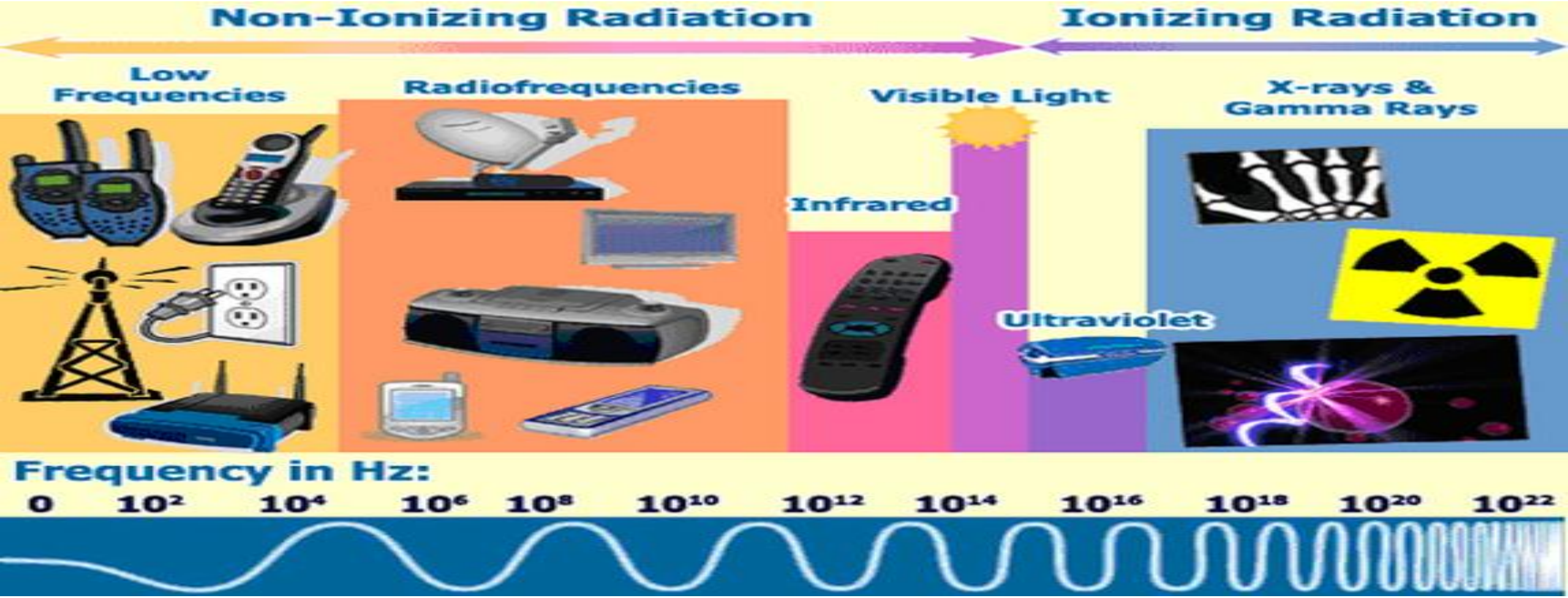
BIOLOGICAL EFFECTS OF RADIATION 6



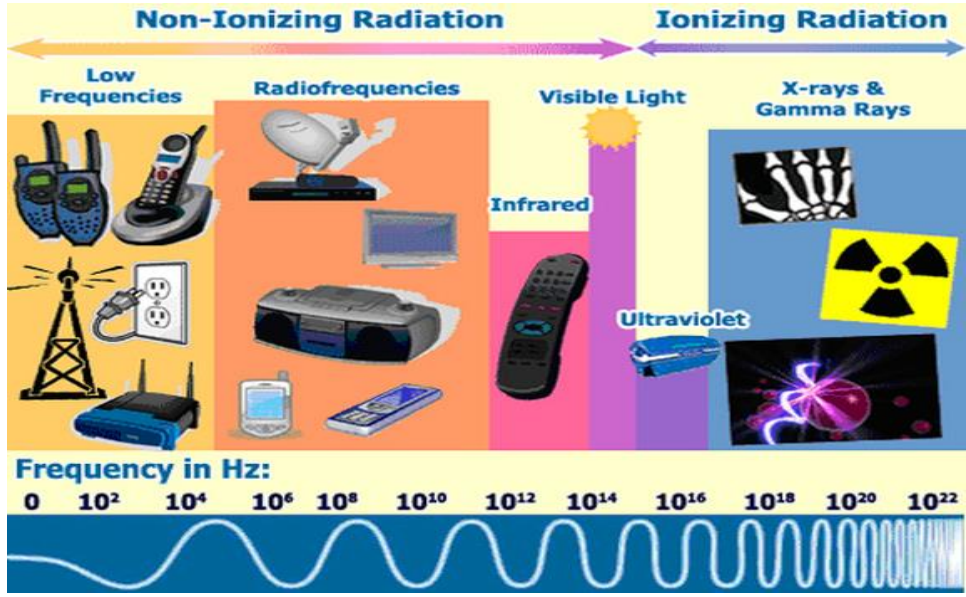
Professor Abbas AY Taher

Types of radiation:

There are two main types of radiation:

1.Non-ionizing radiation consists of optical radiation (ultraviolet, visible, and **infrared**) and **electromagnetic fields** (power frequencies, **microwaves**, and **radio frequencies**)

2.Ionizing radiation occurs as **either electromagnetic rays** (**x-rays and gamma rays**) or particles (**alpha and beta particles**)



Background Radiation

• As a part of living on earth, people are exposed to radiation from various sources every day

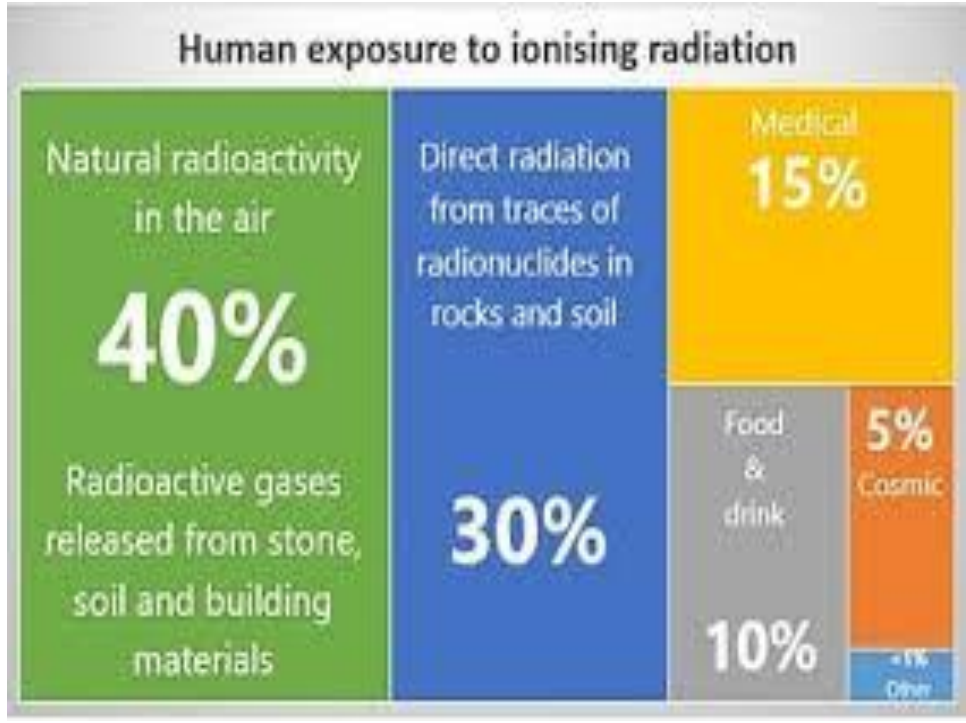
• Some of this radiation comes from:

– **Radon Gas** – Space (in the form of cosmic rays)

– The earth (from the rocks and soil)

– Ourselves (from radioactive carbon and potassium in our bodies)

– Medical Procedures (X-rays, etc)



Effect of Radiation Exposure on Human Health:

The **nature** and **extent of the effects of radiation on the human body depend on** the exposure **levels,** the **frequency of exposure**, and the **penetrating power of the radiation**.

All the atoms in human body has electrical stability when x- ray photon strikes a – ve electron in the atom of living subjects (tissues) it displace the electron leaving the atom electrically unbalance so the atom ionized such process called (ionization), this ionized atom has a strong tendency to seek its stability by accepting a –ve electron from somewhere else and by doing so a new chemical is form and the cell of which the atoms and molecules are parts can be altered. So that the basic effects of ionization are Molecular alteration and creation of new chemicals.
Radiation biology is the study of the effects of ionizing radiation on living systems. The initial interaction between ionizing radiation and matter occurs at the level of the electron within the first 10-13 second after exposure. These changes result in modification of biologic molecules within seconds to hours. In turn, the molecular changes may lead to alterations in cells and organisms that persist for hours, decades, and possibly even generations. They may result in injury or death of the cell or organism.

Radiation has two types of effect:

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

Effects of ionizing radiation

Radiation acts on living systems through direct and indirect effects

1. **Direct effect:** When the energy of a photon or secondary electron ionizes biologic macromolecules, the effect is termed direct. Those effects occurred in specific area of the body where all exposed cells in this area are altered directly by ionization process and death occurred at the time of mitotic cell division.
2. **Indirect effect:** It happened in several ways where new chemicals result from process of ionization are in compatible with body tissues ,ex: when photon absorbed by water in an organism, ionizing the water molecules. The resulting ions form free radicals (radiolysis of water) that in turn interact with and produce changes in the biologic molecules. Because intermediate changes involving water molecules are required, so conversion of water to H2O2 which cause cellular dysfunction also x- radiation can alter the chemical composition of hormones enzymes and other body secretions make them partially or totally in effective such indirect effects depend on the amount of exposure to X- ray. This series of events is termed indirect.

Stochastic effects occur at the **cellular level**. They are caused by more subtle radiation-induced cellular changes, such as DNA mutations. For these effects to occur, radiation exposure must be random in nature with no threshold dose. Cancer is the only observed clinical manifestation of radiation-induced stochastic effects

Deterministic effects occur at **the organ level**. If a sufficient number of cells become affected, the organ is not able to function and becomes impaired. Further, the effects of the radiation are not noticeable until the absorbed dose is greater the threshold level. Therefore, deterministic effects are manifested soon after exposure and include: radiation skin burning, blood count effects, and cataracts.

Comparison of Stochastic and Deterministic Effects of Radiation

	Stochastic Effects	Deterministic Effects
Caused by	Sublethal DNA damage	Cell killing
Threshold dose	No	Yes
	There is no minimum threshold dose. Effect can be caused by any dose of radiation	Effect occurs only when the threshold dose is exceeded
Severity of clinical effects and dose	Severity of clinical effects is independent of dose; all-or-none response—an individual either manifests effect or does not	Severity of clinical effects is proportional to dose; the higher the dose, the more severe the effect
Relationship between dose and effect	Frequency of effect proportional to dose; the higher the dose, the higher the risk of manifesting the effect	Probability of effect independent of dose; most individuals manifest effect when threshold dose is exceeded
Caused by doses used in diagnostic radiology	Yes	No
Examples	Radiation-induced cancer	Osteoradionecrosis
	Heritable effects	Radiation-induced cataract formation
	Radiation-induced skin cancer	Radiation-induced skin burns

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

For example; sunburn.

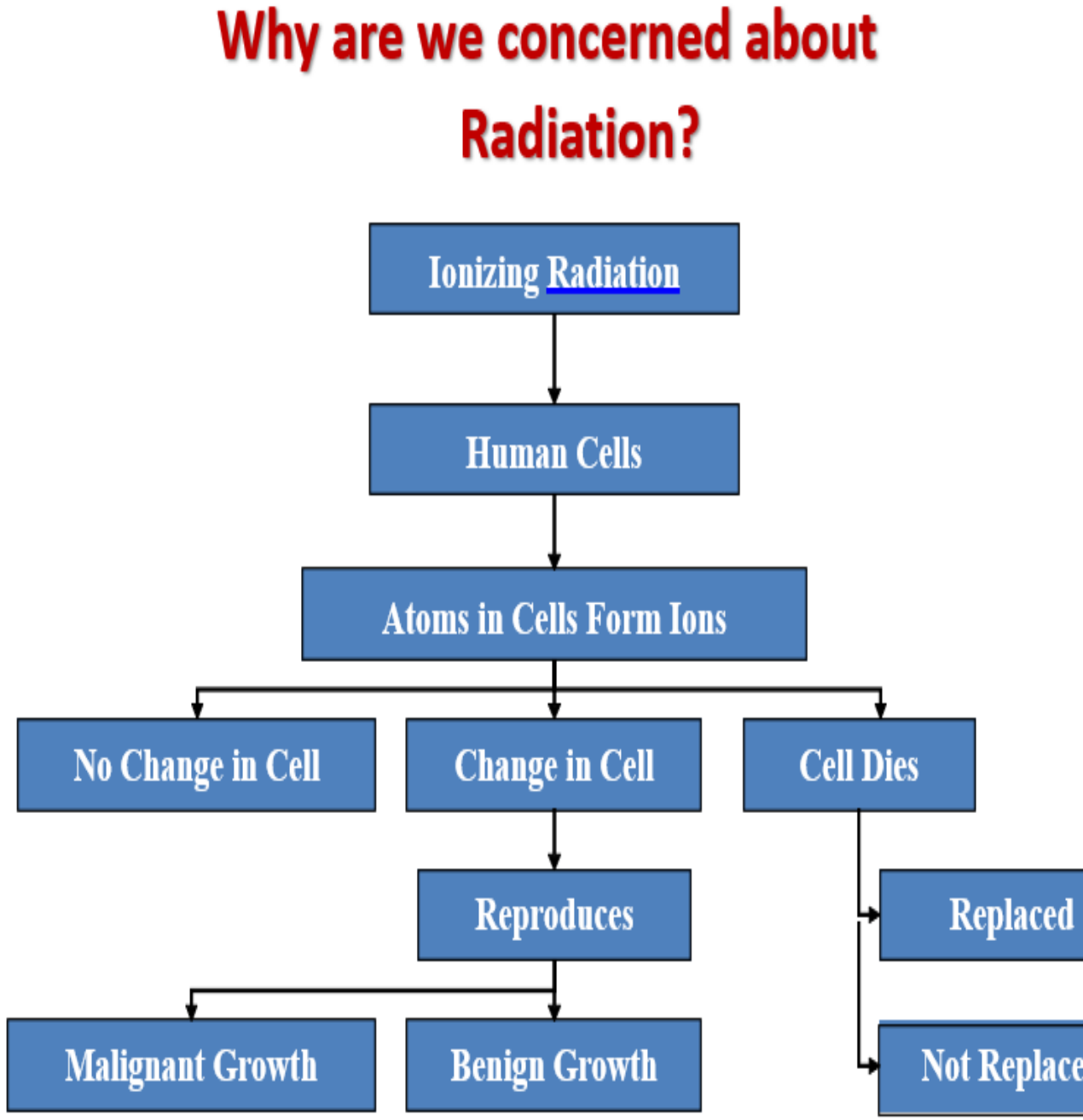
The more you're exposed to the sun, and the higher the 'dose' of sunlight you receive, the more severe the sunburn

Stochastic Effects 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**



Radio sensitivity of tissues and organs

The radio sensitivity of a tissue or organ is measured by its response to irradiation. A fairly small number of lost cells results in no clinical effect. With an increased number of lost cells, all affected organisms display a clinical result. The severity of this change depends on the dose and thus the amount of cell loss. Moderate doses to a localized area may lead to repairable damage. Comparable doses to a whole organism may result in death from damage to the most sensitive systems in the body.

Body tissues differ in their susceptibility to ionizing radiation. Cells are most sensitive to radiation when they are immature, undifferentiated, and rapidly dividing. As cells mature and become specialized they are less sensitive to radiation. If cells are more oxygenated, they are more susceptible to radiation damage which is known as oxygen enhancement ratio.

The following tissue and organs are **listed in order to their susceptibility to x-ray**:

1.high radio sensitivity: lymphoid organs , Blood forming tissues (bone marrow), intestines , stem cells, lymphocyte and reproductive cells

2.intermediate radio sensitivity: Young or growing bone, Growing cartilage, glandular tissue , salivary glands , kidney, liver, lungs and epithelium of alimentary canal.

3. low radio sensitivity: Skin , muscle and optic lens.

4. the least effect seen in nerve tissue and adult bone

Short term effects of radiation on tissue seen in the first days or weeks after exposure while long term effects seen months and years after exposure.
The response of cells, Tissues and organs to irradiation depends on exposure conditions and the cell environment, this modifying factors include :

1. Dose: The severity of deterministic damage seen in irradiated tissues or organs depends on the amount of radiation received. All individuals receiving doses above the threshold level show damage in proportion to the dose.

2. Dose Rate: The term dose rate indicates the rate of exposure. For example, a total dose of 5 Gy may be given at a high dose rate (5 Gy/min) or a low dose rate (5 mGy/min). Exposure of biologic systems to a given dose at a high dose rate causes more damage than exposure to the same total dose given at a lower dose rate.

3. Oxygen : The radio-resistance of many biologic systems increases by a factor of 2 or 3 when irradiation is conducted with reduced oxygen (hypoxia).
The greater cell damage sustained in the presence of oxygen is related to the increased amounts of hydrogen peroxide and hydroperoxyl free radicals formed (Both peroxyl radicals and hydrogen peroxide are oxidizing agents that can significantly alter biologic molecules and cause cell destruction.
They are considered to be major toxins produced in the tissues by ionizing radiation).

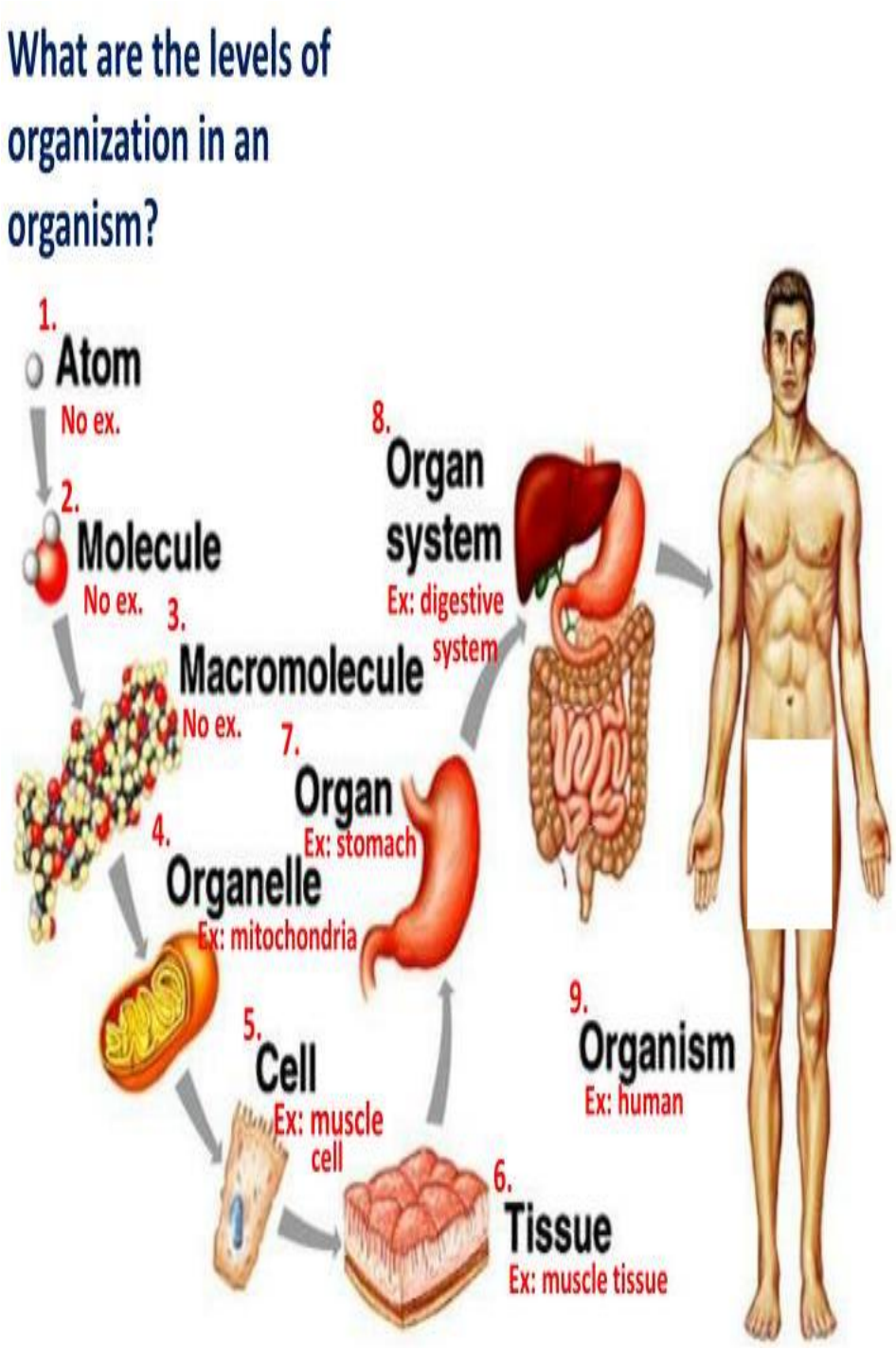
All living entities are made up of protoplasm, which consists if **inorganic** and **organic compounds dissolved or suspended in water**.

The smallest unit of protoplasm capable of independent existence is **the cell**, the basic microscopic unit of all living organisms.

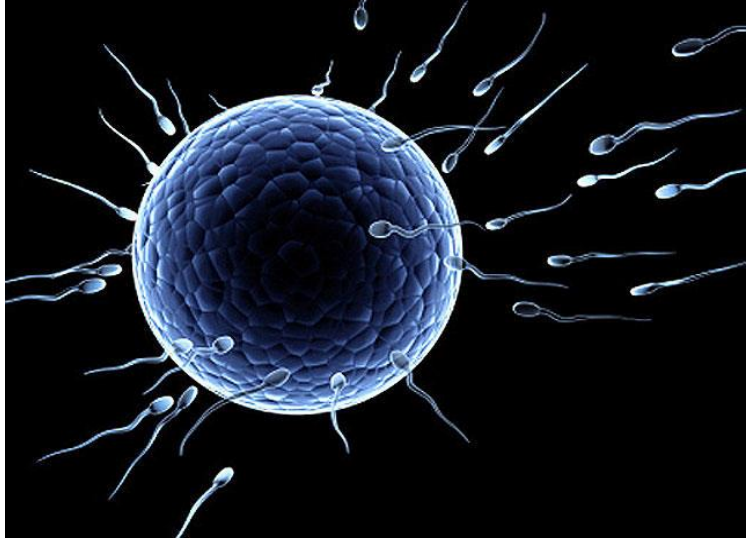
Group of cells that together perform one or more functions is referred to as **tissue.**

Group of tissues that together perform one or more functions is called an **organ**.

Group of organs that perform one or more functions is an organ system or an **organism.**



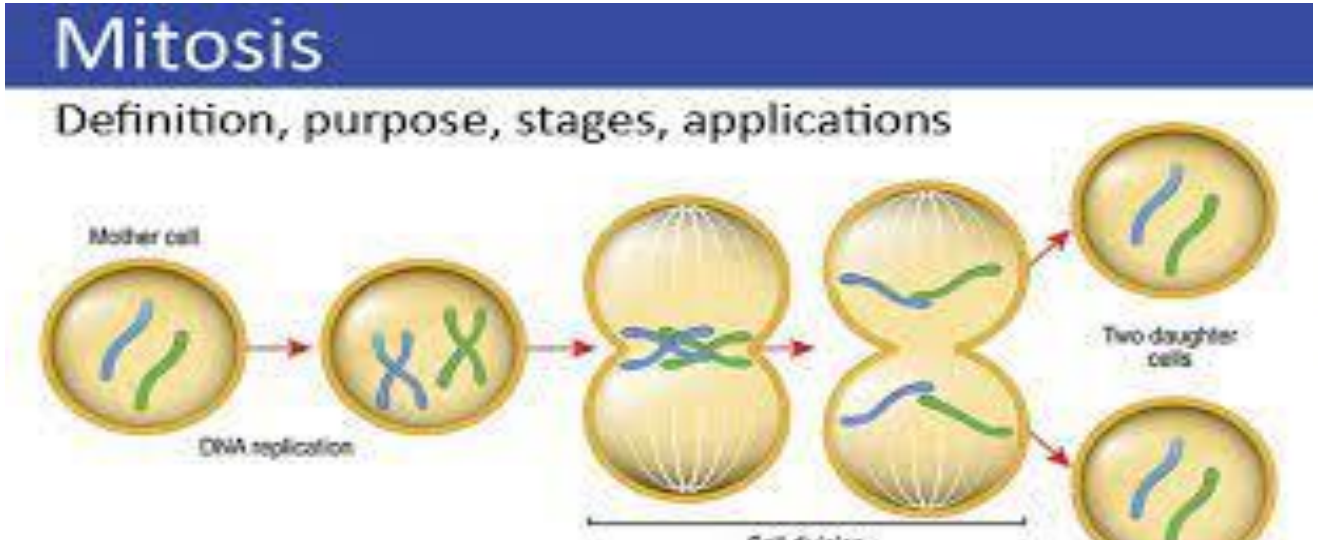
Human cells are either **somatic cells** or **germ cells**.
Germ cells are **either a**
sperm or an
egg,

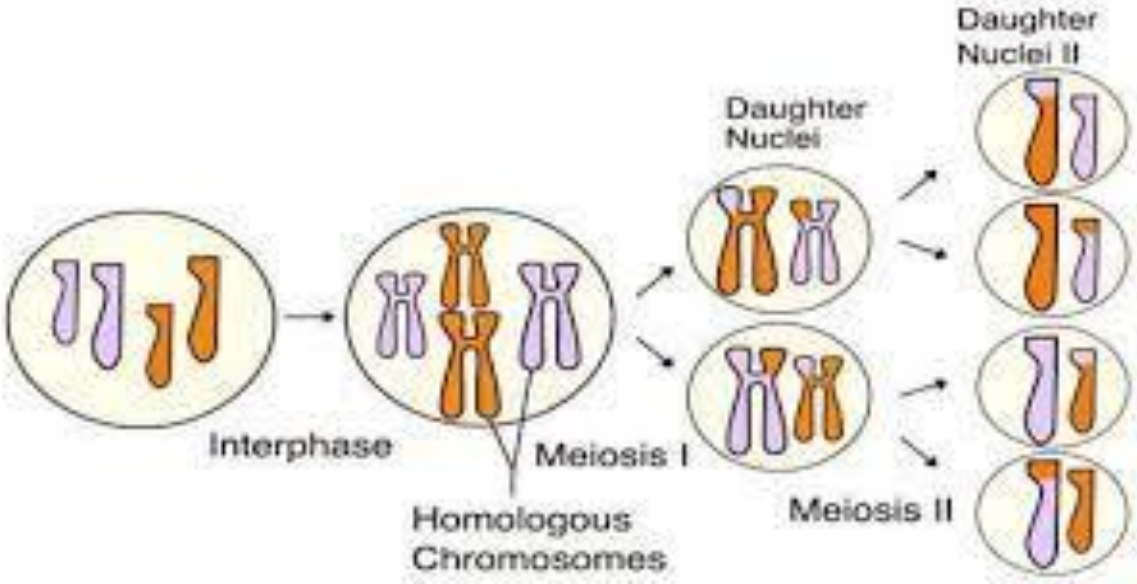


All other human cells are called ***somatic cells***.

 Cells propagate **through division**: • Division of somatic cells is called **mitosis** and results in two **genetically identical daughter cells**.

• Division of germ cells is called **meiosis** and involves two fissions of the nucleus giving rise to four sex cells, each possessing half the number of chromosomes of the original germ cell.





General Safety Tips to Avoid or Reduce Radiation Exposure

1. Television Sets

Watching 4.5 hours of television per day exposes the viewer to **one mrem of x-ray radiation**.
Television sets that contain **cathode ray tubes can generate low-level x-rays**.

2. Computer Monitors

Computer monitors that contain **cathode ray tubes also generate low-level x-rays**.

3. Drinking Water

Water can pick up radiation **from natural sources**, such as **rocks** and **soil**. In urban areas, radiation comes **from rivers and lakes**, while in **rural areas it comes from wells**.
The average person can acquire up to **five mrem of radiation from drinking water per yea**r.

4. Natural Gas

Natural gas used for cooking and heating can increase your radiation exposure by **9 mrem per year.**

5. Cellphones

Cellphones give off radio frequency waves, exposing the average user to **11 mrem of radiation per year.** Fortunately, **these radio frequency waves are at low enough levels not to cause damage to cells or tissues.**

6. Microwave Ovens

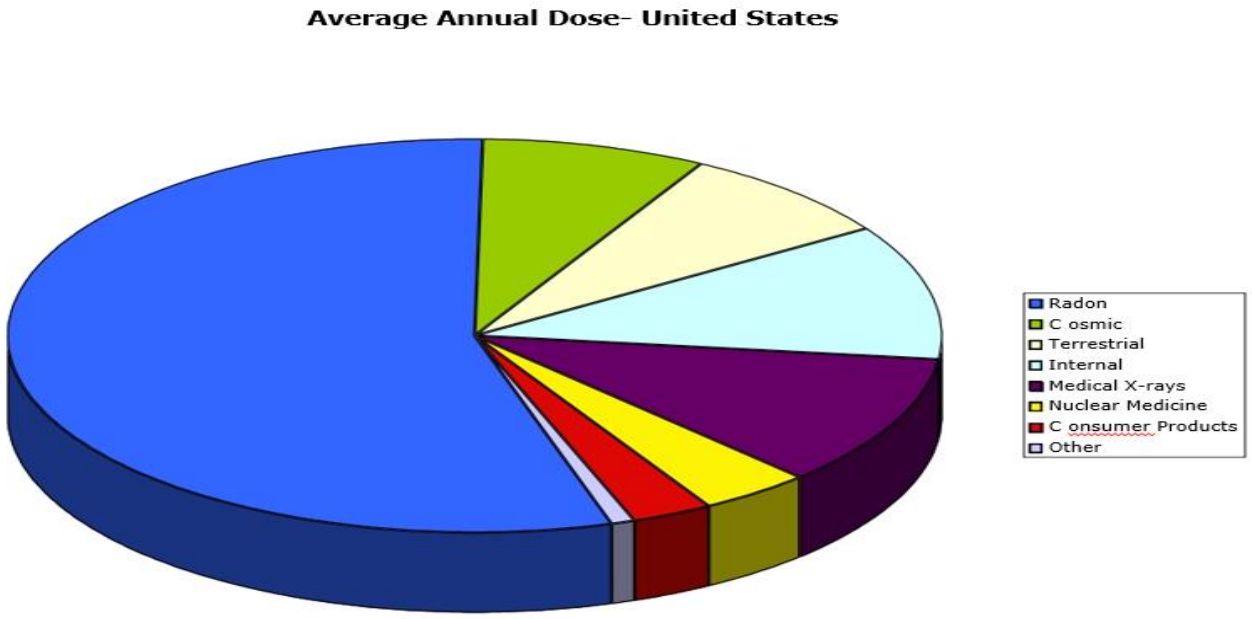
Microwave ovens emit radio frequency electromagnetic energy. Some studies have indicated that microwave energy may leak from your microwave while in use, but it will not have any negative health impacts if it is properly maintained.

7. Soils

Radioactive particles are present in soil due to cosmic radiation in the Earth's crust or from man-made releases such as nuclear power plant disasters. These particles are then released in the form of gases which we either inhale or take in through water or plants. The average person acquires 35 mrem of radiation per year from soils.

8. Radon Gas

Radon is the **second-leading cause of lung cancer in the United States**. It is emitted from the radioactive decay of **natural uranium in the ground**. It is also found in some construction materials. The average person may be exposed to up to **200 mrem of radiation per year** from building materials containing radon.



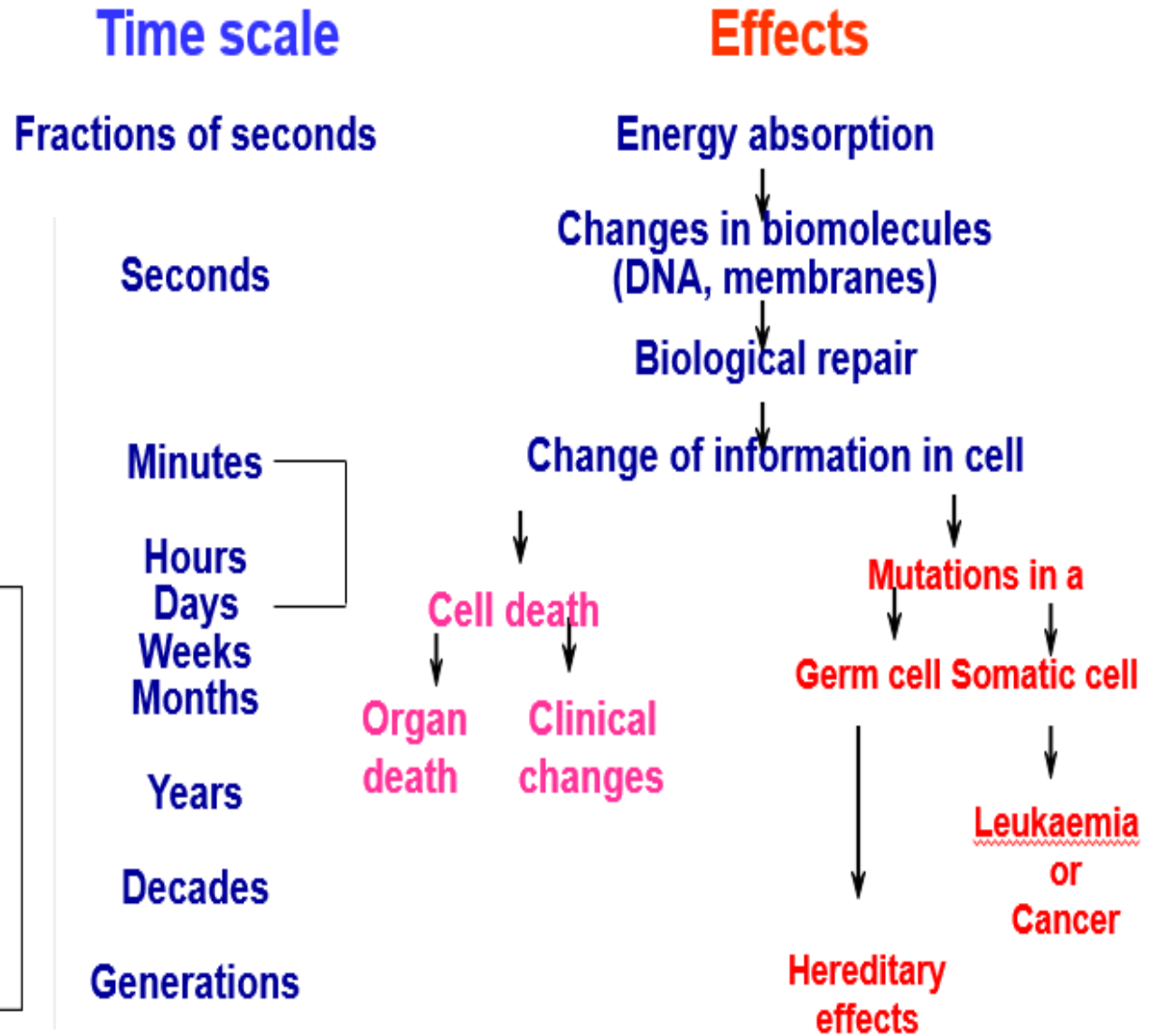
9. Cigarette Smoke

Smokers not only **increase their risk of lung cancer and heart disease**; they also increase their **exposure to radiation**. It's estimated that the **average smoker is exposed to 1,300 rmem of radiation per year from radioactive material in the fertilizers used to grow tobacco plants, as well as other natural sources.**

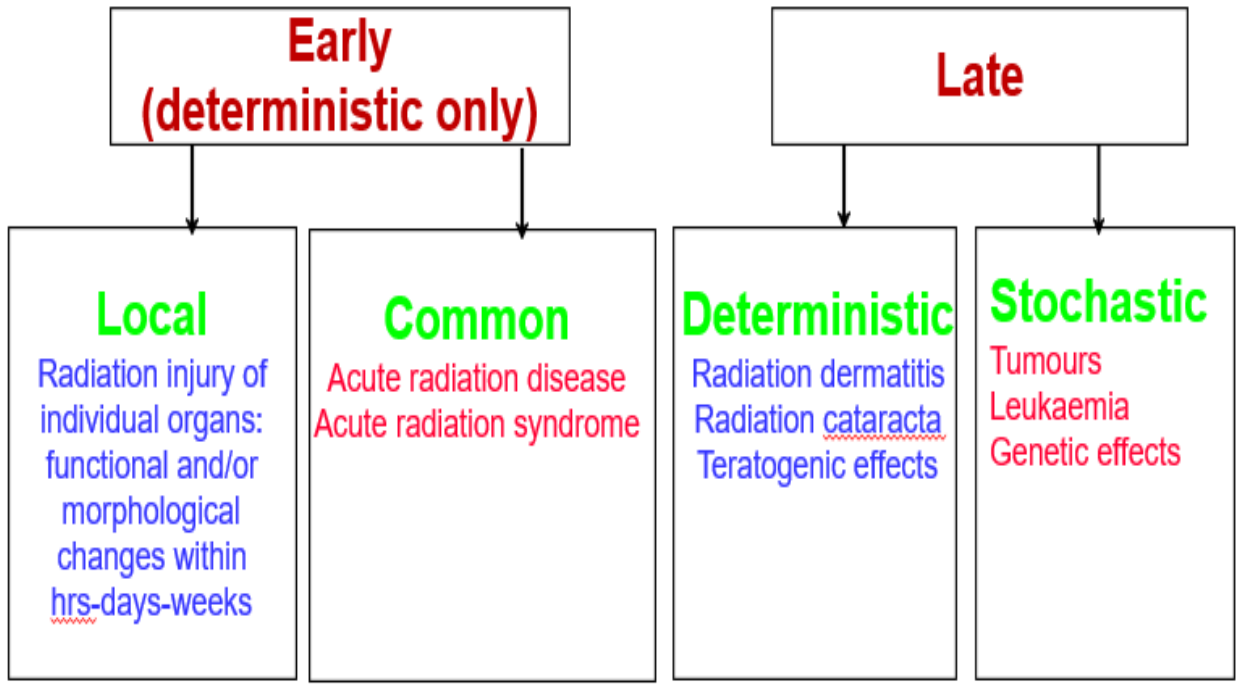
NRC Limits

Subjects Exposed	Time Frame	Dose (mrem)
Nuclear Worker	1 year	5000
General Public (from Nuclear Facility)	1 year	100
Pregnant Woman	9 months	500

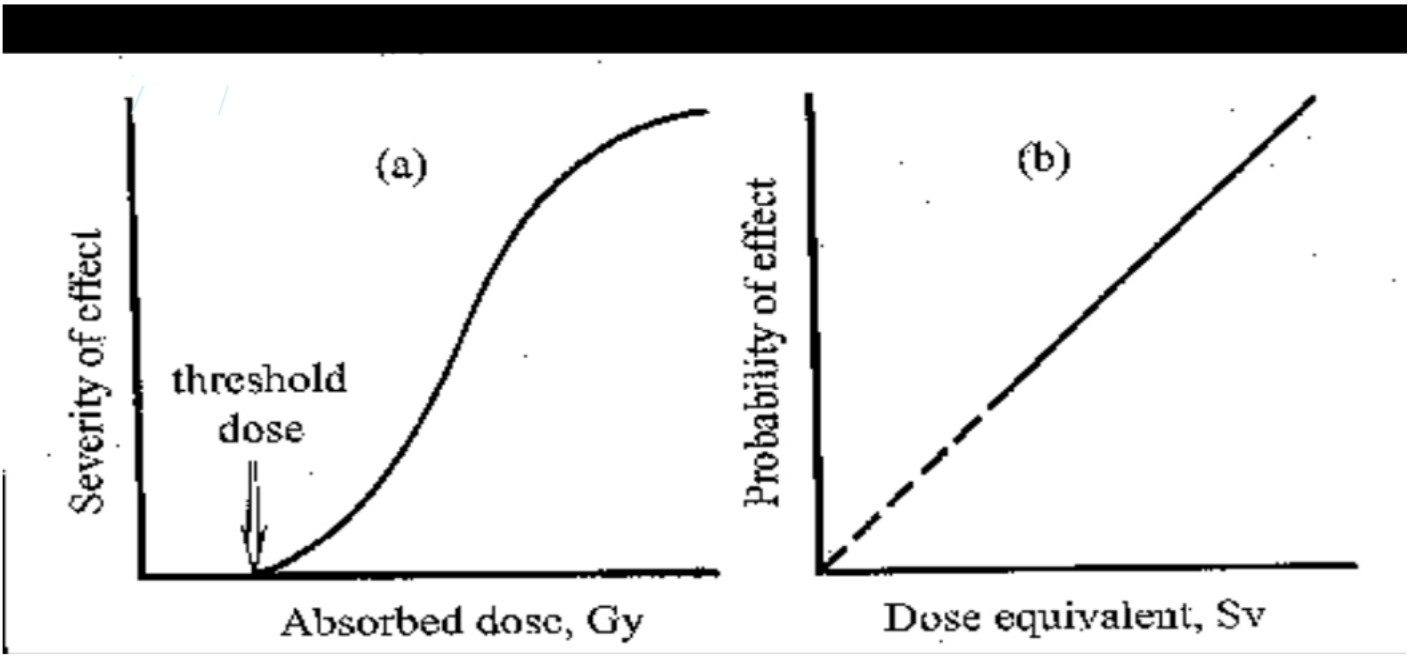
BIOLOGICAL EFFECTS OF RADIATION IN TIME PERSPECTIVE



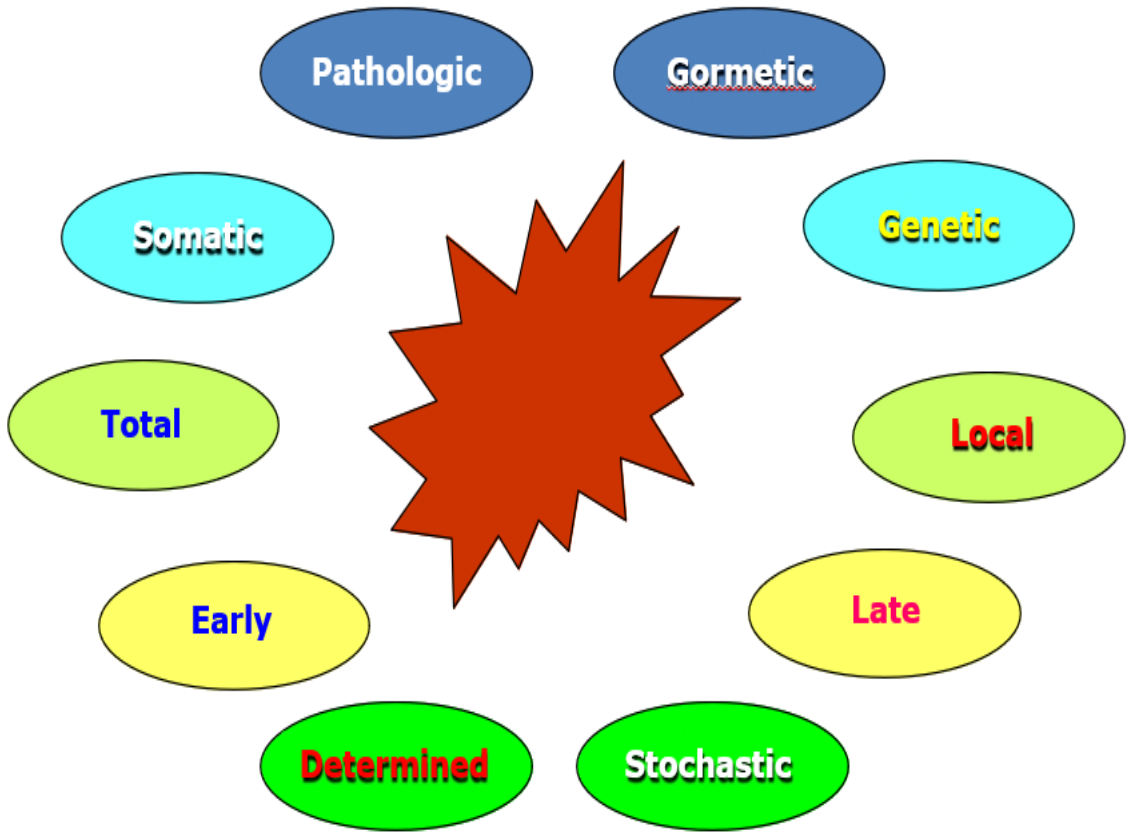
Radiation effects



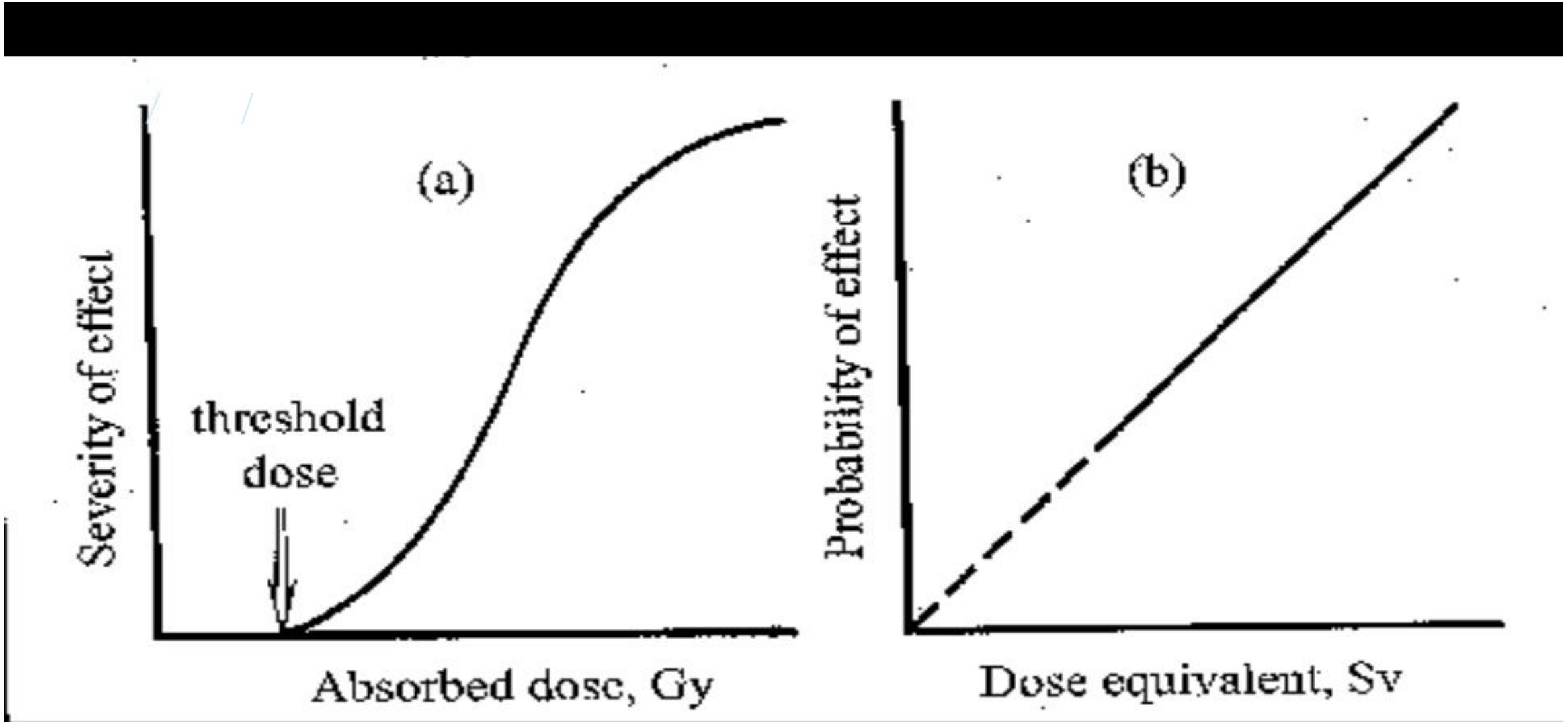
Deterministic (a) and stochastic (b) effects of radiation



Classification of radiobiological effects

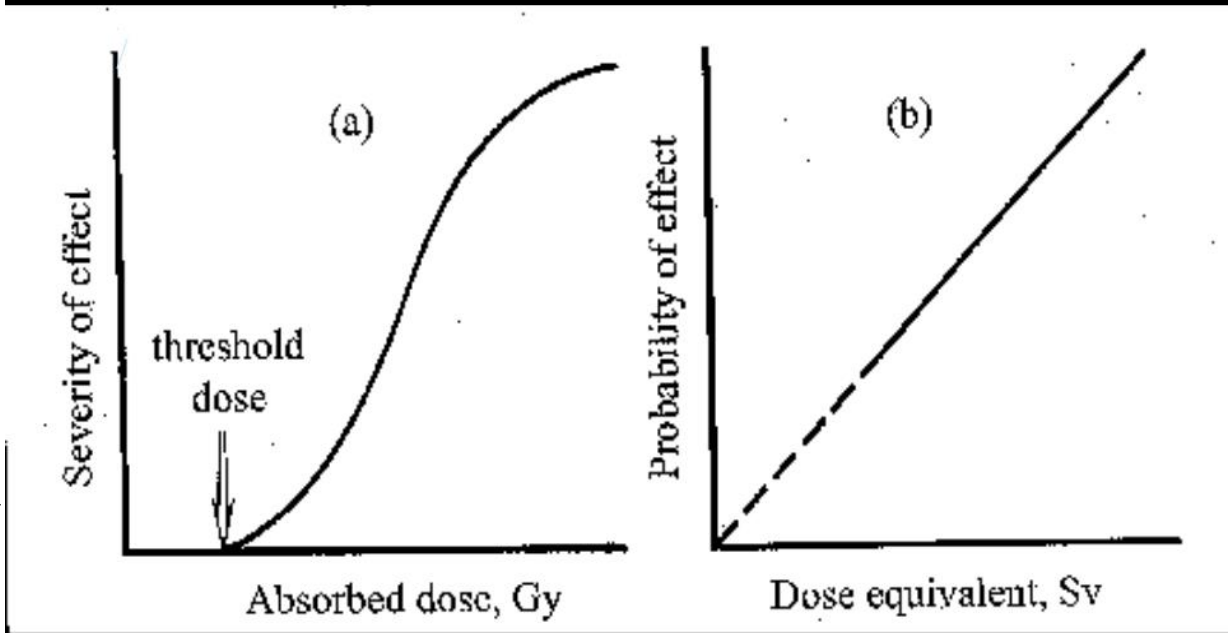


Deterministic (a) and stochastic (b) effects of radiation



Deterministic (a) and stochastic (b) effects of radiation

Deterministic effects develop due to **cell killing by high dose radiation**, appear above a given threshold dose, which is considerably higher than doses from natural radiation or from occupational exposure at normal operation, the severity of the effect depends on the dose, at a given high dose the effect is observed in severe form in all exposed cells, at higher doses the effect cannot increase.



Stochastic effects develop due to **mutation effect** of low dose radiation, the threshold dose is not **known accurately**; it is observed that cancer of different location appears above **different dose ranges**, the severity of the effect does not depend **on the dose**, but the frequency of the appearance of the (probabilistic) effect in the exposed population group is dose dependent, (in most cases) linearly increasing with the dose.

Ray (Gy):

- The new international system (SI) unit of radiation dose, expressed as absorbed energy per unit mass of tissue.
- The SI unit "gray" has replaced the older "rad" designation.
- 1 Gy = 1 Joule/kilogram = 100 rad.
- Gray can be used for any type of radiation (e.g., alpha, beta, neutron, gamma), but it does not describe the biological effects of different radiations.
- Biological effects of radiation are measured in units of "sievert" (or the older designation "rem").
- **Sievert is calculated as follows:** gray multiplied by the "radiation weighting factor" (also known as the "quality factor") associated with a specific type of radiation.

Example of deterministic effects :**0,2 Gy** – increase of number of the chromosomal aberration in bone marrow and lymphocytes , **0,3 Gy** – temporary sterility for man, **0,5 Gy** – depression of haematopoiesis , **1,0 Gy** – acute radiation syndrome ,**2,0 Gy** – detectible opacities **5,0 Gy** – visual impairment ,**2,5 – 6,0 Gy** – sterility for woman,**3,5 – 6,0 Gy** – permanent sterility for man, **3,0 – 10,0 Gy** – skin injury**3,0 – 10,0 Gy** – skin injury, **0,1 Gy** – detectible opacities ,**0,2 Gy** – sterility for woman, **0,4 Gy** – visual impairment ,**0,4 Gy** – temporary sterility for man, **0,4 Gy** – depression of haematopoiesis **1,0 Gy** – chronic radiation syndrome**2,0 Gy** – permanent sterility for man

Time of onset of clinical signs of skin injury depending on dose received

Symptoms	Dose range (Gy)	Time of onset (day)
Erythema	3-10	14-21
Epilation	>3	14-18
Dry desquamation	8-12	25-30
Moist desquamation	15-20	20-28
Blister formation	15-25	15-25
Ulceration	>20	14-21
Necrosis	>25	>21

Ref.: IAEA-WHO: Diagnosis and Treatment of Radiation Injuries.
IAEA Safety Reports Series, No. 2, Vienna, 1998

Acute radiation syndrome *(ARS)*

ARS is the most notable *deterministic effect* of ionizing radiation Signs and symptoms are ***not specific*** **for radiation injury but *collectively highly characteristic* of ARS**

Combination of symptoms appears in phases during hours to weeks after exposure

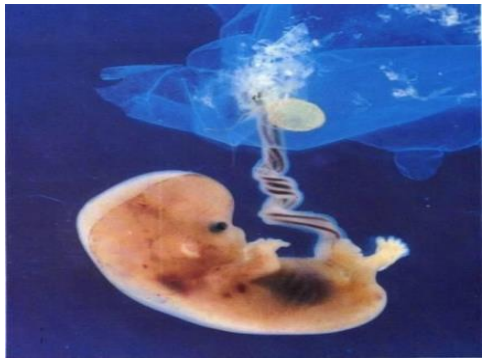
- prodromal phase
- latent phase
- manifest illness
- recovery (or death)

Extent and severity of symptoms determined by

- total radiation dose received
- how rapidly dose delivered (dose rate)
- how dose distributed in body (whole or partial body irradiation)

Teratogenic effects of radiation as special deterministic effects

The foetu :Typical effects of radiation on embryon:



Intrauterine growth retardation (IUGR)

Embryonic, foetal, or neonatal death

Congenital malformations

Effects of radiation according to gestational stage

Gestational age	Stage	Radiogenic effects
0 - 9 days	Preimplation	All or none
10 days -6 weeks	Organogenesis	Congenital anomalies, growth retardation
6 weeks-40 weeks	Foetal	Growth retardation, microcephly, mental retardation

Considerations for pregnancy termination

- Threshold dose for developmental teratogenic effects approximately 0,1 Gy
- Normal rate of preclinical loss > 30 %; at 0,1 Gy –increase of 0,1–1 %
- The foetal absorbed dose > 0,5 Gy at 7–13 weeks: substantial risk of IUGR and CNS damage
- 0,25–0,5 Gy at 7–13 weeks: parental decision with physician ’s guidance

Cancer induction and genetic effects as examples of stochastic effects of radiation exposure

Frequency proportional to dose

No threshold dose

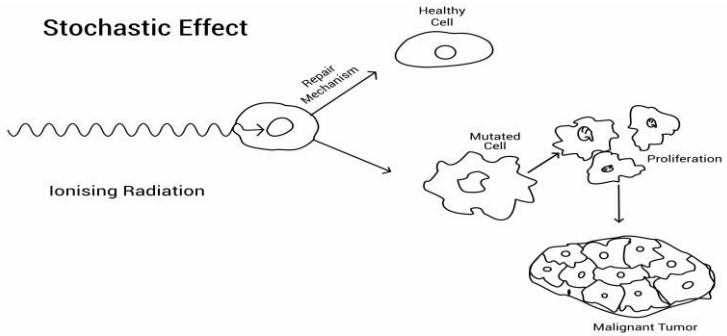
No method for identification of appearance of effect of ionizing radiation in individuals

Increase in occurrence of stochastic effects provable only by epidemiological method Stochastic effects observed in animal experiments

Dose-effect relationship for humans can be studied only in human population groups

Dose-effect relationship in low dose range (below 100 mSv) not yet verified

Extrapolation down to zero excess dose accepted only for radiation protection and safety



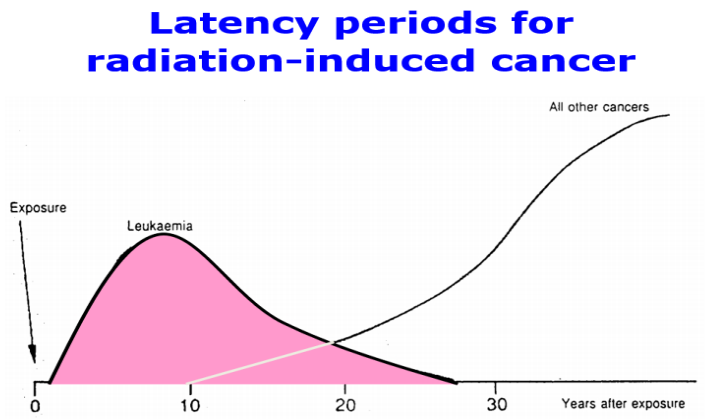
Carcinogenic effects

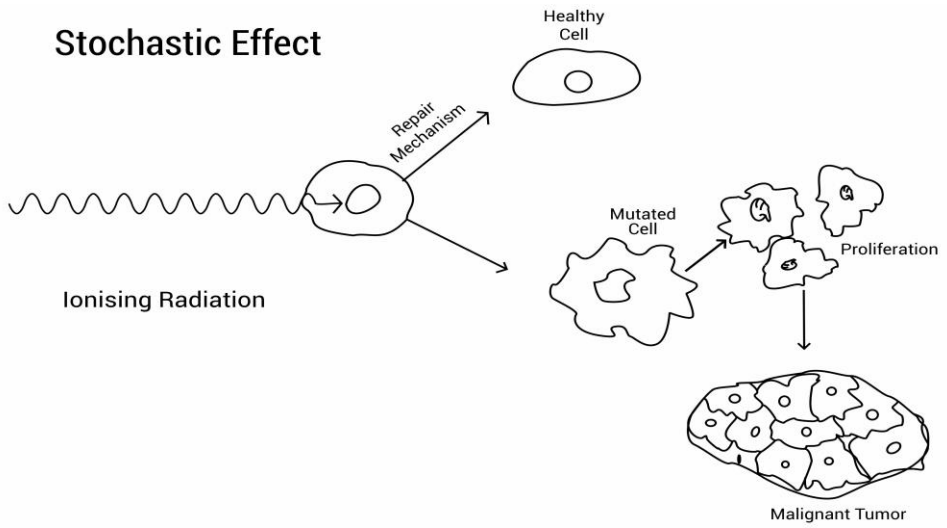
- ***Carcinogenic effects*** **have been known practically since the discovery of radioactivity and since the first case of radiation- induced cancer was described in 1902.**

- **The epidemiological assessment was made from over 575 cancers and leukaemias for the 80,000 survivors irradiated at Hiroshima and Nagasaki, and about 2,000 cancers of the thyroid in children in the Chernobyl region.**

- **The actual data does not enable us to show a risk of cancer at greater than 0,1 Gy by acute irradiation.**

Nevertheless, it is considered that risk of cancer and the relationship dose/risk remains linear for doses below 0,1 Gy.





Genetic effects :

• **Genetic effects might result in lesions of chromosomes in the germinal lineage (ovule and spermatozoid), prone to lead to anomalies in close or distant descendants of the irradiated individual.**

• **The mutagenic action of radiation was discovered by Nadson and Philipov (1925) and then in the fly was demonstrated by Muller from 1927 onwards.**

• **As it has not been possible to find any study showing a genetic effect in man, the risk is evaluated from the data obtained from animals.**

Increase of chromosome aberrations in human spermatogonia following radiation exposure of testes has been detected .

Inheritance of radiation damage in human population (including A-bomb survivors) not yet detected

General Safety Tips to Avoid or Reduce Radiation Exposure

Consider switching to **flat screen television sets** and **computer monitors**. These do not contain cathode ray tubes and, therefore, **do not produce x-ray radiation**.
Opt for bottled water over tap water. **While both may contain radiation**, the levels of radiation in bottled water are far lower.

Although radiation levels from **cellphones are extremely low**, to reduce radio frequency waves near your body you can either get a **hands-free headset** which connects directly to your phone or **use speaker-phone** more often.
Keep your exposure to microwave energy at a minimum by keeping your **microwave oven in good working condition**.
You **cannot see or smell radon**, but it's not difficult to determine if you have a radon problem in your home or workplace. All you need to do is test for radon using any **low-cost do-it-yourself radon testing kit found at any hardware store.**
Quitting smoking eliminates eliminates all the exposure you get from cigarettes.

ALARA principle (The law of radiation protection) **A**s **L**ow **A**s **R**easonably **A**chievable: Radiographs should only be taken at the minimum dosage with reasonable information, so the benefit from radiograph should be weighed against the radiation dose and then decide to take radiograph or not.

Latent period:

Is a period of time interposed between exposure and clinical symptoms such period varies with the dose. So the more is sever dose the shorter is the latent period. sometimes the latent period is as long as 25 years for some minimum doses.