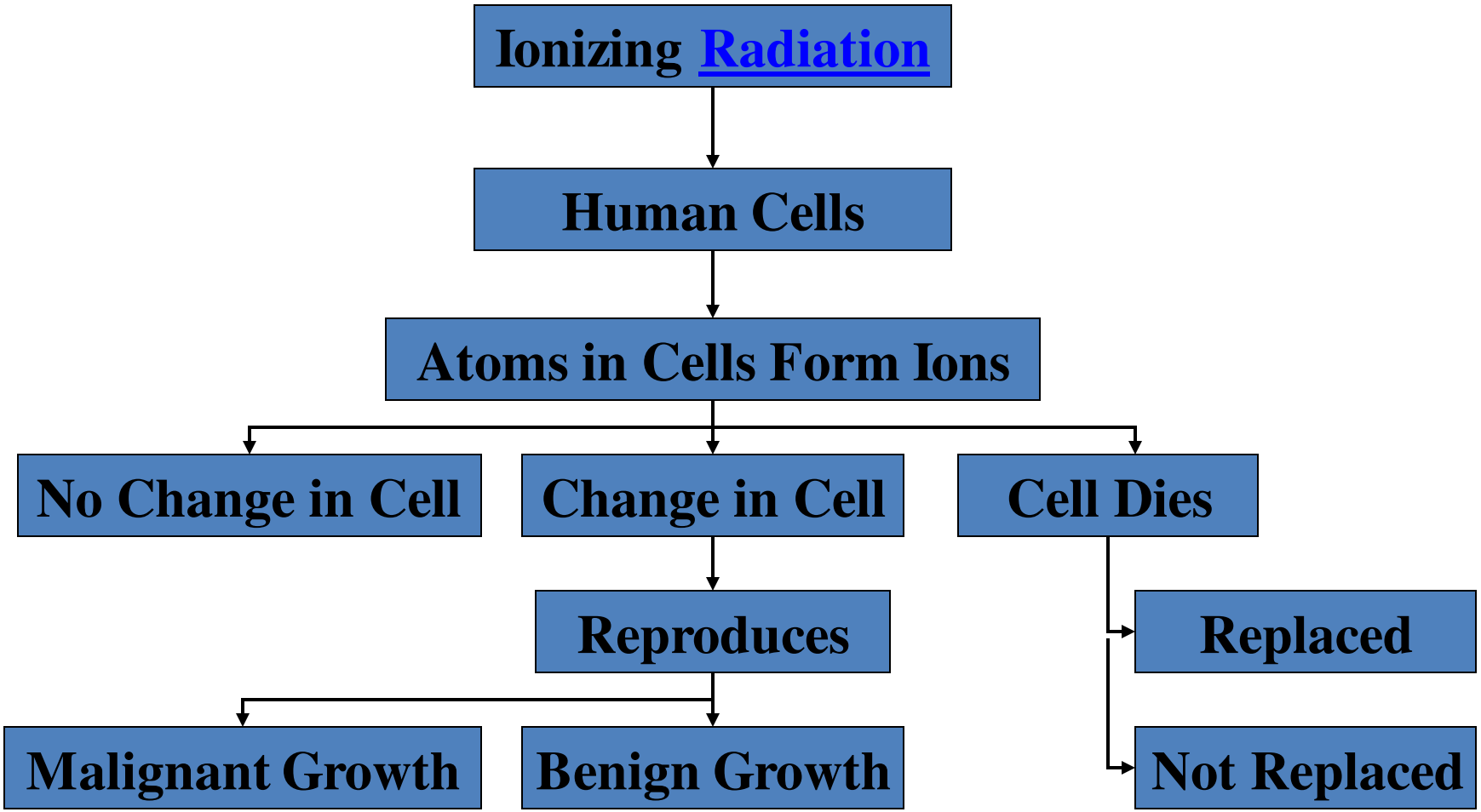
BIOLOGICAL EFFECTS OF RADIATION

Why are we concerned about Radiation?



Biological effects of radiation

Definition:

The harmful effects caused to human beings and other living beings due to their exposure to radiation is called as biological effects of radiation.

Ionizing radiation is any type of particle or electromagnetic wave that carries enough energy to ionize or remove electrons from an atom. There are two types of electromagnetic waves that can ionize atoms: X-rays and gamma-rays, and sometimes they have the same energy.

Biological Effects of Radiation

Biological Effects of Radiation can be broken into two groups according to how the responses (symptoms or effects) relate to dose (or amount of radiation received)

The First Group of biological effects are Stochastic Effects
The Second Group of biological effects are Deterministic Effects

Deterministic Effects

Deterministic Effects are those responses which increase in severity with increased dose

For example; sunburn. The more you're exposed to the sun, and the higher the 'dose' of sunlight you receive, the more severe the sunburn

Stochastic Effects

Stochastic Effects are those effects which have an increased probability of occurrence with increased dose, but whose severity is unchanged

Example; skin cancer and sunlight. The probability of getting skin cancer increases with increasing exposure to the sun

Stochastic Effects are like a light switch; they are either present or not present

Mechanisms of Radiation Damage

Radiation damage occurs via one of two ways –

Direct Damage occurs when radiation damages the DNA directly, causing ionization of the atoms in the DNA molecule. Ionisation of molecule invariably leads to its disruption.

Indirect Damage occurs when radiation interacts with non-critical target atoms or molecules, usually water. This results in the production of free radicals, which then attack other parts of the cell.

- Biological effects of radiation on living cells may result in three outcomes:

(1)injured or damaged cells repair themselves, resulting in no residual damage

(2)cells die, much like millions of body cells do every day, being replaced through normal biological processes; or

(3)cells incorrectly repair themselves resulting in a biophysical change.

- High radiation doses tend to kill cells, while low doses tend to damage or alter the genetic code (DNA) of irradiated cells. High doses can kill so many cells that tissues and organs are damaged immediately. This in turn may cause a rapid body response often called Acute Radiation Syndrome
- low doses – less than 10,000 mrem (100 mSv) – spread out over long periods of time (years) don't cause an immediate problem to any body organ. The effects of low doses of radiation occurs after many years.

Important Radiation Effects

Molecular - Damage to enzymes, DNA etc. and interference to biological pathways

Subcellular -Damage to cell membranes, nucleus, chromosome

Cellular -Inhibition of cell division, cell death, cell transformation to a malignant state

Tissue, Organ -Disruption to central nervous system, bone marrow, intestinal tract. Induction of cancer

Whole Animal : Death; life shortening due to radiation exposure

Population -Changes in the genetic characteristics of individual members

- **EFFECTS OF RADIATION ON CELLS**
- Biological effect begins with the ionization of atoms. The mechanism by which radiation causes damage to human tissue, or any other material, is by ionization of atoms in the material. Ionizing radiation absorbed by human tissue has enough energy to remove electrons from the atoms that make up molecules of the tissue.

- **The following are possible effects of radiation on cells:**
- **Cells are undamaged by the dose**
- Ionization may form chemically active substances which in some cases alter the structure of the cells. These alterations may be the same as those changes that occur naturally in the cell and may have no negative effect.
- **Cells are damaged, repair the damage and operate normally**
- Some ionizing events produce substances not normally found in the cell. These can lead to a breakdown of the cell structure and its components. Cells can repair the damage if it is limited. Even damage to the chromosomes is usually repaired.

- **Cells are damaged, repair the damage and operate abnormally**
- If a damaged cell needs to perform a function before it has had time to repair itself, it will either be unable to perform the repair function or perform the function incorrectly or incompletely. The result may be cells that cannot perform their normal functions or that now are damaging to other cells. These altered cells may be unable to reproduce themselves or may reproduce at an uncontrolled rate. Such cells can be the underlying causes of cancers.
- **Cells die as a result of the damage**
- If a cell is extensively damaged by radiation, or damaged in such a way that reproduction is affected, the cell may die. Radiation damage to cells may depend on how sensitive the cells are to radiation.

Acute radiation dose

Acute dose:

- **An acute radiation dose is defined as a large dose (10 rad or greater, to the whole body) delivered during a short period of time (on the order of a few days at the most).** If large enough, it may result in effects which are observable within a period of hours to weeks.

- Acute doses can cause a pattern of clearly identifiable symptoms (syndromes). These conditions are referred to in general as *Acute Radiation Syndrome*. Radiation sickness symptoms are apparent following acute doses ≥100 rad.

- **Blood-forming organ (Bone marrow) syndrome** (>100 rad) is characterized by damage to cells that divide at the most rapid pace (such as bone marrow, the spleen and lymphatic tissue). Symptoms include internal bleeding, fatigue, bacterial infections, and fever.

- **Gastrointestinal tract syndrome** (>1000 rad) is characterized by damage to cells that divide less rapidly (such as the linings of the stomach and intestines). Symptoms include nausea, vomiting, diarrhea, dehydration, electrolytic imbalance, loss of digestion ability, bleeding ulcers, and the symptoms of blood-forming organ syndrome.

- **Central nervous system syndrome** (>5000 rad) is characterized by damage to cells that do not reproduce such as nerve cells. Symptoms include loss of coordination, confusion, coma, convulsions, shock, and the symptoms of the blood forming organ and gastrointestinal tract syndromes.

- Other effects from an acute dose include:
- 200 to 300 rad to the skin can result in the reddening of the skin (erythema), similar to a mild sunburn and may result in hair loss due to damage to hair follicles.

- 125 to 200 rad to the ovaries can result in prolonged or permanent suppression of menstruation in about fifty percent (50%) of women.

- 600 rad to the ovaries or testicles can result in permanent sterilization.

- 50 rad to the thyroid gland can result in benign (non cancerous) tumors.

Chronic radiation dose

- **A chronic dose is a relatively small amount of radiation received over a long period of time.** The body is better equipped to tolerate a chronic dose than an acute dose. The body has time to repair damage because a smaller percentage of the cells need repair at any given time. The body also has time to replace dead or non-functioning cells with new, healthy cells. **This is the type of dose received as occupational exposure.**

- **SOMATIC VS GENETIC EFFECTs**

- **Somatic effects appear in the exposed person.** Somatic effects may be divided into two classes based on the rate at which the dose was received.
  - **Prompt somatic effects** are those that occur soon after an acute dose (typically 10 rad or greater to the whole body in a short period of time). One example of a prompt effect is the temporary hair loss which occurs about three weeks after a dose of 400 rad to the scalp. New hair is expected to grow within two months after the dose, although the color and texture may be different.
  - **Delayed somatic effects** are those that may occur years after radiation doses are received. Among the delayed effects thus far observed have been an increased potential for the development of cancer and cataracts. Since some forms of cancer are among the most probable delayed effects, the established dose limits were formulated with this risk in mind. These limits are set such that the calculated risk of cancer in radiation workers is an increase of a very small fraction of the normal cancer risk. (More on risk in a moment)

- **Genetic, or *heritable* effects appear in the future generations of the exposed person as a result of radiation damage to the reproductive cells**. Genetic effects are abnormalities that may occur in the future generations of exposed individuals. They have been extensively studied in plants and animals, but risks for genetic effects in humans are seen to be considerably smaller than the risks for somatic effects. Therefore, the limits used to protect the exposed person from harm are equally effective to protect future generations from harm.

Prenatal radiation exposure

- Since an embryo/fetus is especially sensitive to radiation, (embryo/fetus cells are rapidly dividing) special considerations are given to pregnant workers. Protection of the embryo/fetus is important because the embryo/fetus is considered to be at the most radiosensitive stage of human development, particularly in the first 20 weeks of pregnancy.

- Limits are established to protect the embryo/fetus from any potential effects which may occur from a significant amount of radiation. This radiation exposure may be the result of exposure to external sources of radiation or internal sources of radioactive material.

- Potential effects associated with prenatal radiation doses include:
  - Growth retardation
  - Small head/brain size
  - Mental retardation
  - Childhood cancer
- At present occupation dose limits, the actual probability of any of these effects occurring in the embryo/fetus from occupational exposure of the mother is small.