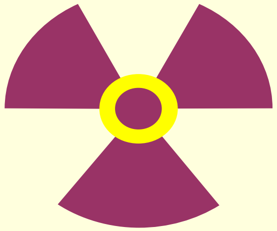
Dosimetry

of

ionizing radiation



Ionizing radiation

Classification according to the primary effect

↙ ↘

Direct ionization

Incoming particles already held charges. E.g. α- and β-particles.

Indirect ionization

Primary electrons ejected by the photons and secondary electrons present charges. e.g. γ-radiation, X.ray.

Ionizing radiation

☺

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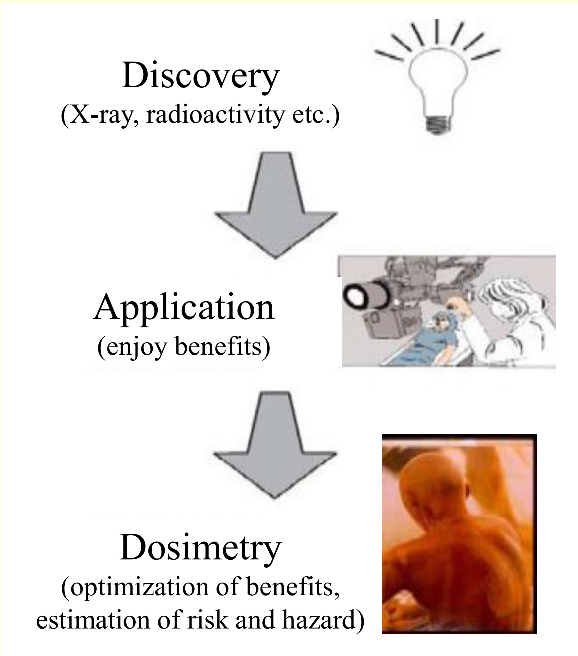


Task for dosimetry

Estimation of health risk for prevention.

Estimation of biological damages.

Design of therapeutic procedures.

Definition of quantities

↓

Design of measuring techniques

↓

Estimation of consequences

1. Dose values sholud be

- proportional to the damagas and expected risk !
- additiv
- independent of other factors!?

Dose concepts

Physical dose concepts: Absorbed dose, Exposure

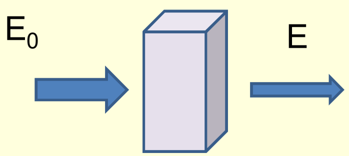
→ **Biological dose concepts:** Equivalent dose, Effective dose

→ **Derived dose concepts:** Collective dose, Dose rate

1. Absorbed dose

measures the absorbed energy in a unit mass

$\Delta E = E_0 - E$



$$D = \frac{\Delta E}{\Delta m} [J/kg]$$

Validity: for any kind of material and any type of radiation without restriction

Louis Harold Gray (1905-1965).

Unit: $[J/kg] \equiv Gy$

How to be measured ????

^{131}I of 0.2 GBq activity is accumulated in 80 g thyroid glands. The effective half-life is 7.5 days . Average β-particle energy is 0.18 MeV. Assume that the particles are fully absorbed in the thyroid glands . What is the absorbed dose in the given tisssue?

$$\Lambda = \frac{\ln 2}{T} N \qquad N = \frac{0,2*10^9 [Bq] * 6,48*10^5 [s]}{0,693} = 1,87*10^{14}$$

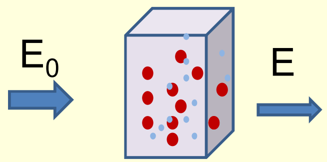
$$E_{sum} = N * E \qquad E = 0,18*10^6 [eV] = 2,88*10^{-14} [J]$$

$$E_{össz} = 1,87*10^{14} * 2,88*10^{-14} = 5,38 [J]$$

$$D = \frac{E_{sum}}{m} \qquad D = \frac{5,38}{0,08} = 67,28 \left[\frac{J}{kg}\right]$$

2. Exposure

measures the amount of positive or negative charges generated by the radiation in a unit mass.



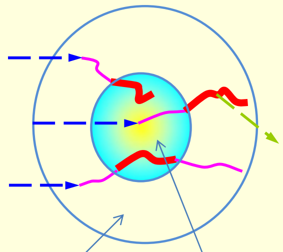
$$X = \frac{\Delta Q}{\Delta m}[C/kg]$$

Validity: in the air, only γ and X –rays, measured in electron equilibrium*

$$X = \frac{\Delta Q}{\Delta m}[C/kg]$$

ΔQ – secondary electrons!!

Electron-equilibrium : net number of the secondary electrons living and entering volume of the cavity are equal.



To be considered:

- composition of surrounding material (chamber wall) –
  air-equivalent wall!
- thickness of the wall
- Photon energy: E< 0.6 MeV

Calculation of the absorbed dose from the exposure

$$X = \frac{\Delta Q}{\Delta m}[C/kg] \qquad D_{air} = f_0 X \qquad D = \frac{\Delta E}{\Delta m}[J/kg]$$

~ 34 J/C

Average ionization energy in air

~ 34 eV.

Absorbed dose in tissue

$$\frac{\Delta E}{\Delta m} \approx \mu_m \cdot J$$

$$D_{air} = \frac{\Delta E}{\Delta m}[J/kg]$$

$$\frac{D_{air}}{D_{tissue}} = \frac{\mu_{m.air}}{\mu_{m,tissue}}$$

Photon energy (MeV)	$\mu_{m,air.}/\mu_{m,tissue}$ (soft tissues)	$\mu_{m,air.}/\mu_{m,tissue}$ (bones)
0,1	1,07	3,54
0,2	1,08	2,04
0,4	1,10	1,24

Biological dose concepts

Equivalent dose

Effective dose

The absorbed energy (absorbed dose) is not sufficient to measure the possible biological consequences.

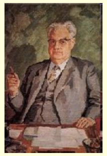
The biological consequences are influenced by :

the type of radiation. → radiation weighting factor

the sensitivity and biological function of target → tissue weighting factor

Equivalent dose (H)

Rolf Sievert
1896-1966



„Efficiency" of various forms of radiation is not uniform.

$$H_T = w_R D_T$$

Radiation weighting factor – estimation of the relative risk of the given radiation

Absorbed dose in tissue

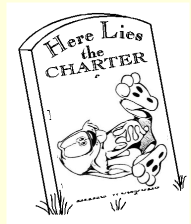
radiation	W_R
photon	1
electron	1
neutron	5-20
proton	5
α-particle	20

Unit of ***H*** : ***Sievert (Sv)***

Why are the fates of the rabbits different?

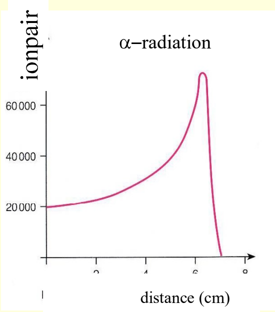
2 Gy absorbed dose – ***X-ray***

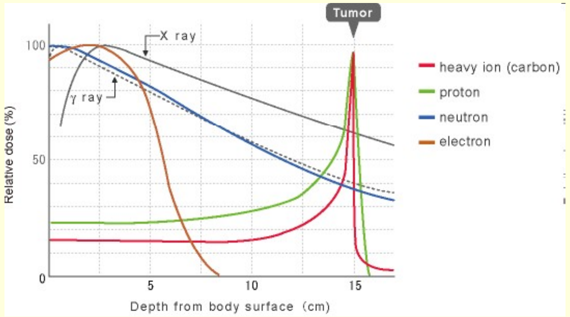
2 Gy absorbed dose – ***α-particles***



Equivalent dose (H)

„Efficiency" of various forms of radiation is not uniform.



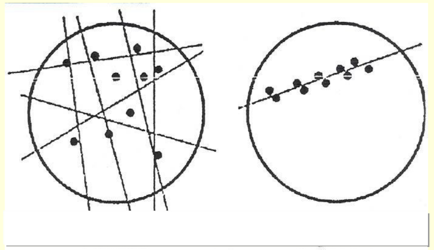


LET (Linear Energy Transfer : the energy transferred to the material surrounding the particle track, by means of secondary electrons. *($nE_{ionpair}/l$)*

Equivalent dose (H)

„Efficiency" of various forms of radiation is not uniform.

$$H_T = w_R D_T$$

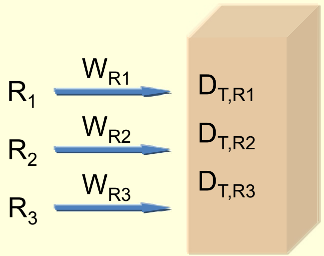


Small LET
e.g. γ, -ray

High LET
e.g.. α, proton

radiatiom	W_R
photon	1
electron	1
neutron	5-20
proton	5
α-particle	20

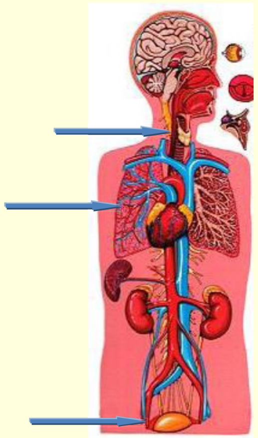
If someone is exposed to more than one type of radiation:



$$H_T = \sum_R w_R D_{T,R}$$

Effective dose (E)

Various sensitivity of tissues has to be considered



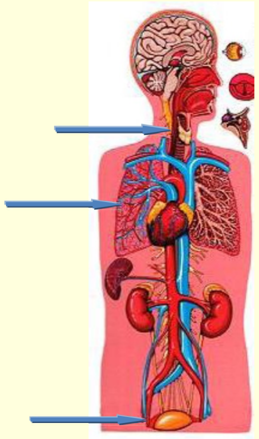
$$E = \sum_T w_T H_T$$

Tissue weighting factor – estimation of the relative sensitivity of tissue

Equivalent dose in the given tissue

Unit of ***E*** : ***Sievert (Sv)***

$$E = \sum_T w_T H_T$$



tissue	W_T	tissue	W_T
gonads	0,2	breast	0,05
bone marrow	0,12	liver	0,05
colon	0,12	oesophagus	0,05
lung	0,12	thyroid gland	0,05
stomach	0,12	skin	0,01
bladder	0,05	bone surface	0,01

$$\sum_T w_T = 1$$

Dose rate

Received dose over time.

Unit: varies with the type of radiation and the time period (pl. Gy/month, mSv/year etc.)

Collective dose

Sum of the doses received by a given number of people (N_i) in the course of a given time interval.

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Sum of the doses received by a given number of people (N_i) in the course of a given time interval.

$$S = \sum_i N_i E_i$$

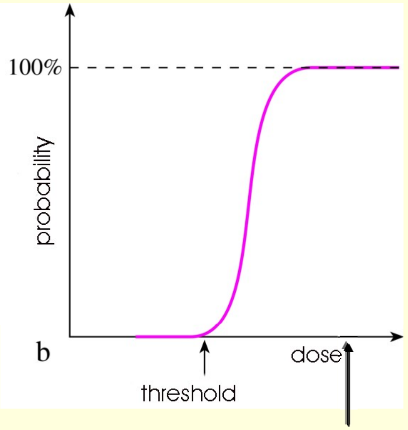
E_i effective dose in each person

Types of damages

Deterministic damages

Stochastic damages

Deterministic damages



Gy

Under threshold: *p=0*

Deterministic damages

A threshold dose exists.

Above threshold severity depends on the dose.

Appear soon after exposition.

Must not be induced during diagnostic procedures.

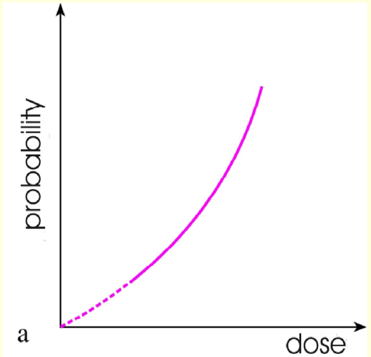
e.g. erythema, epilation, cataract

*1% lethal 60 days after exposition

Dose (Gy) (whole body)	Biological effect
< 0,15-0,2	No observable effect
0,5	Slight blood changes – limit of detection by hematological methods.
0,8	Critical dose – threshold of acute radiation syndrome
2,0	Minimal lethal dose (LD1/60)*
4,0	Half lethal dose (LD50/60)
7,0	Minimal absolute lethal dose (LD99/60)

Chest X-ray: cc 160 μGy in the skin

Stochastic damages



NO threshold!

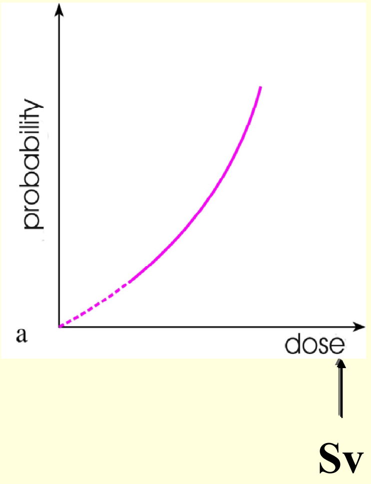
The probability of stochastic damage depends on the dose.

Severity (e.g. cancer) independent of the dose.

Delayed biological effects.

e.g.tumours, heriditary diseases

Stochastic damages



H_T (equivalent dose) and
E (effective dose) provide a basis for ***estimating the probability of stochastic effects*** for doses below the threshold of deterministic effects.

Dose range is under the threshold of deterministic damages.

Stochastic damages

Irradiated cell is modified rather than killed

Severity is not effected by the dose

With increasing dose only the probability* increases

*1 gamma photon: the probability to cause cancer is 3×10^{-16} (1: 3,000 billion, but this is the Russian roulette!)

Damjanovich, Fidy, Szöllősi: Medical Biophysics

II. 4.
- 4.1
- 4.2
- 4.3
- 4.4
- 4.5

In the frame: 184. 186.

Manual :Dosimetry