Biological Effects Of Radiation

Biological Effects of Radiation

- Molecular
- Cellular
- Tissue and organ
- Deterministic
- Stochastic

Cellular Effects

Nucleus:

- Contains chromosomes and DNA.
- Radiosensitive: 1 Gy sufficient to kill cell

Cytoplasm:

- Contains other organs of cell
- Radio-resistant : 10 Gy is required to kill cell

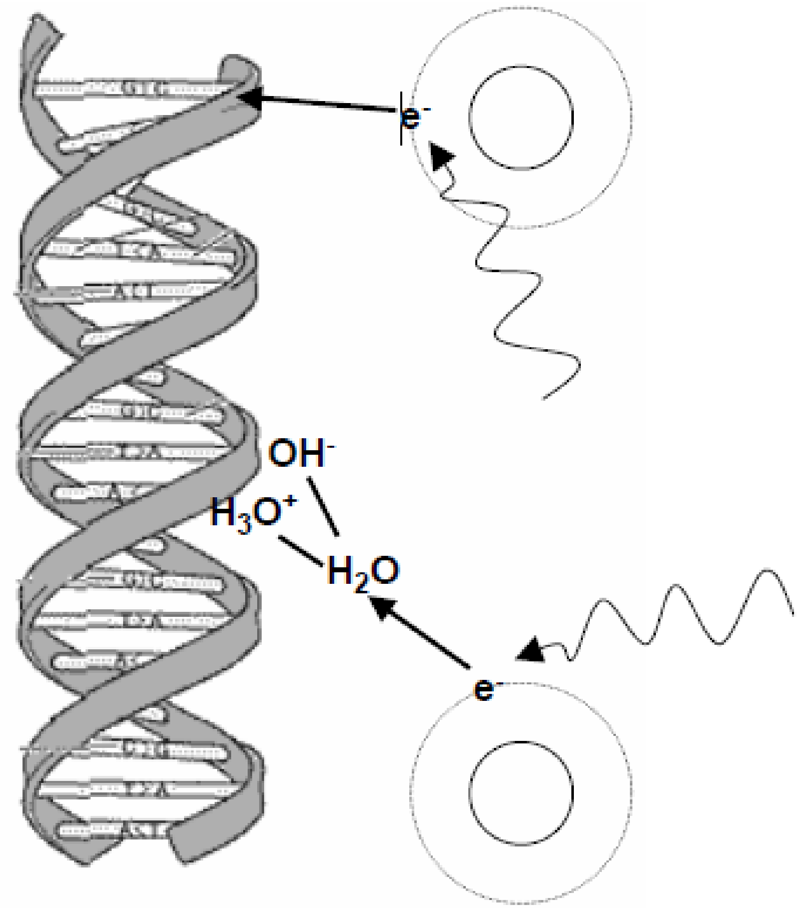
DNA radiation damage

DIRECT (33%)

- e- interacts directly with DNA.

INDIRECT (67%)

- e- interacts with water creating radicals which interact chemically with DNA



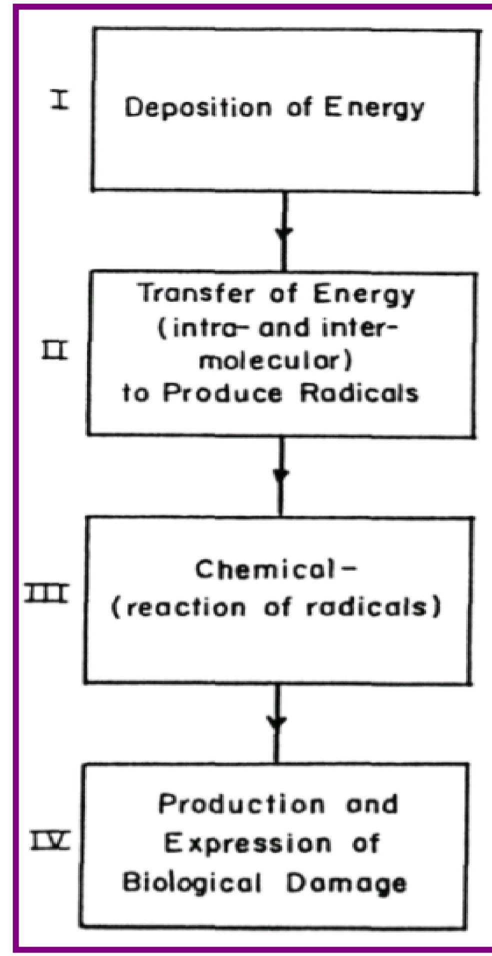
Water Radiolysis - Free Radicals

$\text{Radiation} + H_2O \rightarrow H_2O^+ + e^-$

$H_2O^+ \rightarrow H^+ + OH^0$

$e^- + H_2O \rightarrow H^0 + OH^-$

radicals exist for less than 1 ms but can disrupt molecular bonds of DNA



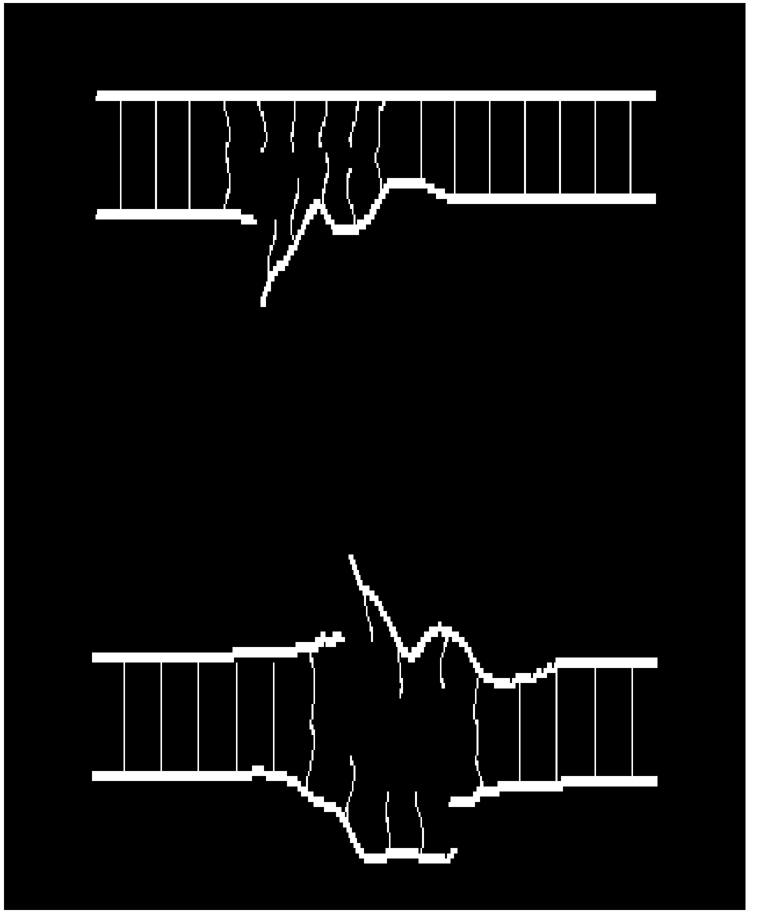
DNA Strand Breaks

Single strand break

- Repairable from mirror half of DNA

Double strand break

- Less repairable
- Chromosome aberration



Damage To Tissue Or Organs

- Radiation damage to cells can result in damage to tissue or organs.
- Principal effect is atrophy (reduction in size).

Tissue Radio-Sensitivity

High

- Lymphoid, bone marrow, gonads

Intermediate

- Skin, GI, kidney

Low

- Brain, muscle, spine

Whole Body Effects

Early (deterministic)

- Usually within weeks or months of exposure
- High dose (>25 cGy)

Late (stochastic)

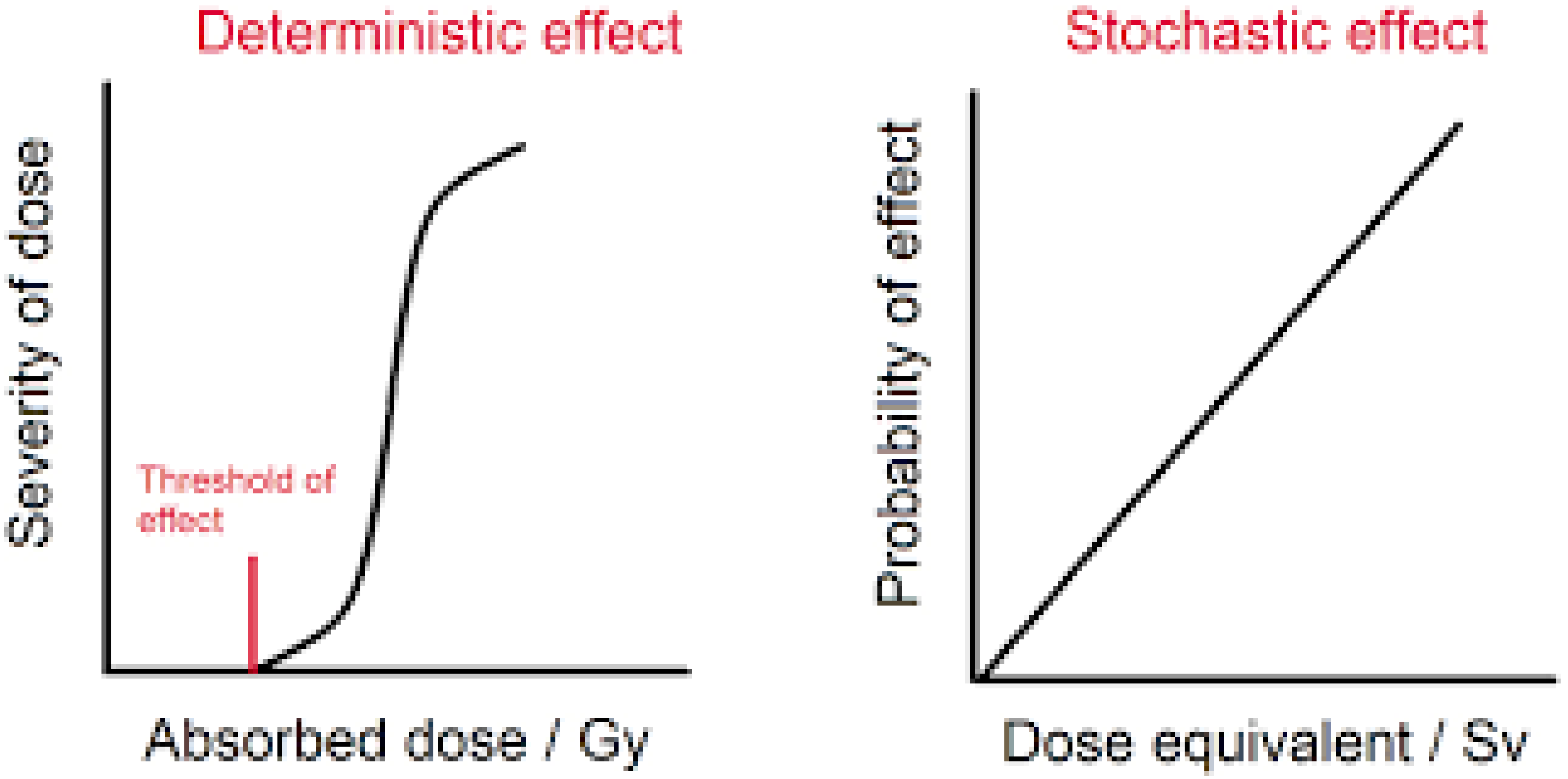
- Years after exposure
- Low doses (<25 cGy)

Deterministic Effects

Significant number of cells are injured or killed causing organ or tissue dysfunction

- Also called early or acute effects
- Dose threshold
- Severity proportional to dose

Deterministic Effects



Deterministic Effects

Some deterministic effects are the result of a tissue dysfunction following irradiation, and are not directly attributed to cell death.

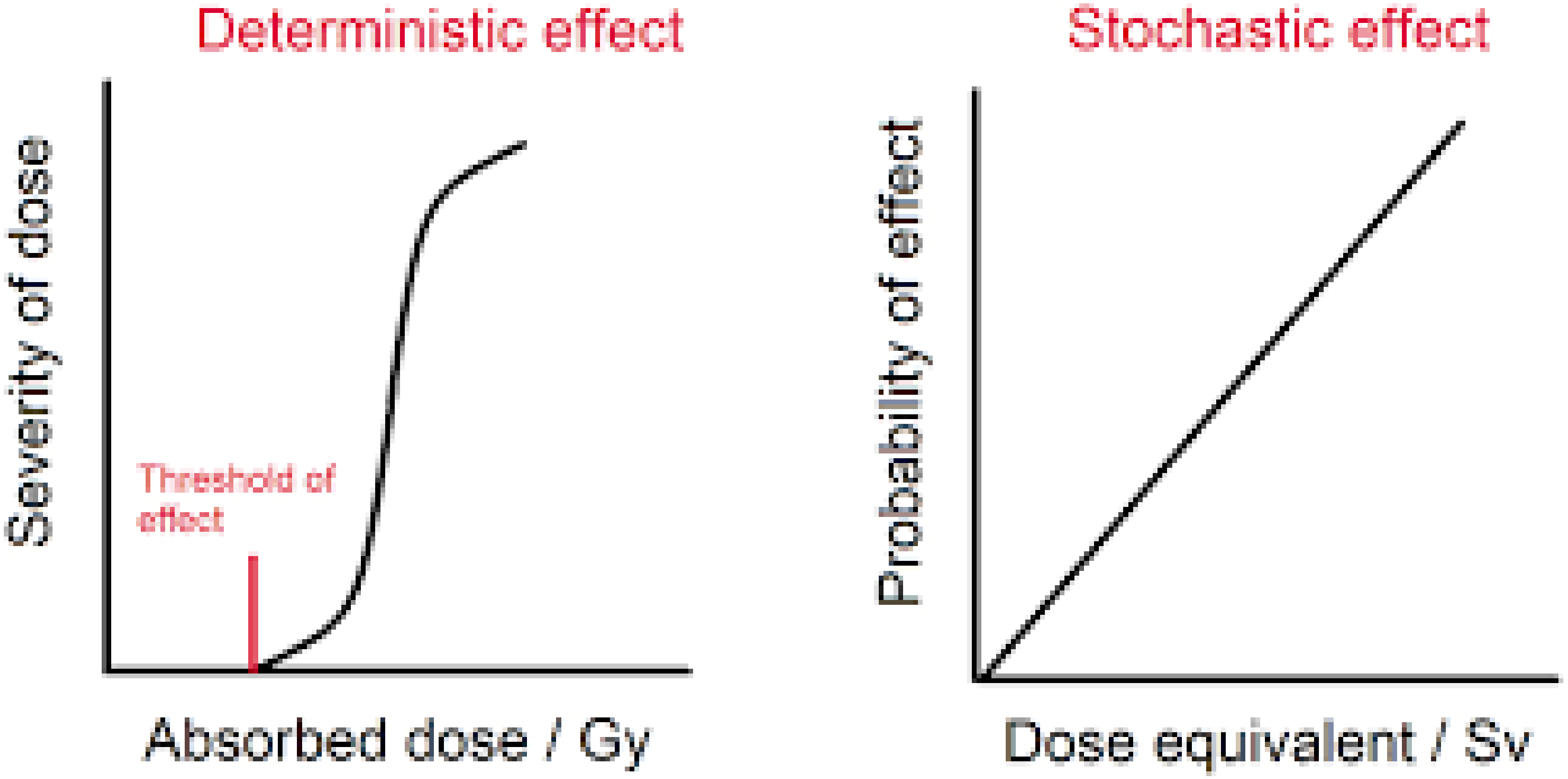
- Hormone dysfunction following pituitary irradiation
- Neurological or immunological effects following radiation

Stochastic Effects

Stochastic means random

- Also known as late effects
- Years after exposure
- Low doses (<25 cGy), sometimes high doses

Stochastic Effects



Stochastic effects

- The probability of a stochastic effect increases with dose
- The severity of the effect is not dose related
- Cancer induction

Stochastic Effects

- Stochastic effects are predicted for populations not individuals
- Applied for low dose, low dose-rate irradiations
- Dose < 2 Gy, rate < 10 cGy/hr

Stochastic Effects

Somatic cells

- May cause cancer induction

Germinal cells

- May cause hereditary effects in progeny of irradiated individual

Radiation carcinogenesis

- Radiation is a weak carcinogen
- Most damaged cells either repair themselves or die
- Cancer induction following radiation is **a stochastic effect**
- Latency is the amount of time required for the cell to grow to macroscopically sized tumor

Median latency is 8 years for leukemias and 16 to 24 years for solid tumors

Minimum latent periods are 2 years for leukemias and 5 to 10 years for solid tumors

Hereditary Effect

Exposure of a population can cause adverse health effects in descendants due to mutations induced in germ cells

- Radiation only increases mutation rate
- Information on mutation rates comes almost entirely from animal studies (ex. Megamouse project)

Radiation Protection

Justification and Optimization in Clinical Practice

All medical exposures must be subject to the principles of justification and optimization of radiological protection, which are common to all practices dealing with potential exposures of humans to ionizing radiation.

Justification

- Justification of medical exposures is the responsibility of both the radiological medical practitioner and the referring medical practitioner.
- A medical exposure is justified if it provides a benefit to the patient in terms of relevant diagnostic information and a potential therapeutic result that exceeds the detriment caused by the examination.
- Imaging methods with lower patient effective dose should be considered if the same diagnostic information can be obtained. This is true for all patients, but is especially important for younger patients.

Justification of medical exposures

- Each procedure should be subject to case by case justification by both the referring clinician who is responsible for the management of the patient and the radiologist who selects the most appropriate imaging examination to answer the referrer’s question.

Optimization

Optimization is a multidisciplinary task involving the medical physicist, radiologist, radiographer, hospital or vendor engineer and department management.

It is a cyclical process comprising:

- Evaluation of clinical image quality and patient dose to identify the need for action
- Identification of the possible alternatives to maintain necessary image quality and minimize patient absorbed doses
- Selection of the best imaging option under the given circumstances
- Implementation of the selected option
- Regular review of image quality and patient dose to evaluate if either requires further action.

Sensitive populations

The cancer excess mortality by age of exposure is approximately two to three times higher for children than for the average population.

Therefore it is important to optimize the imaging conditions for children. Typically lower patient doses are used in pediatric radiology because the body or body part of the child is smaller than that of the adult.

ALARA

The goal of radiation protection is to keep radiation doses As Low As Reasonably Achievable

Minimize External Exposure

Time

(Reduce exposure time)

Distance

(Increase Distance)

Shielding

Time

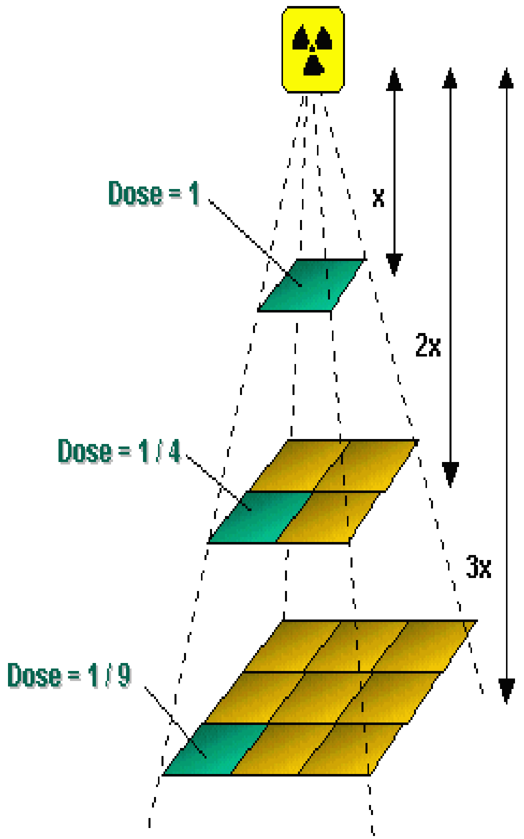
- Reducing the time of exposure can directly reduce radiation dose.
- Dose rate is the total amount of radiation absorbed relative to its biological effect.

Distance

- Effective and Easy
- Inverse Square Law

  Doubling distance from source, decreases dose by factor of four

  Tripling it decreases dose nine-fold
- More Distance = Less Radiation Exposure



Shielding

- Materials “absorb” radiation
- Proper shielding = Less Radiation Exposure
- Plexiglass vs. Lead