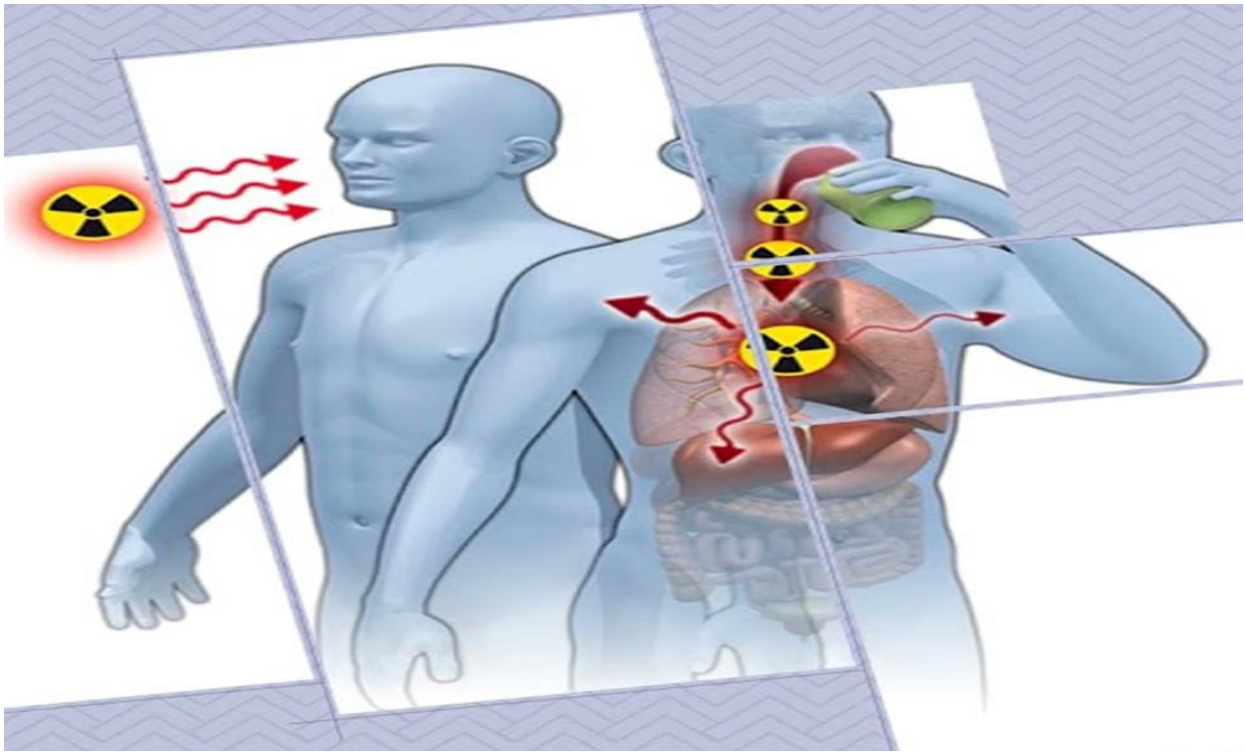
The radiation dose response relationship
3rd Lecture



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Teaching of Biological Radiation hazards

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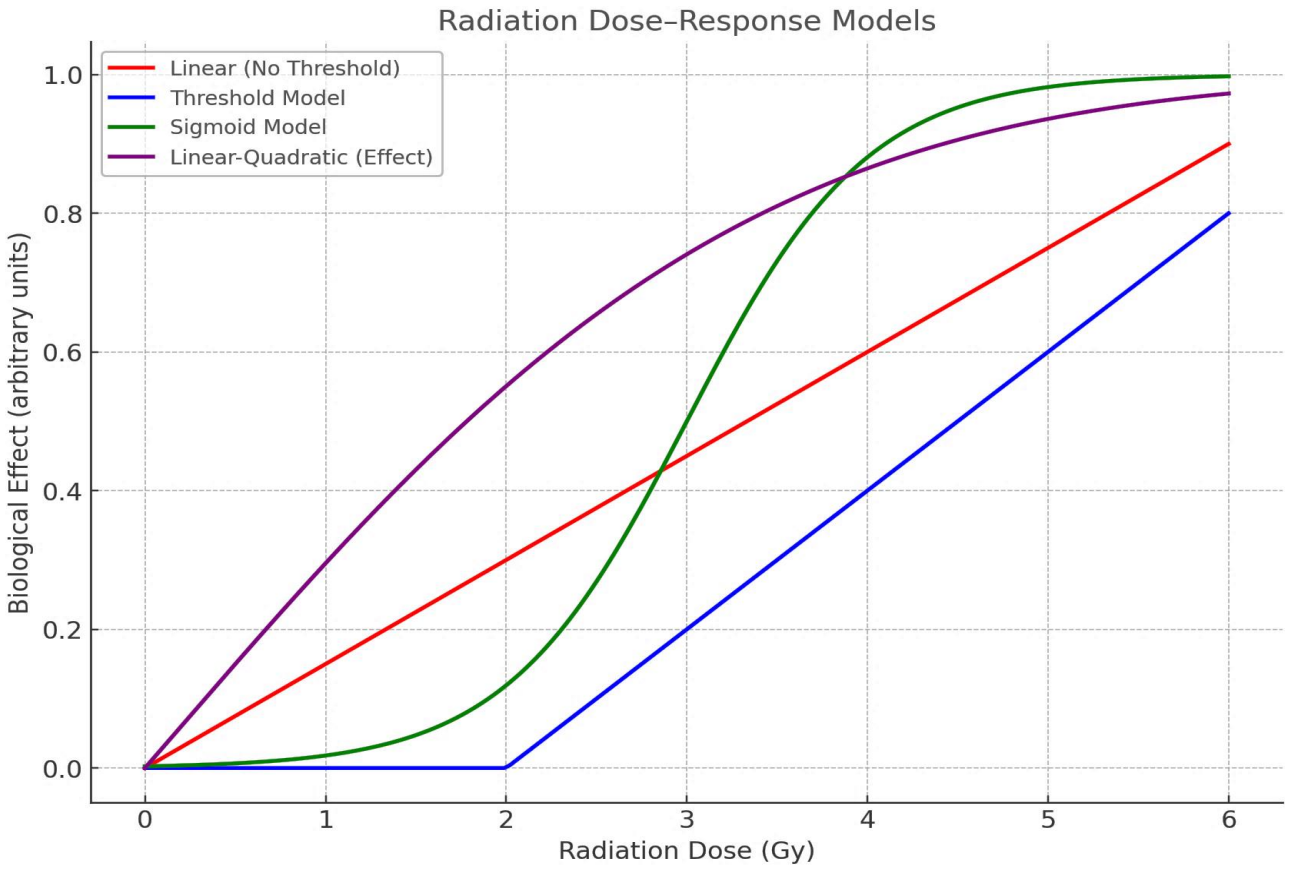
The radiation dose response relationship

The radiation dose response relationship describes how biological systems (cells, tissues, organisms) respond to different levels of ionizing radiation. It shows the correlation between the dose of radiation received and the magnitude of the biological effect produced.

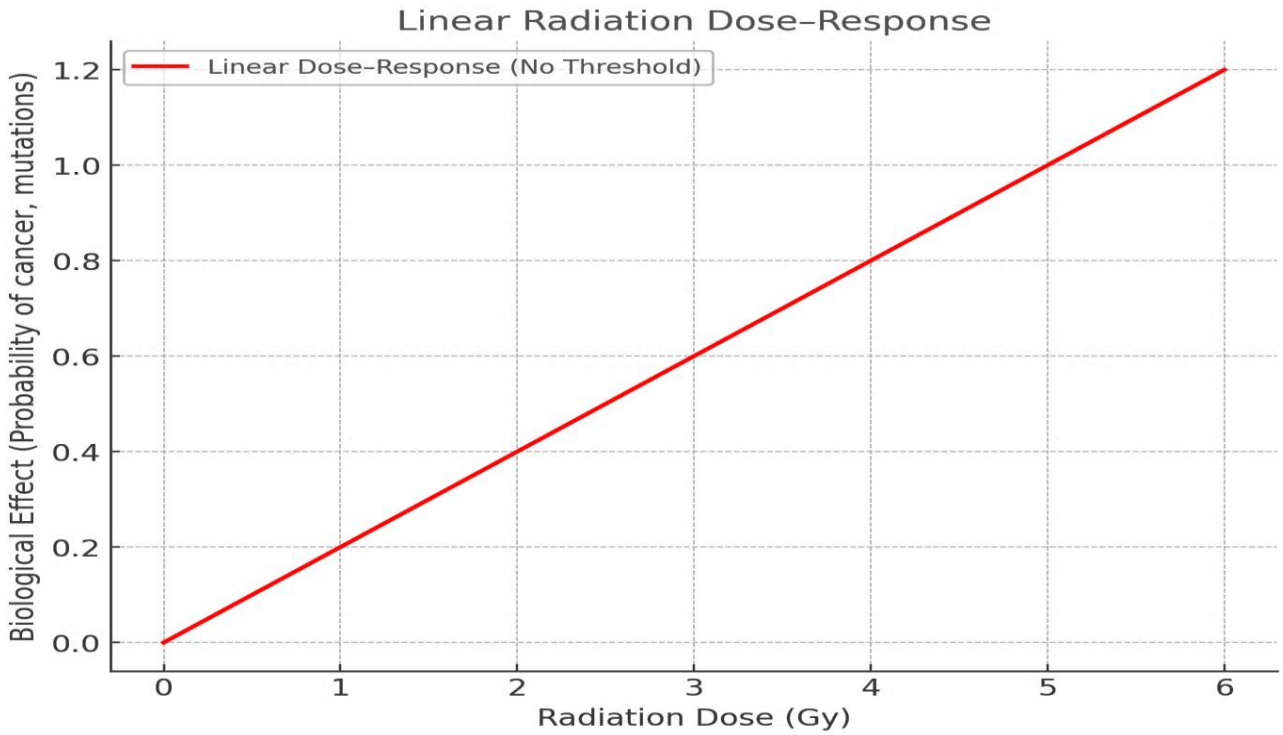


I- Types of Dose Response Relationships

1- Linear Dose–Response

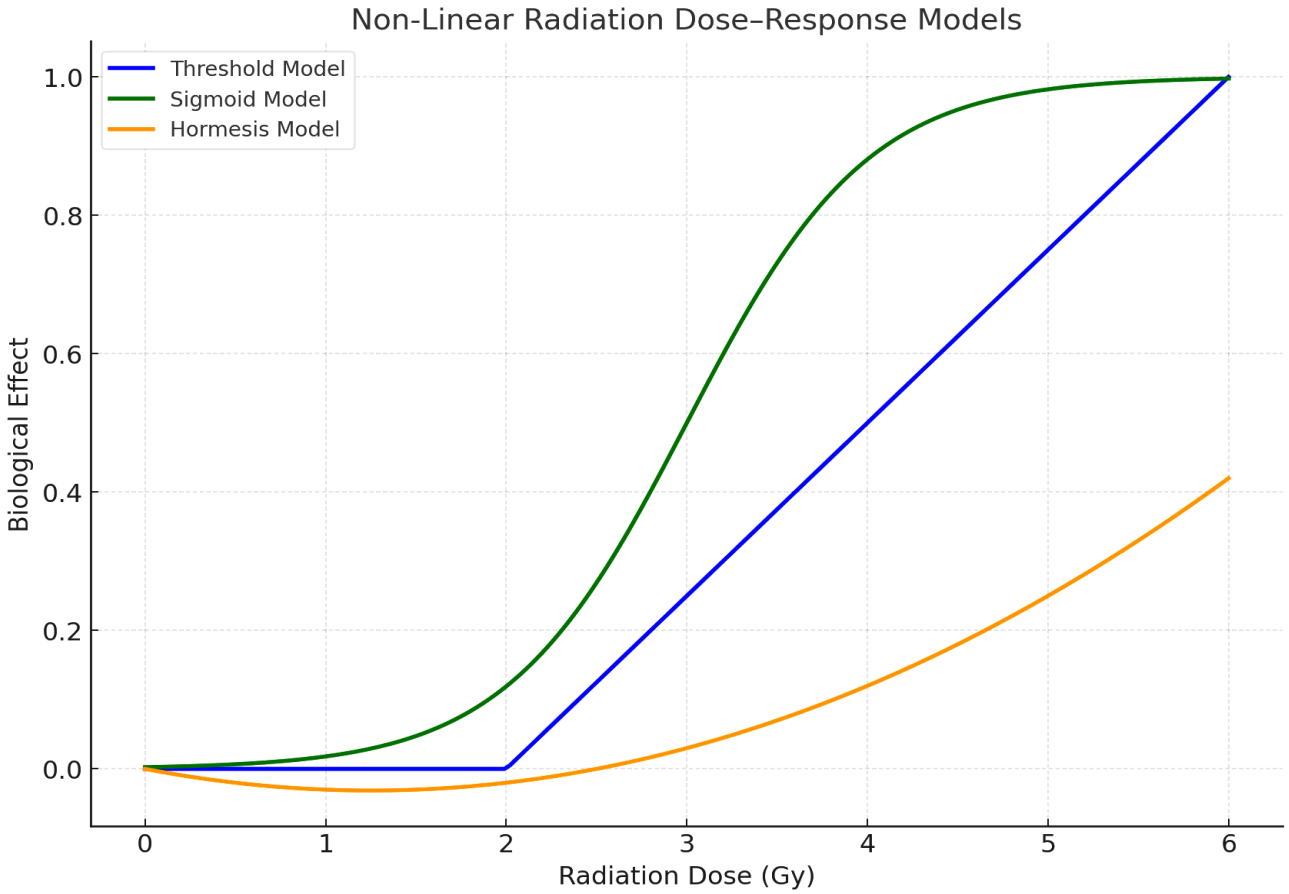
- Response increases directly in proportion to the dose.
- No threshold (any dose may cause an effect).
- It assumes no safe dose — even the smallest dose carries some risk.
- The curve starts at zero and rises in a straight line.
- Often used for stochastic effects like cancer or genetic mutations.

Example: Linear No-Threshold (LNT) model → used in radiation protection standards.



2- Non-Linear Dose–Response

- Relationship is not directly proportional.
- Several patterns exist:
    - **Threshold model**: No effect observed until a certain dose is reached, then effects increase (typical for deterministic effects such as skin burns, cataracts).
    - **Sigmoidal (S-shaped) curve**: Slow response at low doses, steep rise at intermediate doses, then plateau at high doses.
    - **Hormesis model**: Very low doses may have a beneficial effect (stimulating repair or adaptive responses), but high doses are harmful.



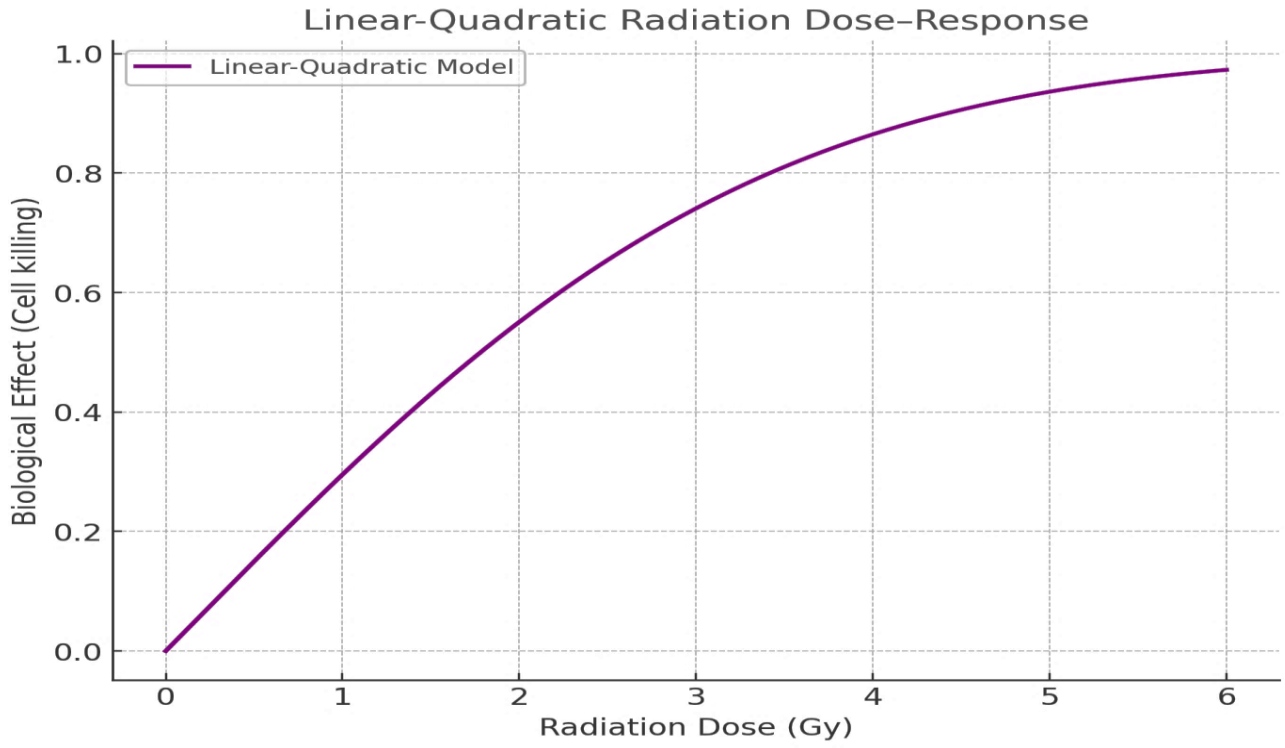
3- Linear-Quadratic Model

- Common in radiation biology and radiotherapy.
- a mathematical framework used to describe the relationship between radiation dose and cell survival, particularly in the context of radiation therapy.
- Describes cell survival:

$$S = e^{-\alpha D - \beta D^2}$$

- S is the fraction of cells surviving a dose D, and α and β are constants.

- Explains why fractionated doses in radiotherapy can spare normal tissue but still kill tumor cells.



II- Types of Biological Effects

- **Deterministic effects (tissue reactions):**
    - Have a threshold.
    - Severity increases with dose (e.g., radiation burns, cataracts, sterility).
- **Stochastic effects:**
    - No threshold.
    - Probability increases with dose (e.g., cancer, heritable mutations).

III- Constructing a Dose–Response Curve

- X-axis: Radiation dose (Gy or Sv).

- Y-axis: Biological effect (e.g., % cell death, cancer risk).

- Plot experimental or epidemiological data.

- Choose model type (linear, threshold, linear-quadratic).

- Fit the curve to predict risks or therapeutic outcomes.

1. The linear dose–response model assumes:
   a) A threshold exists
   b) Effects occur only at high doses
   c) No threshold — any dose may cause an effect
   d) Non-linear proportionality
   e) Hormesis dominates

2. The linear dose–response curve typically starts at:
   a) Threshold level
   b) Zero
   c) Midpoint dose
   d) Plateau
   e) Negative axis

3. Which type of effect is often modeled by the linear no-threshold (LNT) model?
   a) Skin burns
   b) Cataracts
   c) Sterility
   d) Cancer
   e) Sunburn

4. The LNT model is widely used in:
   a) Agriculture
   b) Astronomy
   c) Radiation protection standards
   d) Veterinary sciences
   e) Space engineering

5. The non-linear dose–response model includes:
   a) Strict linearity
   b) Threshold, sigmoidal, and hormesis models
   c) Always a proportional rise
   d) No thresholds at all
   e) Only stochastic effects

6. Deterministic effects such as skin burns usually follow which model?
   a) LNT
   b) Threshold model
   c) Hormesis model
   d) Sigmoidal model
   e) Linear-quadratic

7. A sigmoidal (S-shaped) dose–response curve is characterized by:
   a) Straight-line increase from zero
   b) No plateau
   c) Immediate high effect at low dose
   d) Slow response at low doses, rapid rise at medium doses, plateau at high doses
   e) Random fluctuations

8. Hormesis refers to:
   a) Linear proportionality
   b) Low-dose beneficial effect, high-dose harmful effect
   c) No effect at low doses
   d) Threshold-only response
   e) Plateau effect only

9. The linear-quadratic model is commonly used in:
   a) Environmental studies
   b) Nuclear power plants
   c) Radiation therapy
   d) Chemical toxicology
   e) Astronomy

10. The linear-quadratic equation explains why:
    a) One high dose is better than many small ones
    b) Normal tissue always dies first
    c) Fractionated doses spare normal tissue but kill tumor cells

d) Hormesis is always observed
e) Threshold disappears

11. Deterministic effects are also called:
    a) Stochastic effects
    b) Probabilistic effects
    c) Tissue reactions
    d) Random effects
    e) Adaptive responses

12. A key feature of deterministic effects is:
    a) No threshold
    b) Presence of a threshold
    c) Random occurrence
    d) No severity dependence
    e) Always beneficial

13. Severity of deterministic effects:
    a) Decreases with dose
    b) Is independent of dose
    c) Increases with dose
    d) Remains constant
    e) Is unpredictable

14. Examples of deterministic effects include:
    a) Cancer
    b) Genetic mutations
    c) Cataracts
    d) Leukemia
    e) Skin tanning

15. Stochastic effects are characterized by:
    a) Threshold presence
    b) Dose-independent probability
    c) No threshold, probability increases with dose
    d) Guaranteed severity increase
    e) Sigmoidal pattern

16. An example of a stochastic effect is:
    a) Sterility
    b) Skin erythema
    c) Heritable mutations
    d) Cataracts
    e) Vomiting

17. In stochastic effects, what increases with dose?
    a) Severity
    b) Probability
    c) Duration
    d) Threshold level
    e) Tissue recovery

18. Deterministic effects are more relevant in:
    a) Long-term cancer studies
    b) Mutagenic research
    c) High-dose exposures (e.g., radiation accidents)
    d) Environmental hormesis
    e) Genetic counseling

19. Stochastic effects are usually modeled by:
    a) Threshold curves
    b) Linear no-threshold model
    c) Sigmoidal curves
    d) Hormesis models
    e) Non-dose-dependent assumptions

20. A cataract caused by radiation is classified as:
    a) Stochastic effect
    b) Deterministic effect
    c) Linear effect
    d) Quadratic effect
    e) Random mutation

21. On a dose–response curve, the X-axis typically represents:
    a) Probability of effect
    b) Cell survival fraction
    c) Radiation dose
    d) Cancer risk percentage
    e) Severity of burns

22. On a dose–response curve, the Y-axis usually shows:
    a) Radiation dose
    b) Biological effect
    c) X-ray intensity
    d) Absorbed energy only
    e) Threshold presence

23. What units are commonly used for dose on the X-axis?
    a) Joules
    b) Watts

c) Gray (Gy) or Sievert (Sv)
d) Rads per second
e) Becquerel

24. Which type of data is used to plot dose–response curves?
a) Hypothetical estimates
b) Experimental or epidemiological data
c) Random statistical guesses
d) Only clinical trials
e) Theoretical simulations only

25. The purpose of fitting a curve is to:
a) Eliminate biological variation
b) Create straight lines
c) Predict risks or therapeutic outcomes
d) Remove stochastic effects
e) Ignore thresholds

26. Which model is often selected for predicting cancer risk at low doses?
a) Threshold
b) Linear no-threshold
c) Hormesis
d) Sigmoidal
e) Quadratic only

27. Which model is preferred for describing cell survival in radiotherapy?
a) Threshold
b) Hormesis
c) LNT
d) Linear-quadratic model
e) Purely random model

28. The dose–response curve for deterministic effects often includes:
a) No starting point
b) A curve beginning at zero
c) A threshold before effects occur
d) A straight linear rise
e) Random spikes

29. The sigmoidal model curve shows a plateau because:
a) Dose stops increasing
b) Energy is lost
c) Maximum biological effect is reached
d) Hormesis dominates
e) Probability becomes zero

30. Fractionated doses in radiotherapy are explained by:
    a) Threshold effect
    b) Hormesis effect
    c) Linear-quadratic model
    d) Pure linear model
    e) Deterministic theory

31. Radiation-induced sterility is classified as:
    a) Stochastic
    b) Deterministic
    c) Random
    d) Hormesis
    e) Genetic

32. Cancer risk increases with dose because:
    a) Severity increases
    b) Probability increases
    c) Threshold is crossed
    d) Hormesis stops
    e) Dose decreases

33. What does the LNT model assume about safe dose?
    a) Exists at 1 Sv
    b) No safe dose exists
    c) Only above 10 mSv
    d) Threshold at 100 mSv
    e) Always safe at low doses

34. Which effect has severity proportional to dose?
    a) Stochastic
    b) Deterministic
    c) Hormesis
    d) Linear
    e) Random

35. The linear-quadratic model is especially useful because:
    a) It shows hormesis clearly
    b) It ignores thresholds
    c) It explains fractionation in radiotherapy
    d) It removes stochastic risk
    e) It predicts sterility only

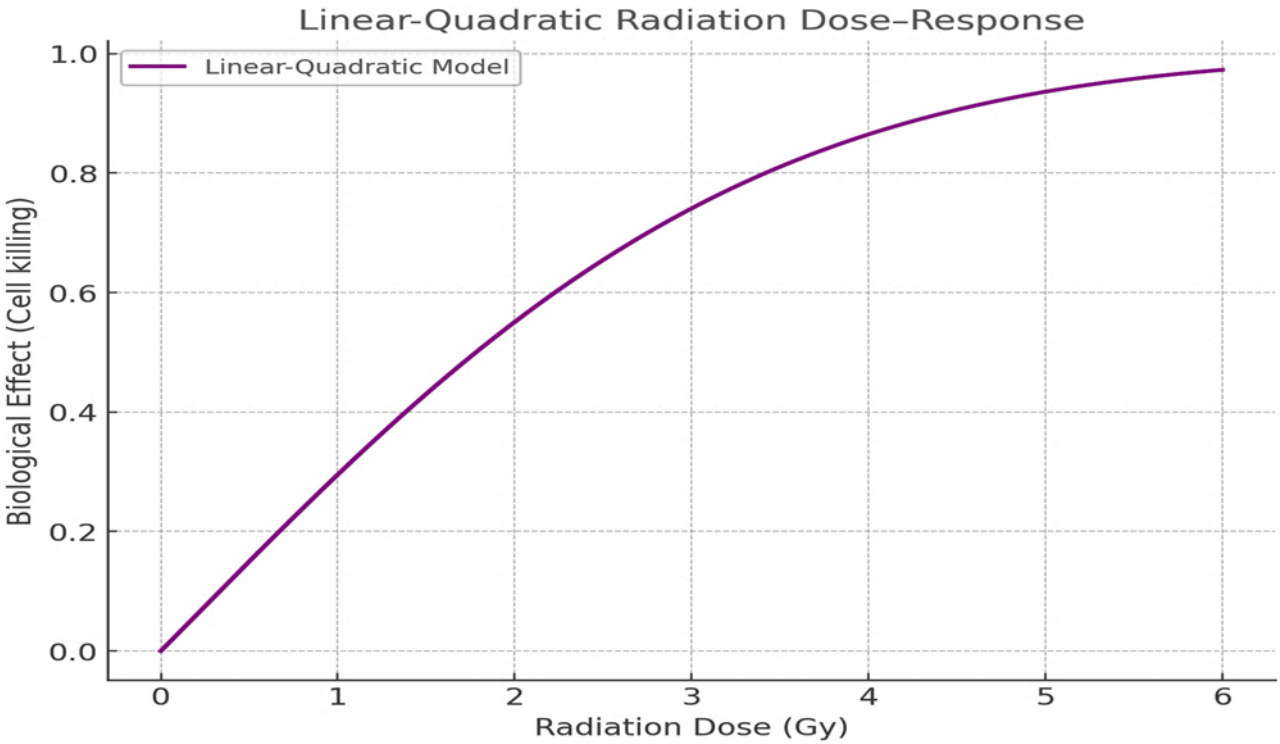
36. Which of the following is NOT a deterministic effect?
    a) Cataracts
    b) Skin burns
    c) Sterility
    d) Genetic mutations
    e) Radiation-induced hair loss

37. Which of the following is NOT stochastic?
    a) Cancer
    b) Heritable mutations
    c) Leukemia
    d) Radiation burns
    e) Genetic risks

38. The dose–response curve helps in:
    a) Building nuclear plants
    b) Predicting risks or therapeutic benefits
    c) Ignoring biological variation
    d) Randomizing therapy
    e) Ensuring only high doses are safe

39. The hormesis model suggests that at very low doses:
    a) DNA always mutates
    b) Cancer is inevitable
    c) Biological repair or benefits may occur
    d) Radiation is useless
    e) Threshold is always zero

40. Which of the following is true about deterministic and stochastic effects?
    a) Both have thresholds
    b) Both have no thresholds
    c) Deterministic depends on probability, stochastic on severity
    d) Deterministic depends on severity, stochastic on probability
    e) Both are severity dependent



1. The graph in the image represents which type of radiation dose–response model?
   a) Linear No-Threshold (LNT)
   b) Threshold model
   c) Hormesis model
   d) Linear-Quadratic model
   e) Sigmoidal model

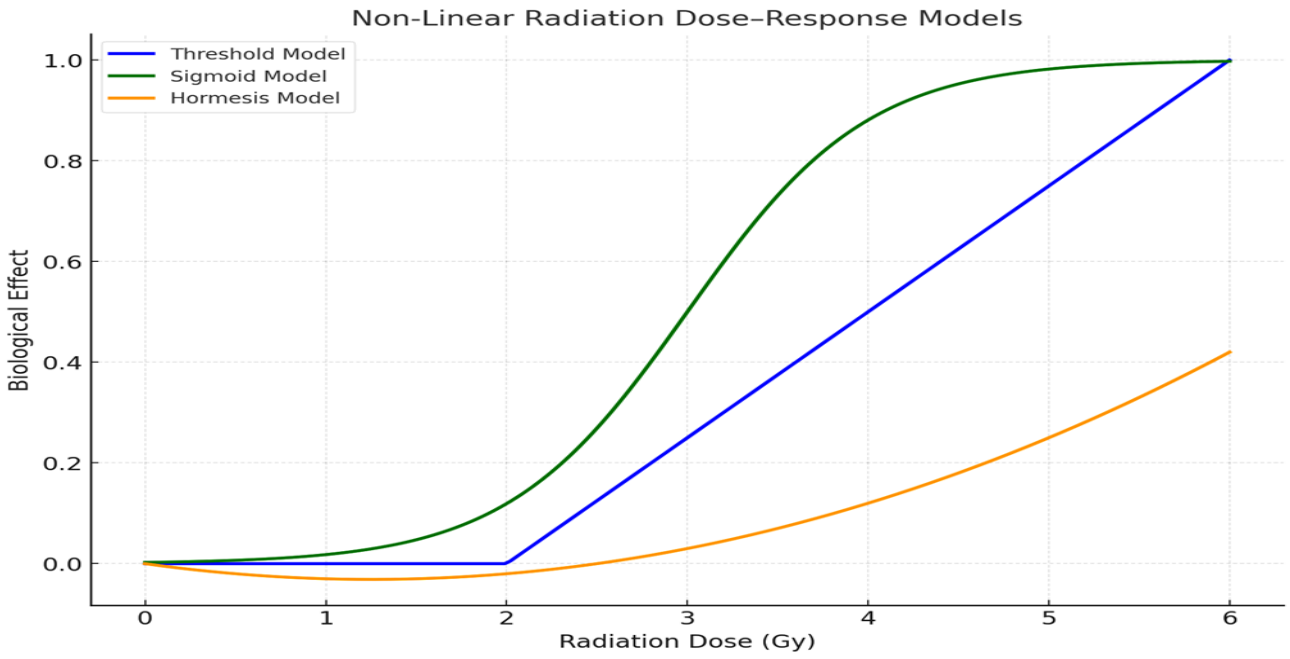
2. What does the Y-axis in the graph indicate?
   a) Radiation dose in Gray (Gy)
   b) Absorbed energy per unit mass
   c) Biological effect (cell killing)
   d) Probability of mutation
   e) Threshold dose

3. Why does the curve bend (showing non-linearity) at higher doses?
   a) Due to complete absence of biological effects
   b) Because cells repair damage more effectively at high doses
   c) Because both linear (αD) and quadratic (βD^2) components contribute to cell killing

d) Because stochastic effects disappear at high dose
e) Because deterministic effects dominate

4. The Linear-Quadratic model is most commonly applied in:
   a) Environmental risk assessment
   b) Nuclear power plant safety
   c) Genetic mutation studies
   d) Radiation therapy (fractionated dosing)
   e) Hormesis studies

5. According to the curve, what happens to cell killing as the dose increases beyond 5–6 Gy?
   a) It decreases sharply
   b) It remains constant at zero
   c) It oscillates randomly
   d) It approaches a maximum (plateau) effect
   e) It becomes reversible



1. Which curve in the graph represents the **Threshold model**?
   a) Orange curve
   b) Green curve
   c) Blue curve

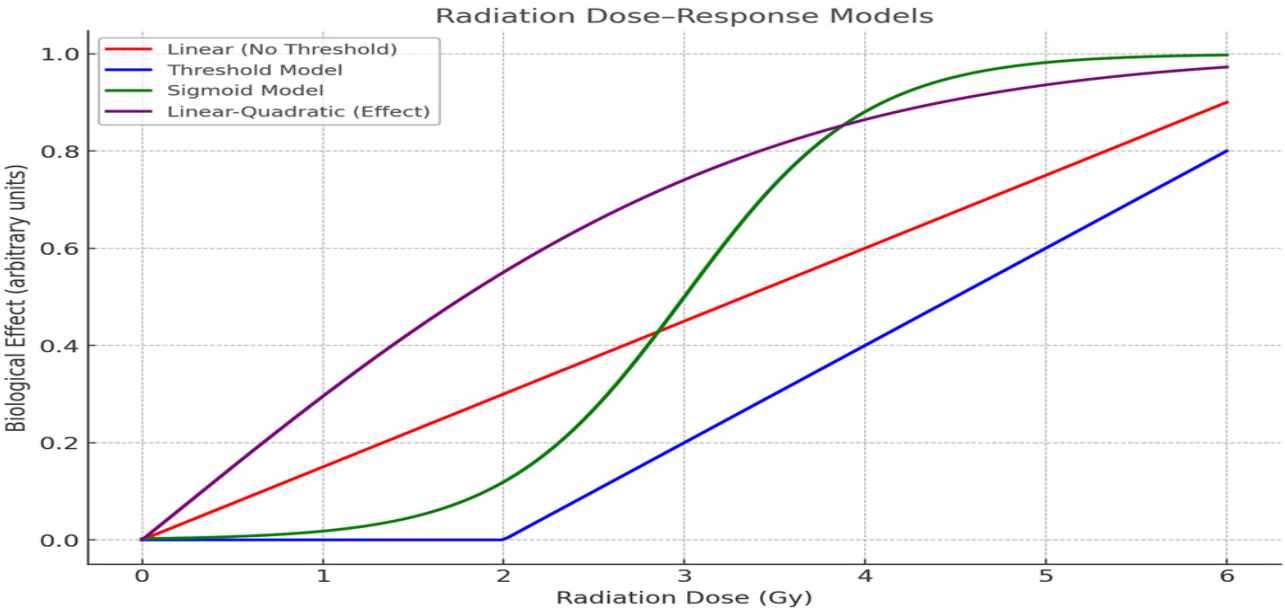
d) Red curve
e) Black curve

2. In the **Sigmoid model**, the biological effect:
   a) Increases linearly with dose from zero
   b) Remains constant after threshold
   c) Increases slowly at low doses, rapidly at intermediate doses, and plateaus at high doses
   d) Shows beneficial effects at low doses
   e) Drops to zero at high doses

3. The **Hormesis model** suggests:
   a) A straight linear increase in effect
   b) No effect until threshold
   c) Low-dose beneficial effect followed by harmful effect at higher doses
   d) No plateau at any dose
   e) Only deterministic effects

4. Which model best describes deterministic effects such as skin burns and cataracts?
   a) Hormesis model
   b) Sigmoid model
   c) Threshold model
   d) Linear no-threshold model
   e) Random model

5. At very high doses (around 6 Gy), which model predicts a **plateau of biological effect**?
   a) Threshold model (blue)
   b) Sigmoid model (green)
   c) Hormesis model (orange)
   d) LNT model
   e) Quadratic model



1. Which curve in the graph represents the **Linear No-Threshold (LNT) model**?
   a) Blue curve
   b) Green curve
   c) Purple curve
   d) Red curve
   e) Orange curve

2. The **Threshold model** (blue curve) indicates that:
   a) Any dose carries some risk
   b) No biological effect occurs until a certain dose is reached
   c) The effect plateaus at high doses
   d) Cell killing decreases at low doses
   e) Hormesis is always present

3. The **Sigmoid model** (green curve) is characterized by:
   a) A straight line from zero
   b) Immediate rise at low doses
   c) No plateau at high doses
   d) Slow effect at low doses, rapid increase at intermediate doses, and plateau at high doses
   e) Only deterministic effects

4. The **Linear-Quadratic model** (purple curve) is commonly applied in:
   a) Environmental protection
   b) Space radiation studies
   c) Nuclear engineering

d) Radiation therapy (fractionated doses)
e) Hormesis experiments

5. Which of the following statements best compares the models?
   a) LNT and Threshold both assume a minimum safe dose
   b) Sigmoid and LNT show the same pattern
   c) LNT assumes no safe dose, while Threshold assumes safety until a certain level
   d) Hormesis and Sigmoid are identical
   e) Linear-Quadratic and Threshold models overlap completely

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