Lecture 5 – Consequences and use of radioactivity

Radiation is produced by radioactive decay

- It has very high energy
- Causes the ionisation of matter by ejecting an electron from an atom
- Can be highly penetrating, able to pass through matter without ionising it

Type of radiation	Approx. energy	No. ionised molecules
Alpha	5 MeV	5×10^5
Beta	0.05 to 1 MeV	5×10^3 to 1×10^5
Gamma	1 MeV	1×10^5

Radiation creates free radicals

Since the body is made up of 70% water, radiation can ionize water within the body and create free radicals

H_2O + ionising radiation $\rightarrow H_2O^+ + e^-$

Both of these products can go on to react further

$H_2O^+ + H_2O \rightarrow H_3O^+ + OH^\bullet$

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

free radicals

Free radicals are very reactive, and damage:
- **DNA strands** → genetic damage, cancer
- **Cell membranes** → cells break apart

Types of Radiation

Type of radiation	Approx. energy	Penetration (air)	Penetration (biological tissue)	Relative biological effectiveness (Q)
Alpha	5 MeV	40 mm	0.05 mm	20
Beta	0.05-1 MeV	6 – 300 mm	0.06 – 4 mm	1 – 1.7
Gamma	1 MeV	400 m	50 cm	1
X-ray (to compare)	< 250 keV	200 m	20 cm	1

Damage of Radiation depends on the length and amount of radiation along with the source of radiation

2. Length of exposure

Short term (acute): Called **radiation poisoning**. High doses for short periods of time cause acute cell damage and often death.

Long term (chronic): **Radiation-induced cancer**. Anything that interrupts DNA can lead to cancer.

3. Source of exposure

Internal exposure: Ingestion or inhalation. α and β are most dangerous. Most γ radiation escapes the body

External exposure: α and β can't penetrate through air and skin. γ radiation can penetrate skin - more dangerous.

We do get exposed to radiation on a daily basis.

The **sievert (Sv)** is the unit that measures the biological effect of radiation. It takes into account the **type** of radiation, the **energy** of radiation, and the **activity** of the source.

We are exposed to about 3 mSv of natural radiation per year:

Radiation can be used as cancer therapy

1) focusing ionising radiation on the tumour – using gamma radiation as it is able to penetrate air and skin (this is external exposure to radiation)
2) Internal administration of the radiopharmaceutical (internal exposure to radiation)
    a. Using alpha or beta emitters as they have a short range effect
        i. Thyroid is treated using Iodine-131, which has a half life of 8 days. Iodine naturally accumulates at the thyroid so it will be a targeted treatment
        ii. Patients are isolated 8 days after treatment since it will be radioactive for 8 days

Radio-imaging is used to map the body -->X-rays, which uses radiation emitted from within the body.

- This uses gamma radiation and it can come from multiple sources including technetium 99 and positron emitters.
- Note that X-rays cannot penetrate bones nor identify tumor/issues with the organs.

Technetium 99 imaging

- This is a metastable nucleus, which decays into ^{99}Tc via gamma emission (and not the harmful alpha or beta particles).
- It is ideal for imaging as it is able to target different parts of the body and easily incorporated into many drugs
- It is easily prepared from Mo-99 and doesn't change its chemistry when it decays.
- Has a half-life of 6 hrs.

Positron Emission Tomography (PET)

This uses a radionuclide that emits positron to identify parts of the body that uses high level of glucose by using fludeoxyglucose, which is an oxygen atom of glucose, which is replaced by fluorine 18 (it will decay back to O2 and glucose).

For nuclides used in medical imaging, the preferred half life is to be in hours as this allows for time to prepare and administer the dosage. Additionally you need a high enough activity to get a good quality image.