Objectives

- **Describe and use the following quantities and their units:**
  a) Absorbed dose
  c) Radiation weighting factor
  d) Equivalent dose
  e) Tissue weighting factor
  f) Effective dose
  g) Annual Limit on Intake and Derived Air Concentration
  h) Committed equivalent dose
  i) Committed effective dose
  j) Collective dose
- **Describe and use the quantity "exposure" and its units.**
- **Calculate the following quantities, given an exposure scenario:**
  a) Equivalent dose
  b) Effective dose
  c) Committed equivalent and committed effective dose
  d) Collective effective dose
  e) Exposure

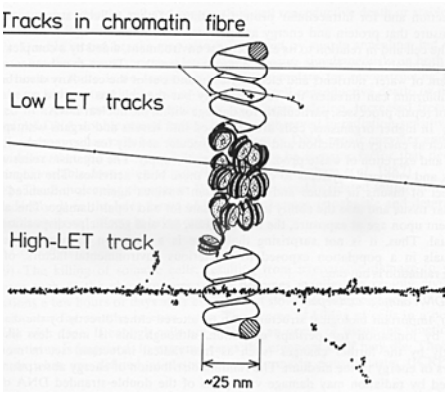
Quantities and Units

- Quantity: a physically measurable variable
- Unit: an agreed upon amount of the quantity which forms the basis of the measurement system

Absorbed Dose (D)

- **The amount of energy absorbed per unit mass of absorber.**
- **Absorbed dose is the fundamental dosimetric quantity in radiation protection. All other quantities are based on the absorbed doses.**
- **It is strictly a physical quantity and can be applied to radiation interactions in any material.**
- **The SI unit is the Gray (Gy) and the traditional unit is the rad.**
- **1 Gy = 1 J/kg**
- **1 Gy = 100 rad**

Varying Effects Due to LET



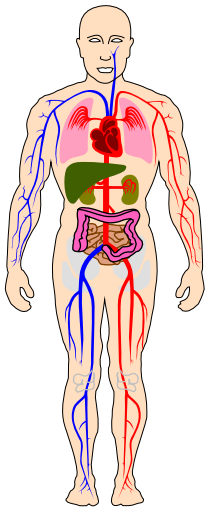
Radiation Weighting Factors (w_R)

Type and Energy Range	Radiation Weighting Factor (W_R)
Photons, all energies	1
Electrons and muons, all energies	1
Neutrons, energy < 10 keV	5
10 keV to 100 keV	10
> 100 keV to 2 MeV	20
> 2 MeV to 20 MeV	10
> 20 MeV	5
Protons, other than recoil protons, energy > 2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20

Equivalent Dose

- For a tissue or organ, the average absorbed dose multiplied by the radiation weighting factor w_R.
- $H_T = \Sigma w_R \times D$
- Equal equivalent doses to a tissue or organ due to different radiations produce the same probability of stochastic effects. The radiation weighting factor "adjusts" for the varying ability of different radiations to produce these effects.
- The SI unit is the sievert (Sv) and the traditional unit is the rem.
- 1 Sv = 100 rem

Tissue Weighting Factors



Tissue or organ	Tissue weighting factor, w_T
Gonads	0.20
Bone marrow (red)	0.12
Colon	0.12
Lung	0.12
Stomach	0.12
Bladder	0.05
Breast	0.05
Liver	0.05
Oesophagus	0.05
Thyroid	0.05
Skin	0.01
Bone surface	0.01
Remainder	0.05[2,3]

[1] The values have been developed from a reference population of equal numbers of both sexes and a wide range of ages. In the definition of effective dose they apply to workers, to the whole population, and to either sex.

[2] For purposes of calculation, the remainder is composed of the following additional tissues and organs: adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. The list includes organs which are likely to be selectively irradiated. Some organs in the list are known to be susceptible to cancer induction. If other tissues and organs subsequently become identified as having a significant risk of induced cancer they will then be included either with a specific w_T or in this additional list constituting the remainder. The latter may also include other tissues or organs selectively irradiated.

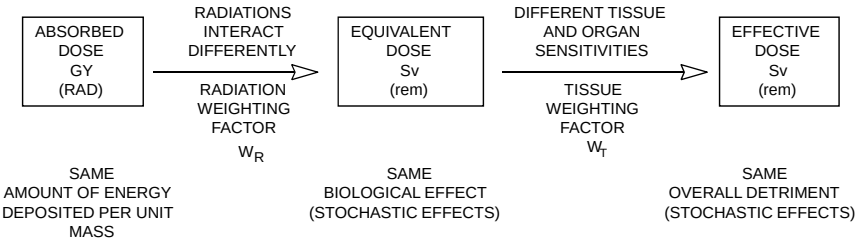
[3] In those exceptional cases in which a single one of the remainder tissues or organs receives an equivalent dose in excess of the highest dose in any of the twelve organs for which a weighting factor is specified, a weighting factor of 0.025 should be applied to that tissue or organ and a weighting factor of 0.025 to the average dose in the rest of the remainder as defined above.

Effective Dose (E)

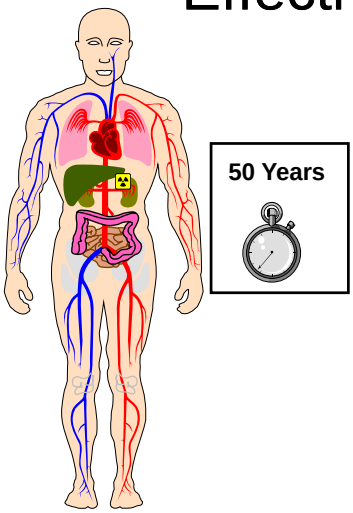
- **For a person, the equivalent dose to each organ or tissue multiplied by the tissue weighting factor w_T.**
- **$E = \Sigma\, w_T \times H_T$**
- **Equal effective doses to different tissues or organs produce the same detriment. The tissue weighting factor "adjusts" for the varying sensitivity of tissues and organs and the varying detriment arising from exposure.**
- **The SI unit is the sievert (Sv) and the traditional unit is the rem.**

1 Sv = 100 rem

FUNDAMENTAL DOSIMETRIC QUANTITIES



Committed Equivalent and Effective Dose



Dose quantities that reflect the eventual consequences of intake of radioactive material.

Committed Equivalent Dose (H_T50):

The equivalent dose to an organ or tissue that will occur over 50 years following an intake.

Committed Effective Dose ($H_E(50)$)

The effective dose that will occur over 50 years following an intake.

Collective Effective Dose (S)

- The sum of the effective doses to an exposed population
- Tally of all Effective Doses

Unit: person-Sv
(person-mrem)

3 people @ 2 mSv each
= 6 person-mSv

Example: 2002 Doses – Operations: 18.7 person-mSv
I-125: 17.6 person-mSv

Annual Limit on Intake (ALI)

That quantity of a radionuclide (Bq) which if taken in to the body by Reference Man, would result in a committed effective dose of 20 mSv (2 Rem) over a period of 50 years.

ALIs are for ingestion or inhalation and depend on chemical and physical form

Example:

ALIs for I-125

Ingestion	1 MBq (27 μCi)
Inhalation (Elemental)	1 MBq (27 μCi)
Inhalation (Methyl)	2 MBq (54 μCi)

Example Question:

What dose would you expect to result from an accidental ingestion of 1.3 kBq of I-125?

Example Question 2:

If a "drop" is 10 micro-litres and the I-125 stock material is 1Ci/ml, how many ingestion ALIs are there in one drop?

Derived Air Concentration (DAC)

- *That concentration of a radionuclide in air (Bq/m³) that if breathed in by unprotected Reference Man continuously for 2000 Hours, would result in an intake of 1 ALI.*

$$DAC = \frac{ALI}{2400 m^3}$$

- *Note – the MNR Respirator Action Level is 1/10th of a DAC*
- *Example:*
  - *The DAC for elemental I-125 vapour is 580 Bq/m³*

Exposure

- A traditional way to characterize photon radiation field strength
- Corresponds to the ability of the radiation field to produce ionization in air
- The traditional unit is the roentgen (R)
- 1 R = 1 sC/cm^3 charge of either sign at 0 degrees C, 760 mmHg (1 R = 2.58 C/kg of air)
- BY LUCK 1 R to air ~ 1 rem (10 mSv) to tissue