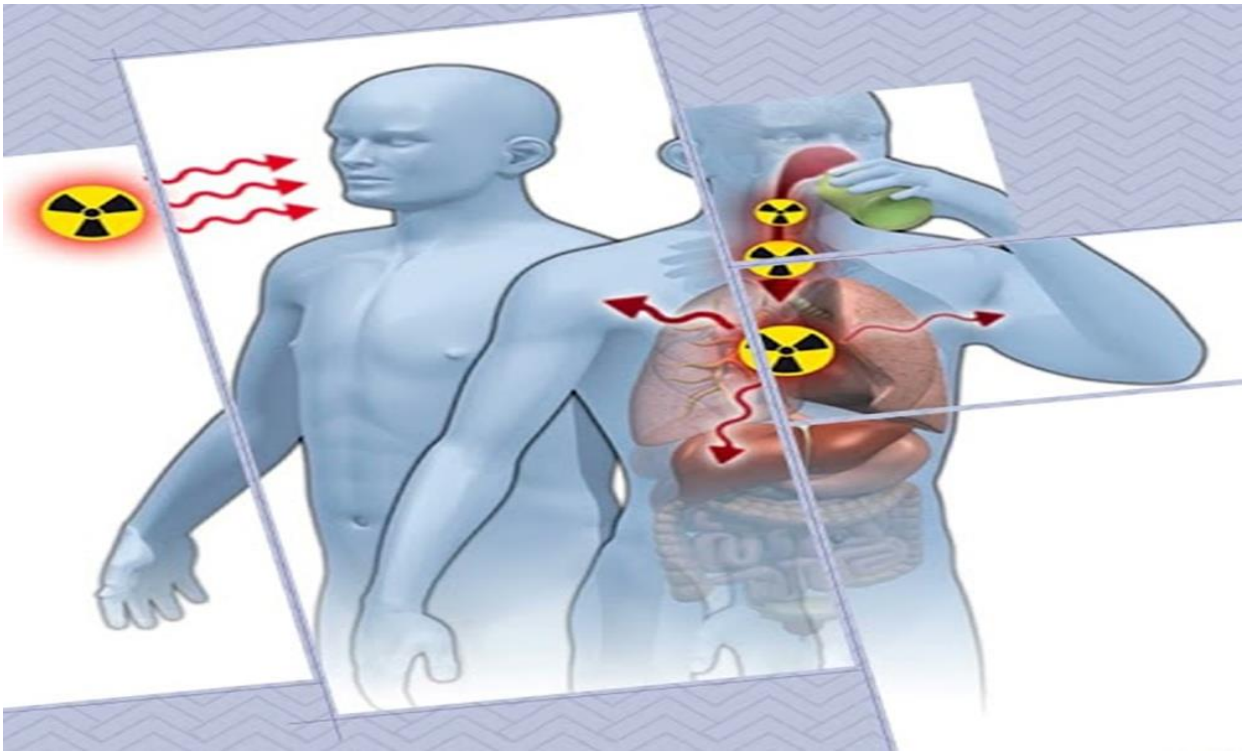
Effect of Radiation on Cells
5th Lecture



Prepared and Presented by:

Lecturer Dr/ Arshed Shaker
Lecturer Dr/ Ayad Abdelsalam
Assist. Lecturer Dr/ Noor sabah

3rd year, 1st course

Teaching of Biological Radiation hazards

College of Technology & Health Sciences
Radiology Techniques Department

Effect of Radiation on Cells :

The basic difference between ionizing radiations and the more commonly encountered radiations such as light is that the former have sufficient energy to cause ionization in matter. When it is incident on the body, a part or whole of the energy may be absorbed by the cell through the process of ionization and excitation. Since the water content in human tissues is more than 7% most of the energy will be initially deposited in the water molecules and only a small part is taken up directly by the other bio-molecules. The excited and ionized water molecules undergo a series of reactions. Radiation on interactions with water produces the radiolytic products of water such is H, OH, HO2, eraq, O2 and H2O2.

These free radicals react readily with bio-molecules in the cell and result in damage to important bio-molecules such as DNA and proteins. Such damages may lead to

(a) Inhibition of cell division,

(b) Chromosome aberrations,

(c) Genes mutation, and

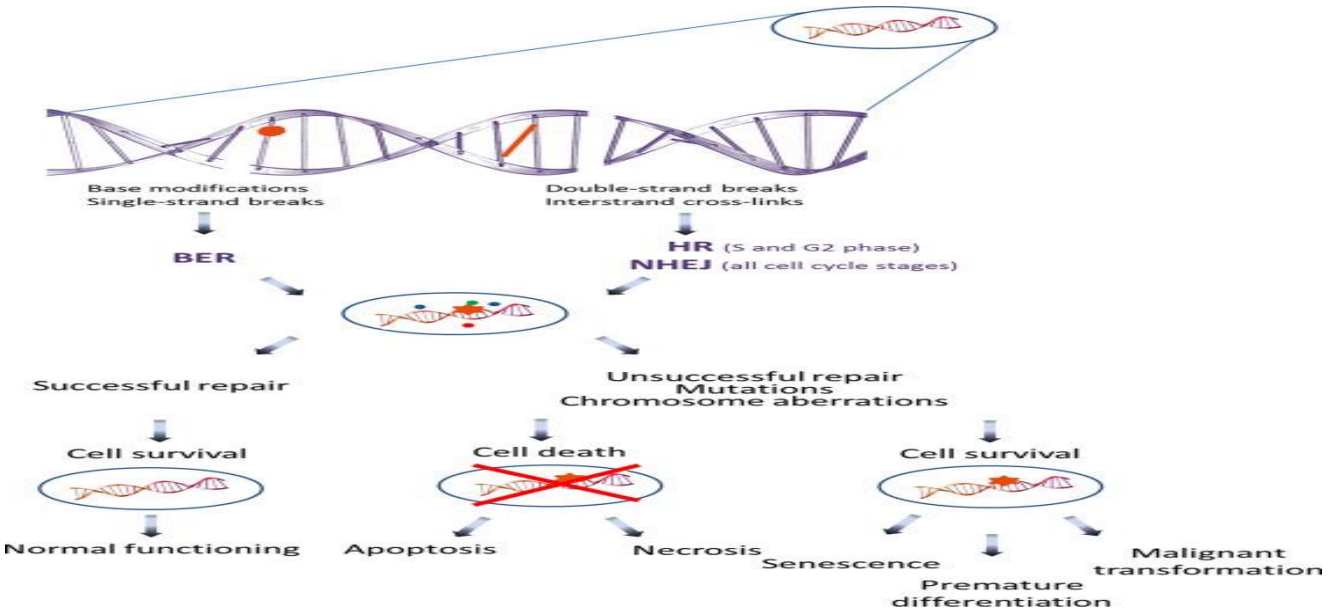
(d) Cell death. While the absorption of radiation energy in the organ tissues takes a very short time (only 10-15 sec), the appearance of following biological effects (damage due to absorption of radiation) may take a few hours to several years.

a. Inhibition of cell division: Cells originate and multiply by the process of cell division. It is one of the basic functions in all living organisms. Even in an adult human body, cells in certain organs are in a constant process of division, radiation might hamper the cell division process, which causes impairment of the function of tissue and organ.

b. Chromosome aberrations : Radiation can cause breaks in chromosomes. Majority of the breaks may get repaired and the damage may not manifest. However, certain breaks may lead to rearrangements of genetic material which can be seen under a microscope. Such events are called chromosomal aberrations. The frequency of various types of di-centric chromosome aberrations can be correlated to dose and hence can serve as a biological dosimeter.

c. Gene mutation : Alterations in the information content of genes (DNA) are known as gene mutation. Damage to chromosomes (Chromosome aberrations) may lead to change the information content of DNA

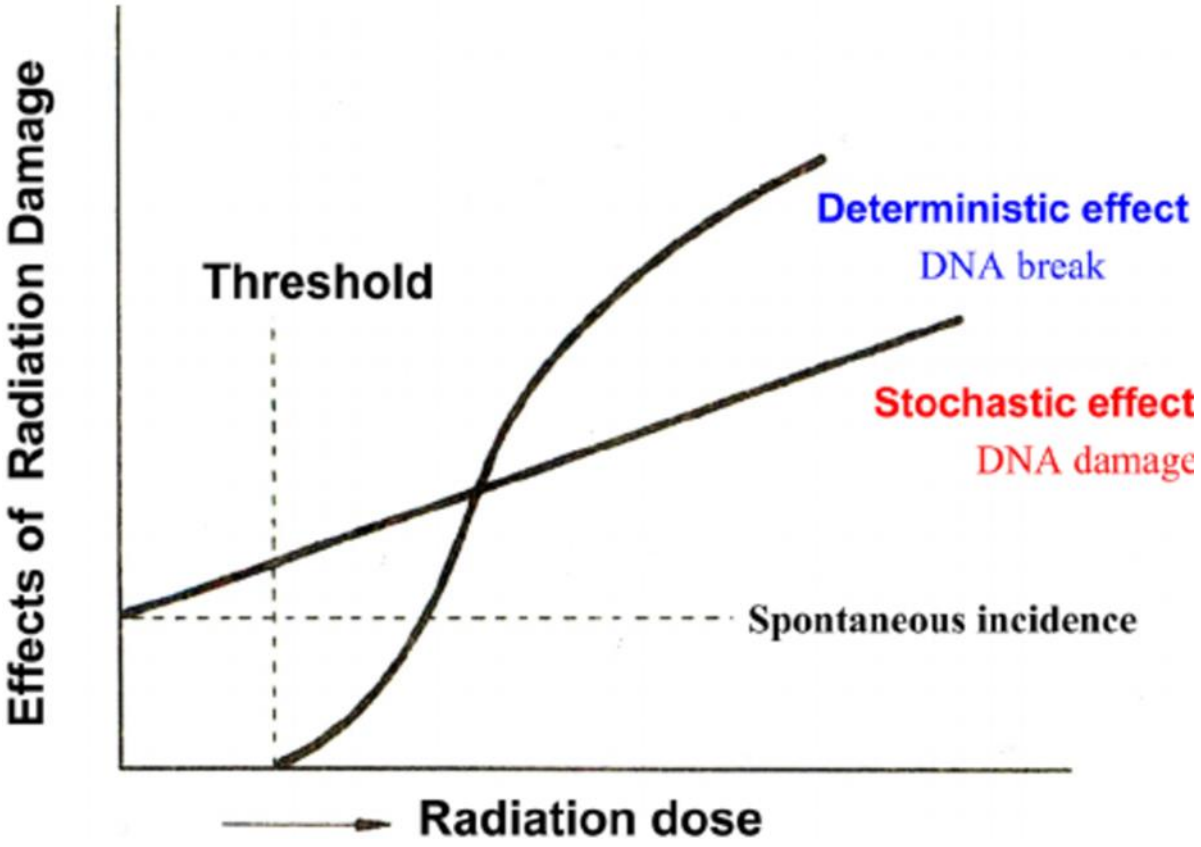
d. Cell death : Irradiation can lead to cell death as a result of any or all of the above effects. Cell death is usually expressed as fraction of cells surviving after a given exposure.



Radiobiological Effects : The harmful effects of the radiation fall into two categories, non-stochastic & stochastic effects.

Non-Stochastic Effects : These effects are **deterministic** in nature and do not occur below a particular threshold radiation dose. Severity of these effects increases with increase in dose received. Now ICRP-6016 has replaced this term of non-stochastic effects by 'detrimental effects'. Skin erythema, desquamation, necrosis, vomiting, hemorrhage and even death are some of the examples of non-stochastic effects.

Stochastic Effects : These effects do not have any threshold dose and are probabilistic in nature. Incidence of these effects increases with the dose received. Stochastic effects occur due to small exposure received over long period that may cause cancer (e.g. Leukemia, lymphoma, etc) and genetic effects by changing the coded genetic information which causes various deformation (e.g. mental retardation, death of the offspring or many other damages).



Further radiation effects are classified into another two categories, somatic & genetic effects.

Somatic effects are exhibited on the person being exposed to radiation. While genetic effects are manifested in future generations of the person exposed to radiation.

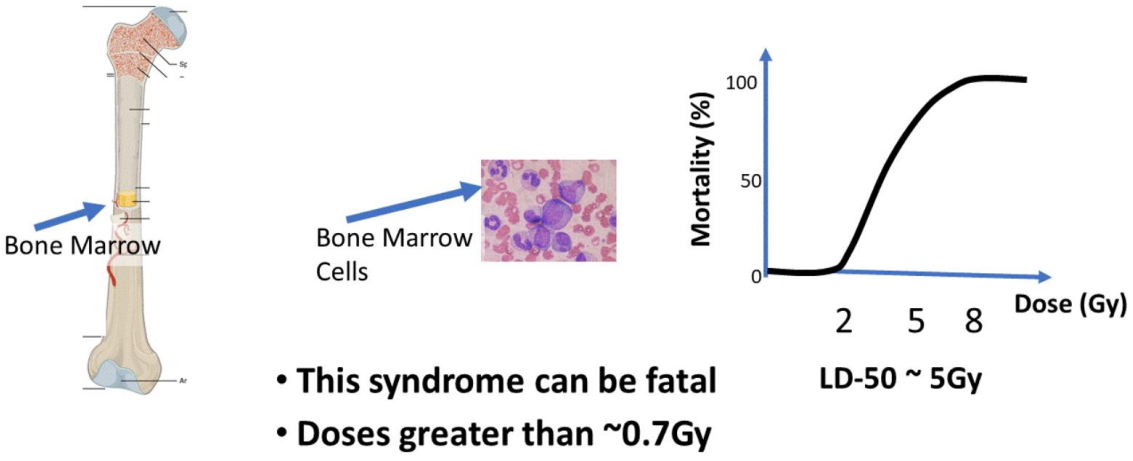
Somatic Effects Early effects : Somatic effects of radiation may appear immediately after exposure (within a few hours to weeks) or much later (years or decades after exposure).

The early effects are due to an acute exposure, i.e., large doses received over a short period of time (a. few hours or less) and attributed to depletion of cell population due to cell-killing.

Acute exposure of whole body to about 1 Gy may lead to reduction in lymphocyte and granulocyte counts and radiation sickness in the form of nausea and vomiting. These are however transient and the exposed person recover after one or two days. But the severity of the effect increases with radiation dose. At doses higher than 3 Gy, irrecoverable damage occurs to the blood forming organs (bone marrow, spleen, lymph node etc., with the possibility of death in a few weeks time.

In the dose range of 3-5 Gy about 50% of the exposed persons may die within 60 days (LD50/60). Anemia, infection, and high fever are the main symptoms. These symptoms are called **Haematopoietic Syndrome** .

At higher doses, in the range of 7 to 10 Gy, cells in the gastrointestinal system get severely damaged leading to diarrhoea, loss of appetite, dehydration, electrolyte imbalance, weight loss and high fever. These symptoms are typical of Gastrointestinal Syndrome (GIS). Death occurs in 7 to 14 days time. As the dose is increased further, consequences of damage to central nervous system manifest.



At doses in the range of 25 Gy and above, the damage becomes so severe that depression, fatigue, delirium and comma appear and death occurs within a few hours to 2 days. These symptoms are known as Central Nervous System Syndrome (CNS). The quickness of occurring early symptoms such as nausea, vomiting etc and the degree of severity is good indications of the level of exposure.

Persons exposed to doses in the range of **LD50/60** exhibit these symptoms within one or two hours. The nature and seriousness of the early effects also depend upon whether the exposure is to the whole body or part of the body. Even though whole body irradiation to 3-5 Gy may kill 50% of the exposed persons, the same dose given to a part of the body will cause only local effects (Table-2). Some of the local effects are reddening of the skin (erythema), hair falling off (epilation), temporary or permanent sterility (when reproductive organs are exposed).

Late effects - Persons who recover from early effects may still develop some other types of effects later in life. Similarly exposure to low levels of radiation over long periods of time, which cannot produce any early effects, may also lead to late effects. Late effects are characterized by a long latent period, which can be as long as 30-40 years. The important late effects are cancer, fibrosis in various tissues and cataract of the eye lens. Cataract is progressive loss of vision. The transparent cells in the eye lens, which facilitate vision, are killed by high doses of radiation. Since there is no blood flow through lens, the dead cells are not removed. Accumulation of dead cells results in the opacity of lens, which lead to the impairment of vision. Opacities of the lens of the eyes require an acute dose of 200 rad (2 Gy) to the lens. The latent period for cataract formation ranges from 6 months to 35 years. A single dose of 750 rad (7.5 Gy) will cause cataract formation in everyone exposed.

Genetic Effects : Genetic effects constitute radiation damage to a descendant resulting from modification of genetic material in a parent. Genetic changes have been observed in plants and animals following very high doses. Follow-up studies of the population of Hiroshima and Nagasaki atomic bomb survivors have not seen statistically significant effects, such as stillbirths, neonatal deaths, malformations, birth weight, infant mortality, leukemia, mutation rates, or cytogenetic analyses.

Congenital abnormalities and malformations are practically nonexistent in fetuses exposed in utero to fetal doses of about 5 rad or less. The risk of childhood cancer from prenatal exposure in this dose range is small compared to other risks normally associated with pregnancy.

Genetic effects (an example of stochastic effect), occur in the progeny of exposed persons, if the germ cells carrying radiation induced damages (mutations, chromosomal aberrations, etc.) participate in the process of fertilization. Only that exposure of the

reproductive organs which occurs up to the time of conception can affect the genetic characteristics of the off-spring. There is no human data which demonstrate that radiation induces genetic defects in man.

However, based on animal experiments, the ICRP (International Commission on Radiological Protection) has estimated the risk of serious genetic disorders in future generations following irradiation of either parent, to be about 10 per million live births per milli-sievert (mSv). To put these estimates into perspective, it may be noted that more than 500 types of human diseases are attributable to genetic factors and nearly 10 percent of all new born children suffer from spontaneous genetic disorders. It may be mentioned that mutations induced by various agents like heat and chemicals etc. are indistinguishable from that induced by radiations.

---

1. The main difference between ionizing radiation and non-ionizing radiation like light is:
   a) Ionizing radiation has less energy
   b) Ionizing radiation cannot penetrate tissues
   c) Ionizing radiation has sufficient energy to cause ionization in matter
   d) Ionizing radiation is visible
   e) Ionizing radiation is not harmful
   Answer: c)

2. In human tissues, more than ____% of energy from radiation is absorbed by water molecules.
   a) 30%
   b) 50%
   c) 60%
   d) 70%
   e) **>70%**
   Answer: e)

3. The primary products of water radiolysis include:
   a) CO2, H2, CH4
   b) **H, OH, HO2, eaq–, O2, H2O2**
   c) DNA fragments
   d) ATP molecules

e) Enzymes
Answer: b)

4. Free radicals generated by radiation damage cells mainly by:
   a) Enhancing metabolism
   b) **Damaging DNA and proteins**
   c) Repairing chromosomes
   d) Increasing energy supply
   e) Decreasing apoptosis
   Answer: b)

5. Which of the following is NOT a major radiation-induced cellular effect?
   a) Inhibition of cell division
   b) Chromosomal aberrations
   c) Gene mutation
   d) **Increased protein synthesis**
   e) Cell death
   Answer: d)

6. Radiation damage to DNA that changes the information content of genes is called:
   a) Chromosomal aberration
   b) Apoptosis
   c) **Gene mutation**
   d) Recombination
   e) Transformation
   Answer: c)

7. Radiation-induced breaks in chromosomes that rearrange genetic material are termed:
   a) Mutations
   b) **Chromosome aberrations**
   c) Inversions
   d) Gene duplication
   e) Protein folding errors
   Answer: b)

8. Radiation-induced cell death is usually expressed as:
   a) Mutation frequency
   b) Repair rate
   c) **Fraction of cells surviving after exposure**
   d) Level of free radicals
   e) Number of cell divisions
   Answer: c)

9. Non-stochastic effects are also called:
   a) Probabilistic effects
   b) **Deterministic (detrimental) effects**
   c) Random effects
   d) Genetic effects
   e) Somatic mutations
   Answer: b)

10. Stochastic effects are characterized by:
   a) A threshold dose
   b) Severity proportional to dose
   c) **No threshold dose, probability increases with dose**
   d) Reversibility
   e) Rapid onset
   Answer: c)

11. An example of a non-stochastic (deterministic) effect is:
   a) **Skin erythema**
   b) Leukemia
   c) Lymphoma
   d) Genetic mutation
   e) Cataract after decades
   Answer: a)

12. An example of a stochastic effect is:
   a) Skin necrosis
   b) Vomiting
   c) **Cancer induction**
   d) Acute radiation sickness
   e) Hemorrhage
   Answer: c)

13. Effects that appear in the person exposed to radiation are called:
   a) Stochastic
   b) **Somatic**
   c) Genetic
   d) Mutational
   e) Hereditary
   Answer: b)

14. Effects passed on to future generations due to radiation-induced damage in germ cells are:
   a) Somatic

b) **Genetic**
c) Deterministic
d) Acute
e) Stochastic only
Answer: b)

15. Congenital abnormalities in fetuses are practically nonexistent below:
a) 0.5 rad
b) 2 rad
c) 3 rad
d) **5 rad**
e) 10 rad
Answer: d)

16. Genetic effects of radiation are best described as:
a) Non-stochastic
b) Somatic
c) **Stochastic and hereditary**
d) Acute
e) Deterministic
Answer: c)

17. Early effects appear after:
a) Years
b) **Hours to weeks**
c) Generations
d) Centuries
e) Never
Answer: b)

18. The dose of whole-body acute exposure that leads to nausea and vomiting but recovery in 1–2 days is about:
a) 0.1 Gy
b) 0.5 Gy
c) **1 Gy**
d) 10 Gy
e) 20 Gy
Answer: c)

19. The LD50/60 for humans corresponds to a dose of about:
a) 1–2 Gy
b) **3–5 Gy**

c) 6–8 Gy
d) 10 Gy
e) 20 Gy
Answer: b)

20. Symptoms like anemia, infection, and high fever due to bone marrow damage represent:
a) CNS Syndrome
b) **Haematopoietic Syndrome**
c) Genetic Syndrome
d) Cataractogenesis
e) Somatic mutation
Answer: b)

21. Radiation dose range 7–10 Gy causes:
a) Bone marrow failure
b) **Gastrointestinal Syndrome (GIS)**
c) CNS Syndrome
d) Cataract
e) Genetic mutation
Answer: b)

22. The CNS Syndrome typically occurs at doses of:
a) 1–2 Gy
b) 3–5 Gy
c) 7–10 Gy
d) **25 Gy and above**
e) 15 Gy
Answer: d)

23. Local early effects of partial body exposure include:
a) Cataract
b) **Erythema and epilation**
c) Genetic mutation
d) Cancer
e) Leukemia
Answer: b)

24. Late somatic effects are characterized by:
a) Rapid onset
b) **Long latent period (years to decades)**
c) Immediate DNA repair
d) High reversibility

e) No genetic risk
Answer: b)

25. An important late somatic effect of radiation is:
    a) Acute diarrhea
    b) Vomiting
    c) **Cancer**
    d) Hair loss
    e) Epilation
    Answer: c)

26. Cataract formation due to radiation requires a minimum single dose of:
    a) 0.5 Gy
    b) 1 Gy
    c) **2 Gy**
    d) 5 Gy
    e) 10 Gy
    Answer: c)

27. A single dose of 7.5 Gy to the eye lens will:
    a) Have no effect
    b) Cause temporary vision loss only
    c) **Cause cataract formation in everyone exposed**
    d) Lead to epilation
    e) Induce genetic mutation
    Answer: c)

28. Radiation-induced genetic effects result from damage to:
    a) Somatic cells
    b) **Germ cells**
    c) Neurons
    d) Bone marrow cells
    e) Muscle fibers
    Answer: b)

29. Human data proving radiation-induced genetic defects is:
    a) Conclusive
    b) **Not demonstrated**
    c) Extremely strong
    d) Always present
    e) Irrefutable
    Answer: b)

30. Based on ICRP estimates, risk of serious genetic disorders in future generations is about:
    a) 1 per million/mSv
    b) 5 per million/mSv
    c) **10 per million/mSv**
    d) 50 per million/mSv
    e) 100 per million/mSv
    Answer: c)

31. The first molecules affected by ionizing radiation in human tissue are:
    a) Proteins
    b) DNA
    c) Lipids
    d) **Water molecules**
    e) Enzymes
    Answer: d)

32. The speed of absorption of radiation energy in tissues is:
    a) Hours
    b) Days
    c) Weeks
    d) **10–15 seconds**
    e) Years
    Answer: d)

33. The biological effects of absorbed radiation may appear after:
    a) Seconds only
    b) Minutes only
    c) **Hours to several years**
    d) Instantly
    e) Never
    Answer: c)

34. The severity of non-stochastic effects:
    a) Is probabilistic
    b) Does not depend on dose
    c) **Increases with increasing dose**
    d) Decreases with dose
    e) Is random
    Answer: c)

35. Stochastic effects result mainly from:
    a) Acute high doses

b) **Chronic low doses over long periods**
c) Mechanical trauma
d) Enzyme overproduction
e) Protein misfolding
Answer: b)

36. Vomiting, hemorrhage, and necrosis are examples of:
a) Stochastic effects
b) Genetic effects
c) **Non-stochastic effects**
d) Mutations
e) Cataractogenesis
Answer: c)

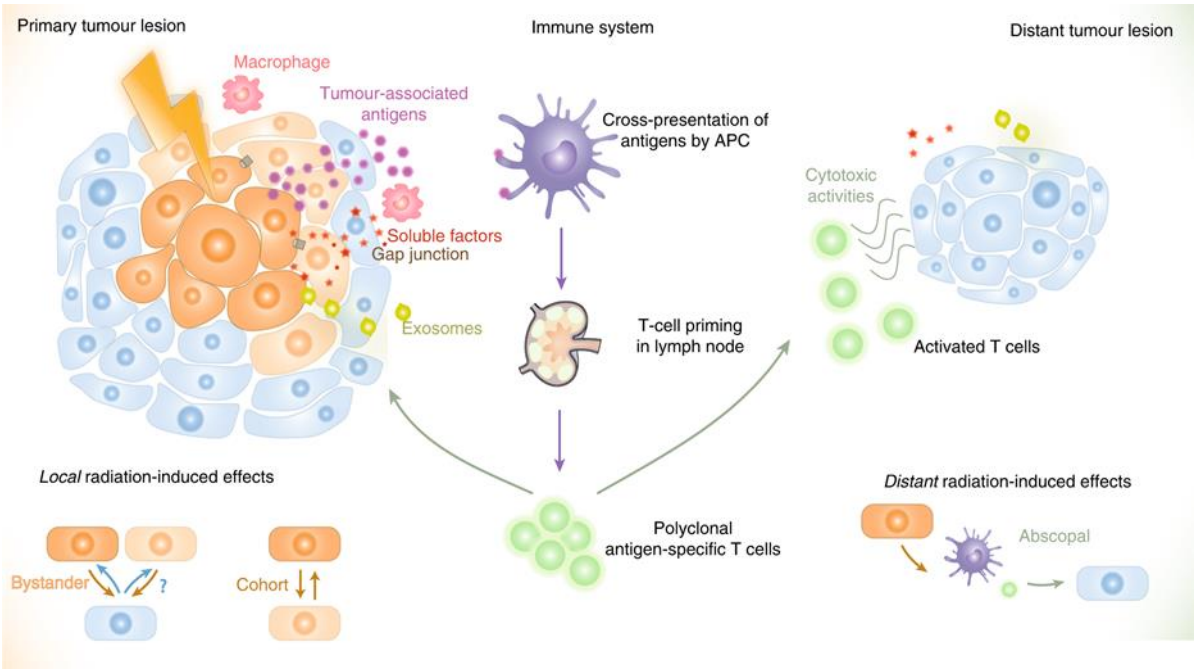
37. The appearance of nausea and vomiting within hours of exposure indicates:
a) **High dose acute exposure**
b) Genetic mutation
c) Stochastic effect
d) Low dose chronic exposure
e) Partial body exposure only
Answer: a)

38. At doses above 3 Gy, irrecoverable damage occurs to:
a) Nervous tissue
b) **Blood forming organs**
c) Muscle fibers
d) Eye lens
e) Skin cells
Answer: b)

39. Radiation-induced fibrosis, cancer, and cataract are considered:
a) Early somatic effects
b) **Late somatic effects**
c) Genetic effects only
d) Acute effects
e) Deterministic effects only
Answer: b)

40. Which syndrome causes death within hours to 2 days after exposure?
a) Hematopoietic syndrome
b) Gastrointestinal syndrome
c) **Central Nervous System syndrome**
d) Cataractogenesis

e) Epilation
Answer: c)



1.

Which of the following best describes the **abscopal effect** shown in the diagram?
a) Direct killing of irradiated tumor cells
b) Local transfer of signals between neighboring cells
c) **Immune-mediated regression of distant, non-irradiated tumors**
d) Repair of DNA in tumor cells after radiation
e) Radiation-induced apoptosis in normal tissue
Answer: c)

2.What role do **antigen-presenting cells (APCs)** play after radiation exposure of a tumor?
a) Directly kill tumor cells
b) **Cross-present tumor-associated antigens to T cells**
c) Prevent macrophage recruitment
d) Block soluble factor release

e) Inhibit lymphocyte activity
Answer: b)

3.

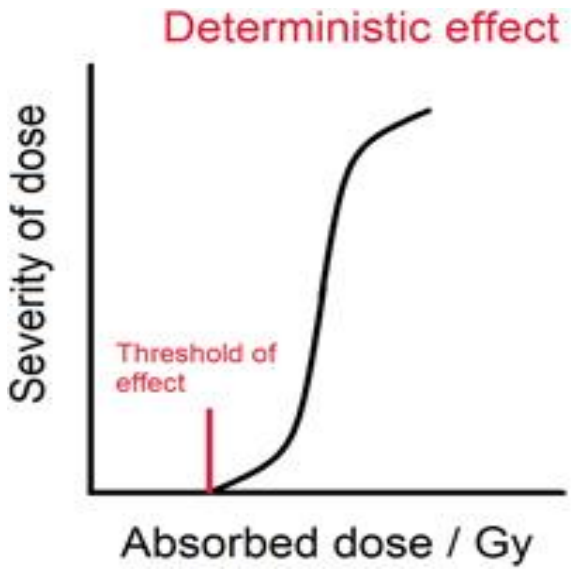
Which molecules are released from irradiated tumor cells that contribute to immune activation?
a) Glucose and ATP
b) **Exosomes and soluble factors**
c) Platelets and cytokines only
d) Hemoglobin and myoglobin
e) Immunoglobulins only
Answer: b)

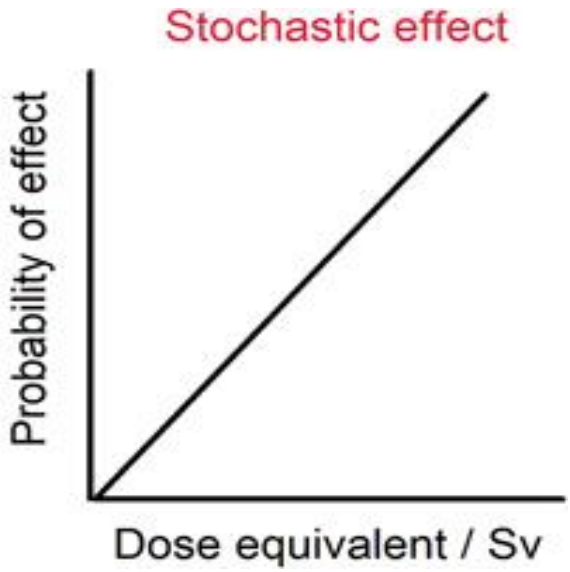
4.

The **bystander effect** in local radiation-induced effects refers to:
a) Radiation-induced cataract formation
b) **Non-irradiated neighboring cells being affected by signals from irradiated cells**
c) Mutations passed to offspring
d) Dose-dependent deterministic effects
e) Repair of irradiated DNA
Answer: b)

5.

What is the final step in the immune-mediated pathway triggered by radiation, as illustrated?
a) Release of soluble factors
b) Exosome-mediated signaling
c) Antigen presentation by macrophages
d) **Activation of polyclonal antigen-specific T cells that attack distant tumors**
e) Suppression of lymph node activity
Answer: d)





1.Which feature characterizes **deterministic effects** of radiation?
a) No threshold dose
b) Severity independent of dose
c) **Presence of a threshold and severity increases with dose**
d) Probability increases with dose but not severity
e) Random occurrence only
Answer: c)

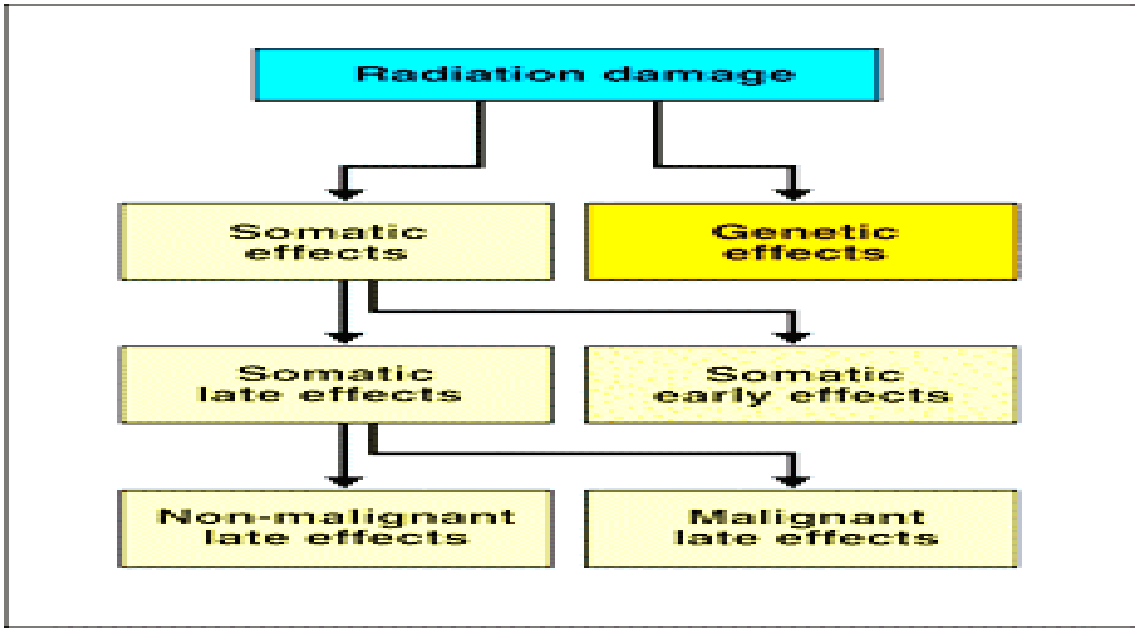
2.Which of the following is an example of a **stochastic effect**?
a) Skin erythema
b) Hair loss (epilation)
c) Radiation burns
d) **Cancer induction**
e) Cataract after high dose
Answer: d)

3.The vertical red line labeled **"Threshold of effect"** in the deterministic effect graph represents:
a) A lethal dose
b) **The minimum dose required before effects appear**
c) The average survival dose
d) The LD50/60
e) The probability of stochastic effects
Answer: b)

4.In stochastic effects, radiation dose is related to:
a) Severity of effect
b) **Probability of effect**
c) Threshold value

d) Immediate cell death
e) Tissue repair rate
Answer: b)

5.Which statement best describes deterministic effects?
a) They occur randomly with no threshold
b) **They have a threshold and severity increases with dose**
c) They are always genetic in nature
d) They occur mainly after chronic low-dose exposure
e) They are only probabilistic, not dose-dependent
Answer: b)



1. Radiation damage can be broadly divided into:
a) Acute and chronic effects
b) Stochastic and deterministic effects
c) **Somatic and genetic effects**
d) Non-malignant and malignant effects
e) Direct and indirect effects
Answer: c)

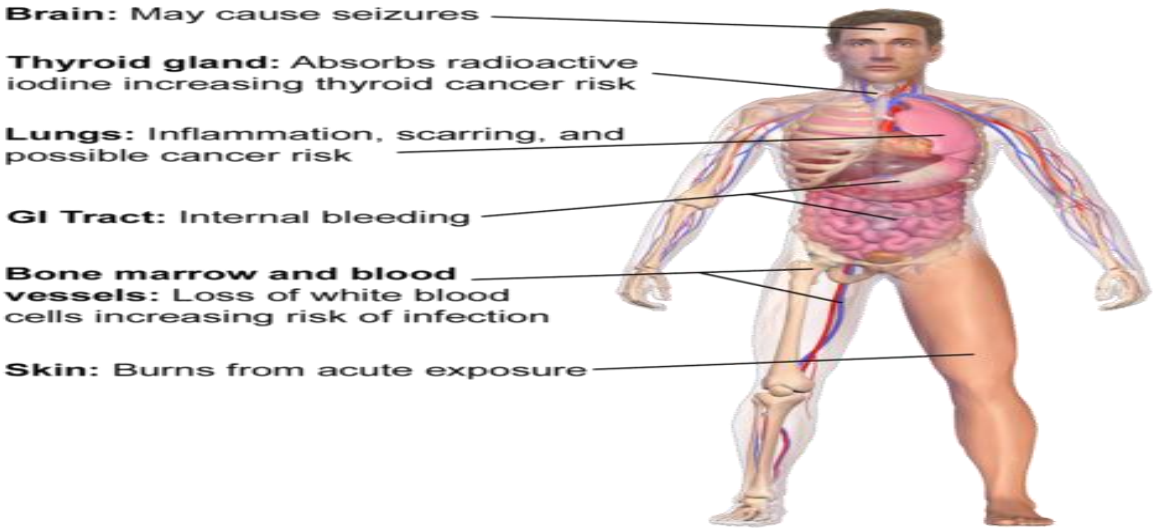
2.Which of the following refers to radiation effects that appear in the **individual exposed**?
a) Genetic effects
b) Hereditary effects

c) **Somatic effects**
d) Germline mutations
e) Prenatal effects only
Answer: c)

3.Somatic effects can be further classified into:
a) Mutational and chromosomal
b) **Early and late effects**
c) Genetic and hereditary
d) Acute and stochastic
e) Deterministic and probabilistic
Answer: b)

4.Late somatic effects of radiation can be:
a) Only genetic mutations
b) Always reversible
c) **Malignant or non-malignant**
d) Limited to skin erythema
e) Limited to eye cataracts only
Answer: c)

5.Radiation effects passed to **future generations** are termed:
a) Somatic effects
b) **Genetic effects**
c) Non-malignant late effects
d) Early effects
e) Deterministic effects
Answer: b)



Selected Risks from Radiation Sickness