Health Effects of Exposure to Radiation

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- Radiation dose
- Indirect effects of radiation
- Direct effects of radiation
  - Hereditary effects
  - Somatic effects
    - Stochastic effects
    - Deterministic effects

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Radiation Dose

- Radiation dose, in the simplest terms, can be thought of as the amount of radiation an individual is exposed to either from:
  - Work activities with radioactive materials
  - Medical tests such as from a diagnostic x-ray
  - Background radiation

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Radiation Dose Measurement

- The measurement of an individual's radiation dose is very complicated and depends on many factors:
  - Type of radiation
  - Type of exposure
    - External
    - Internal
  - Duration of exposure
  - …..

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Radiation Dose

- When radiation passes through matter, it interacts with the molecules and atoms giving up some or all of its energy
- The amount of energy transferred to the matter is referred to as the radiation dose

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Radiation Dose

- In living tissue, this energy transfer or radiation dose can result in damage to molecules and cells
- In radiation safety, there are three categories of radiation dose:
  - Absorbed dose
  - Equivalent dose
  - Effective dose

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Absorbed Dose

- *Absorbed dose* is a measure of the amount of radiation energy transferred to matter per unit mass
- The unit of absorbed dose is the ***gray*** (Gy)

$$1\ Gy = 1\ J/kg$$

  - Where J (joule) is a unit of energy

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Measuring Damage

- Different types of radiation (alpha, beta, neutrons, gamma, x-rays) will, by their nature, cause different amounts of damage in living tissue
- 1 Gy of absorbed dose from an internal alpha radiation source causes more damage in tissue than 1 Gy of absorbed dose from beta, gamma or x-ray radiation

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Equivalent Dose

- Measuring the absorbed dose alone provides little information about the biological damage to living tissue
- There is a need for a common scale with which to measure the radiation dose to living tissue independent of the radiation type
- This brings us to the ***equivalent dose***

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Equivalent Dose

- The ***equivalent dose*** is simply the *absorbed dose* multiplied by a radiation weighting factor
- The radiation weighting factor helps to account for the different levels of biological damage caused by different types of radiation
- The unit of equivalent dose is the ***millisievert*** (mSv)

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Radiation Weighting Factors

Radiation	Energy	w_R
Gamma / x-ray	All	1
Beta	All	1
Alpha particles (internal)	All	20

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Equivalent Dose

- Equivalent dose allows us to compare radiation doses from different types of radiation.
  - 1 mSv of equivalent dose from gamma radiation is comparable to 1 mSv of equivalent dose from beta or alpha radiation, in terms of biological damage

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Radiation Dose to Tissues

- We now know that different types of radiation cause different levels of damage in living tissue
- In addition, some tissues in the body are more sensitive to radiation than others
  - Reproductive organs are more sensitive to radiation than the skin or the lungs

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Radiation Dose to Tissues

- The equivalent dose does not account for the varying sensitivities to radiation exposure of different organs or tissues in the body
- There is a need for a common scale with which to measure the overall risk to a person's health, regardless of which tissue or organ is exposed
- This takes us to the ***effective dose***

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Effective Dose

- The ***effective dose*** is the *equivalent dose* multiplied by a tissue weighting factor
- The tissue weighting factor helps to account for the varying sensitivities to radiation exposure of the different tissues and organs
- The unit of effective dose is the ***millisievert*** (mSv)

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Effective Dose

- Effective dose accounts for the type of radiation and the tissue or organ irradiated
  - 1 mSv of **effective dose** is just 1 mSv, regardless of whether the dose was delivered to the lungs, thyroid, bone marrow, or any other tissue.
  - Unfortunately, mSv is the unit equivalent dose as well as effective dose though they are not equal

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Molecular Effects of Irradiation

- In living systems, biological damage can occur as a result radiation-induced damage to molecules and cells
- Radiation may cause damage to molecules or cells either directly or indirectly

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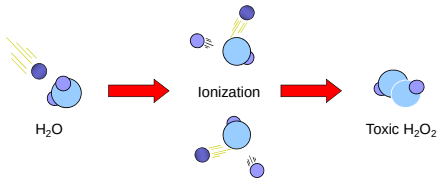
Indirect Damage

- Indirect damage involves the effects of reactive free radicals created by the interaction of radiation with water (H_2O).



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Indirect Damage

- The fractured water molecule components, H and OH, can undergo a variety of reactions:
  - $H\cdot + OH\cdot \rightarrow H_2O$ (Water)
  - $H\cdot + H\cdot \rightarrow H_2$ (Hydrogen gas)
  - $OH\cdot + OH\cdot \rightarrow H_2O_2$ (Hydrogen peroxide)

H_2O_2

- Hydrogen peroxide is a chemical poison.
  - Its effects resemble radiation sickness (nausea, vomiting, diarrhoea, malaise).

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Direct Damage

- When radiation interacts directly with vital biological molecules such as DNA (deoxyribonucleic acid), RNA (ribonucleic acid), proteins and enzymes, damage to these molecules can occur through ionization interactions and the absorption of energy
- These ionization and excitation interactions can literally break chemical bonds resulting in impaired molecular function

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Radiation Effect Categories

- The effects of exposure to radiation can be divided into two categories:
  - Hereditary (genetic) effects
  - Somatic (body) effects

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Hereditary Effects

- Hereditary effects are those which do not become apparent until future generations are born
- Possible result of radiation induced damage to the DNA molecule in the germ cells (sperm, ova).

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Somatic Effects

- Somatic effects are those which are experienced directly by the people exposed to the radiation
- There are two types of somatic effects:
  - Stochastic effects
  - Deterministic effects

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Stochastic Effects

- A stochastic effect is one which may or may not occur
  - There is a probability attached to the event
- Examples of stochastic events:
  - Winning the lottery
  - Developing cancer from smoking
  - Developing cancer from radiation exposure

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Stochastic Effects

- All we can say is that radiation exposure ***increases the likelihood*** of developing a disease such as cancer
- The greater the exposure, the greater the likelihood
- We can never be certain that an effect will occur

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Radiation-Induced Cancers

- Early radiation scientists
  - Many died from skin, bone, and blood cancers.
- Radium watch dial painters
  - Many died of bone cancer 8 to 40 years later.
- UK X-ray patients
  - 6,500 patients were treated with 3 Gy x-rays.
  - 30 developed leukemia (7 expected without x-rays).
- Japanese bomb survivors (80,000 people)
  - 350 cancer deaths, double the expected figure.

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Risk: Cancer from Radiation

- The risk of developing a fatal cancer as a result of exposure to radiation is thought to be approximately 4% per 1000 mSv
- Consider a person who worked for 50 years and received 20 mSv per year
  - This person's total lifetime radiation dose would be 1000 mSv
  - This person could have an extra 4% chance of developing a fatal cancer

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Risk: Cancer in General

- Note that 25% of all people develop a fatal cancer in their life
- So, this person's risk of developing cancer becomes 29%, instead of 25%
- No profession is risk free

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Risk of Death at Work

Occupation	Risk of Death per Year
Finance	1 in 60,000
Trade	1 in 40,000
2 mSv radiation per year	1 in 12,000
Manufacturing	1 in 11,000
Construction	1 in 3,000
20 mSv radiation per year	1 in 1,200
Fishing and hunting	1 in 500

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Risk of Death from Accidents

Hazard	Risk of Death Per Year
Accidents on the road	1 in 5,000
Accidents at home	1 in 11,000
1 mSv per year legal limit (dose limit for public)	1 in 20,000
Accidents at work	1 in 24,000
0.05 mSv per year	1 in 400,000

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Deterministic Effects

- A deterministic effect is one which will certainly result from exposure
- There will be a minimum exposure (threshold) above which the effect will occur
- The severity of the effect will depend on the exposure
  - Example: cataract formation, radiation sickness

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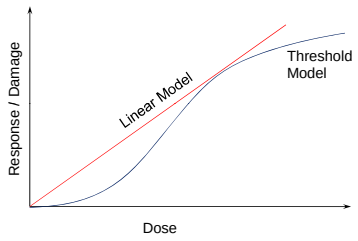
Radiation Dose/Response



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Acute Exposure

- Exposure to a high dose delivered within seconds, minutes or days
- Possible deterministic effects
  - Blood changes
  - Nausea
  - Diarrhea
  - Hair-loss
  - Malaise
  - Death

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Acute Exposure

Acute Dose	Effect
< 250 mSv	No detectable effects
> 3,000 mSv	Chance of death 50% and above
> 6,000 mSv	Death an almost certainty, time between exposure and death depends on amount of dose

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Acute Exposure

- The rapidly reproducing cells are most affected by acute radiation:
  - The skin
  - The blood-forming tissues
  - The gonads
  - The digestive system lining (the gastrointestinal tract or GI tract)

Red Blood Cell

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