Radioisotopes in action

Diagnostic application of radioisotopes

Steps of diagnostic procedure

- Radioactive material introduced into the patient

- Distribution and alteration of activity is detected

-Monitoring of physiological pathways and/or identification and localization of pathological changes

Information from various medical imaging techniques

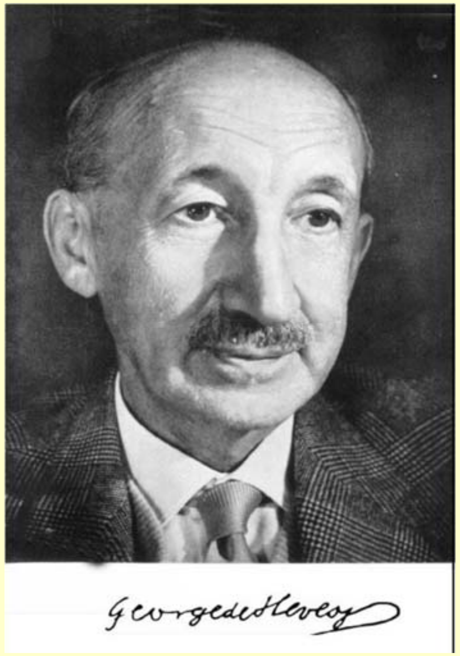
Structure	X-ray Ultrahang MRI	*differences according to the different physical parameters / properties of tissues*
Function	Isotope diagnostics MRI	*dynamic physiological / metabolic processes of different body organs can be followed*

X-ray

Shows the structure

Isotope diagnostics

Report the metabolic activity



Father of Nuclear Medicine

Georg Charles de Hevesy
(1885 - 1966)

Nobel Prize in Chemistry
1943

for his work on the use of isotopes as tracers in the study of chemical processes

George Hevesy and his landlady

In any event, he became convinced that his landlady had a nasty habit of recycling food. Hevesy secretly spiked the leftovers on his plate with radioactive material. A few days later, the electroscope he smuggled into the dining room revealed the presence of the tracer

The choice of the appropriate radioisotope for nuclear imaging

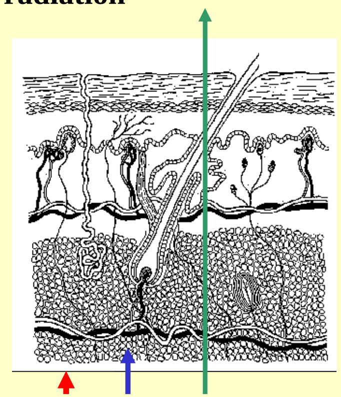
Maximize the information

Minimize the risk.

For that find the optimal

- type of radiation
- photon energy
- half-life
- radiopharmacon

Type of radiation



α β γ

decay via photon emission

to minimize absorption

effects in body tissue

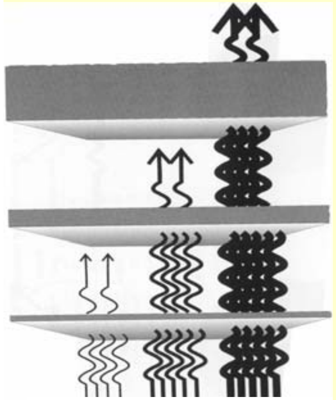
Only **γ-radiation** has

sufficient penetration

distance.

purely gamma-emitting isotope would be preferable

photon energy hf > 50 keV



Photon must have sufficient energy to penetrate body tissue with minimal attenuation

BUT!

Photon must have sufficiently low energy to be registered efficiently in detector and to allow the efficient use of lead collimator systems (must be absorbed in lead)

a suitable physical half-life

$$\Lambda = \lambda N = \frac{0,693}{T} N$$

smaller is better
but
the value is limited from below e.g., by the sensitivity of the detector

smaller is better
dosimetric considerations for patients

shorter is better

but

it has to be long enough for monitoring the physiological organ functions to be studied

radiopharmaceutical – is substance that contain one or more radioactive atoms and are used for diagnosis or treatment of disease.
It is typically made of two components, the radionuclide and the chemical compound to which it is bound.

Basic requirements:

specific localizing properties;
high *target : non-target* ratio

have no pharmacological or toxicological effects which may interfere with the organ function under study.

A number of factors is responsible for the ultimate distribution of the radioisotope:

– blood flow (percent cardiac input/output of a specific organ)

– availability of compound to tissue, or the proportion of the tracer that is bound to proteins in the blood

– basic shape, size, and solubility of molecule which controls its diffusion capabilities through body membranes examples

pharmaceutical	radioisotope	activity (MBq)	target organ
Pertechnetate	^{99m}Tc	550 - 1200	brain
Pirophosphate	^{99m}Tc	400 - 600	heart
Diethylene Triamine Penta Acetic Acid (DTPA)	^{99m}Tc	20 - 40	lung
Mercaptoacetyltriglycine (MAG3)	^{99m}Tc	50 - 400	kidney
Methylene Diphosphonate (MDP)	^{99m}Tc	350 - 750	bones

Optimal activity for diagnostic procedure

Maximize the information

Minimize the risk

$$\Lambda \sim 100 \text{ MBq}$$

Types of images

Static picture – spatial distribution of isotope / activity at a certain time

Dynamic picture – variation of the amount of isotope / activity in time

Static and dynamic picture – series of static recordings

Emission CT

SPECT (Single Photon Emission Computed Tomography)

PET (Positron Emission Tomography)

Types of images

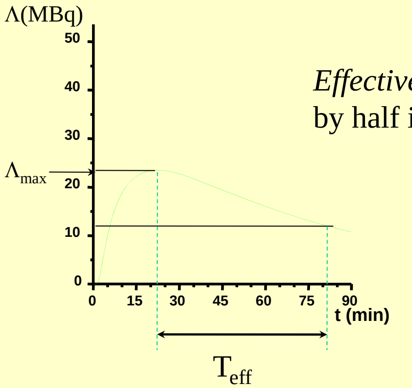
Static picture – spatial distribution of isotope / activity at a certain time

Isotope accumulation in

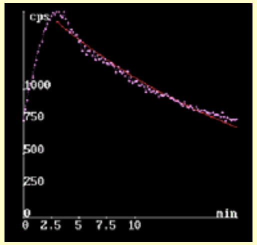
thyroid glands kidneys

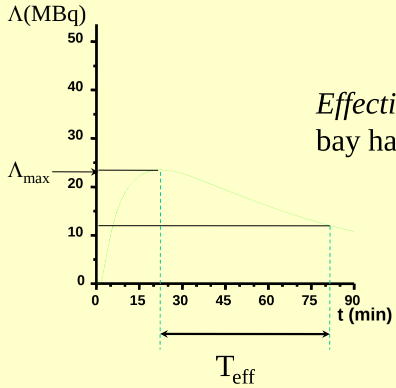
Types of images

Dynamic picture – variation of the amount of isotope / activity in time



Effective half -life – activity decreases by half in the target organ





Effective half-life – activity decreases bay half in the target organ

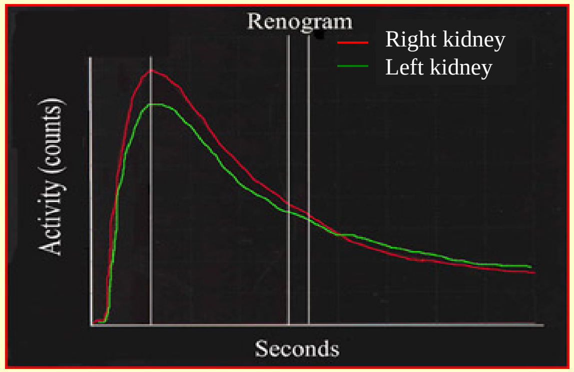
$$\Lambda = \Lambda_0 e^{-(\lambda_{phys} + \lambda_{biol})t}$$

$$\lambda_{effective} = \lambda_{phys} + \lambda_{biol}$$

$$\frac{1}{T_{eff}} = \frac{1}{T_{phys}} + \frac{1}{T_{biol}}$$

The final fate of the radiotracer depends on how the addressed organ deals with the molecule, whether it is absorbed, broken down by intracellular chemical processes or whether it exits from the cells and is removed by kidney or liver processes. These processes determine the **biological half-life** $\boldsymbol{T_{biol}}$ of the radiopharmaceutical.

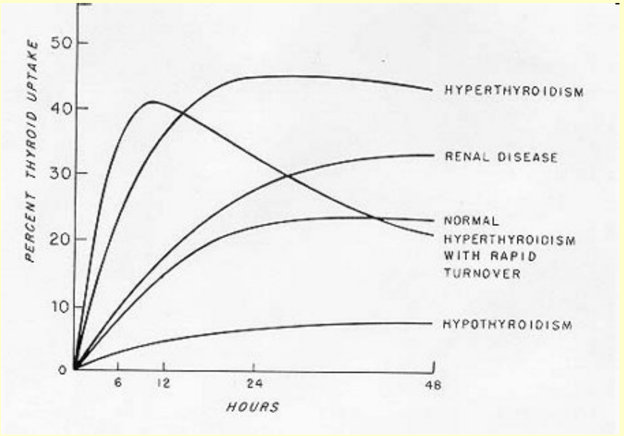
example



kidney

Isotope accumulation

example



Thyroid glands

Isotope accumulation