



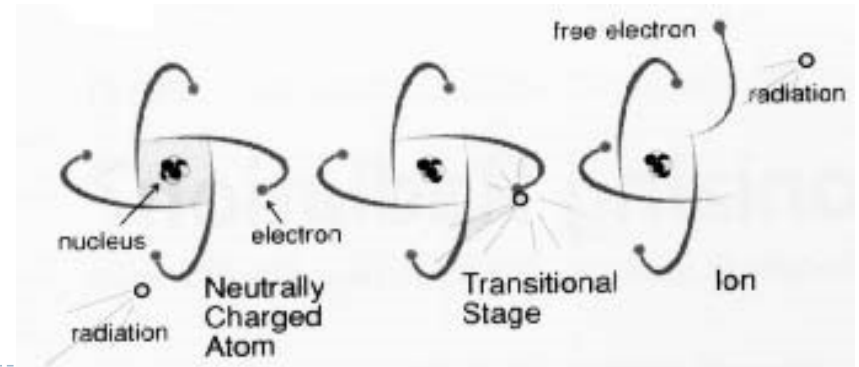
# **NUCLEAR MEDICINE IMAGING SYSTEMS**

# Ionizing Detectors

- Humans does not have a sense with which he could register ionizing radiation



- It can only be registered with specially designed DETECTOR devices



# Ionizing Detectors

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## 1 What are Ionizing Detectors?

Ionizing detectors are devices that detect ionizing radiation such as alpha and beta particles, gamma rays, and X-rays. They work on the principle of ionization which occurs when radiation interacts with the detector material.

## 2 Types of Ionizing Detectors

There are several types of ionizing detectors including Geiger-Muller tubes, proportional counters, and semiconductor detectors. Each type has its own working principle, advantages, and disadvantages.

## 3 Applications of Ionizing Detectors

Ionizing detectors have a wide range of applications such as in medical imaging. They are also used for detecting radiation in the environment and in food.

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# Types of ionizing detectors

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Based on the medium in which ionization occurs

- **Gas filled detectors**

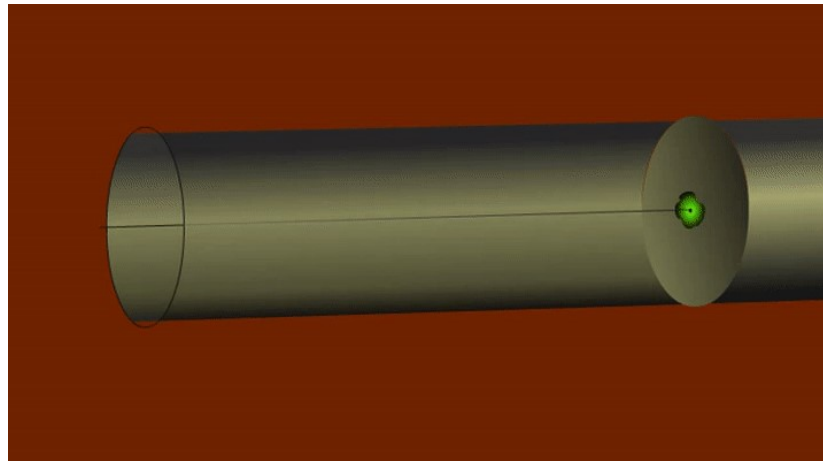
- **Liquid Detectors**

- **Solid state**

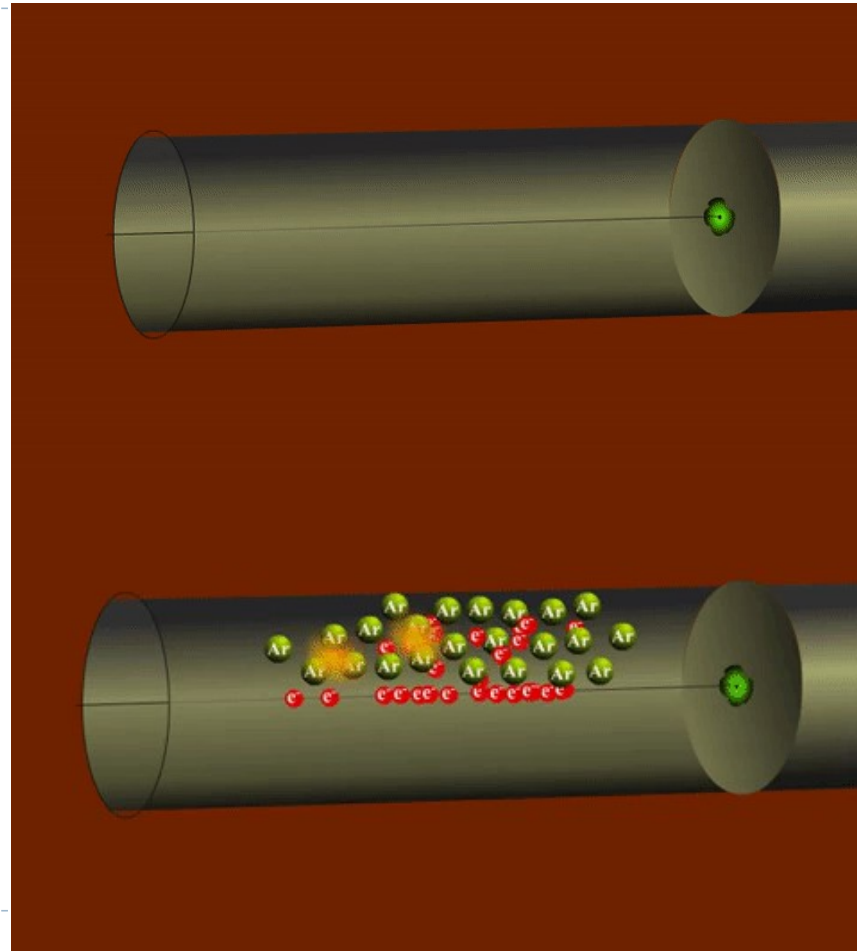


# Gas filled detectors

- A vacuumed cylindrical tube with a positive electrode along the axis of the cylinder. The pipe wall is at negative voltage and is grounded. The tube is filled with a working gas (most often a mixture of argon, neon and helium) and a substance that serves for extinguishing (quenching), i.e. preventing the formation of a Volta arc in the tube (most often it is ethyl alcohol)



# Gas filled detectors



# Gas filled detectors



## Geiger Counter

The classic gas-filled detector that measures the ionizing particles in the air.



## Proportional Counter

Higher level of accuracy and precision than Geiger counters. Measures the energy deposited by particles, not just their number.



## Ion Chambers

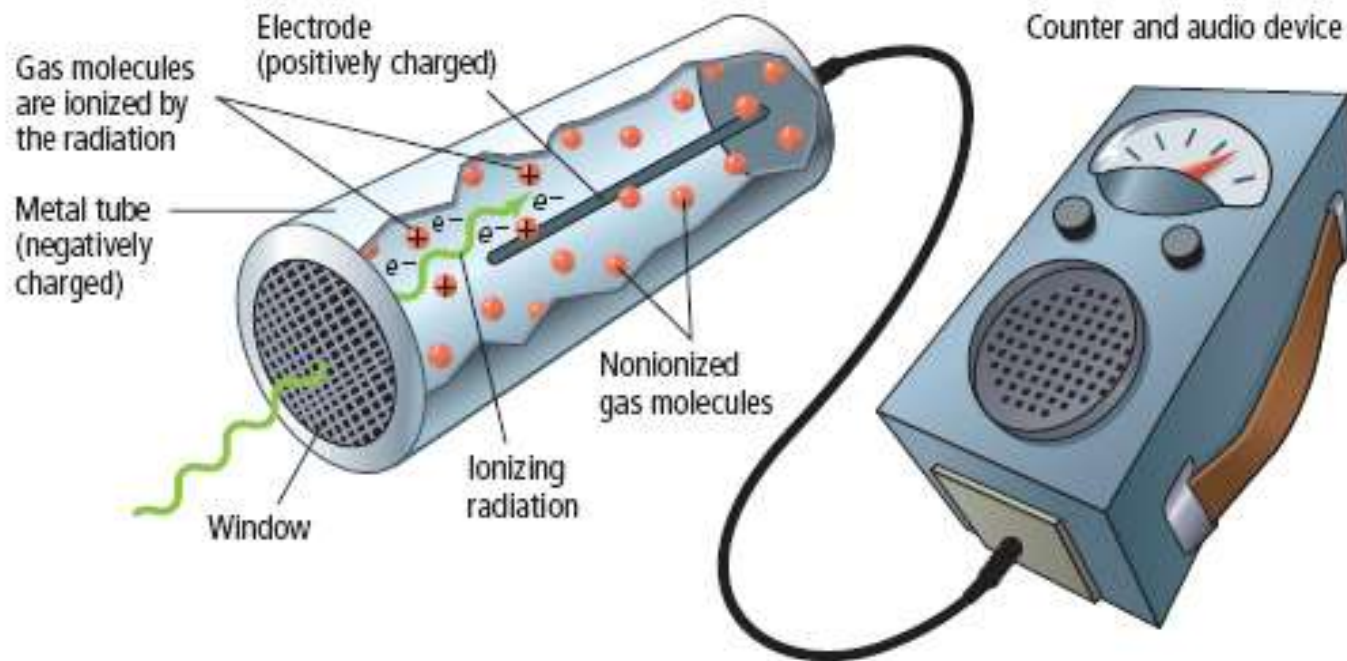
Used for measuring radiation levels in air, water, or other materials.



## GM Tube

Measures radiation by detecting ion pairs formed in the gas filled tube.

# Geiger-Müller counter

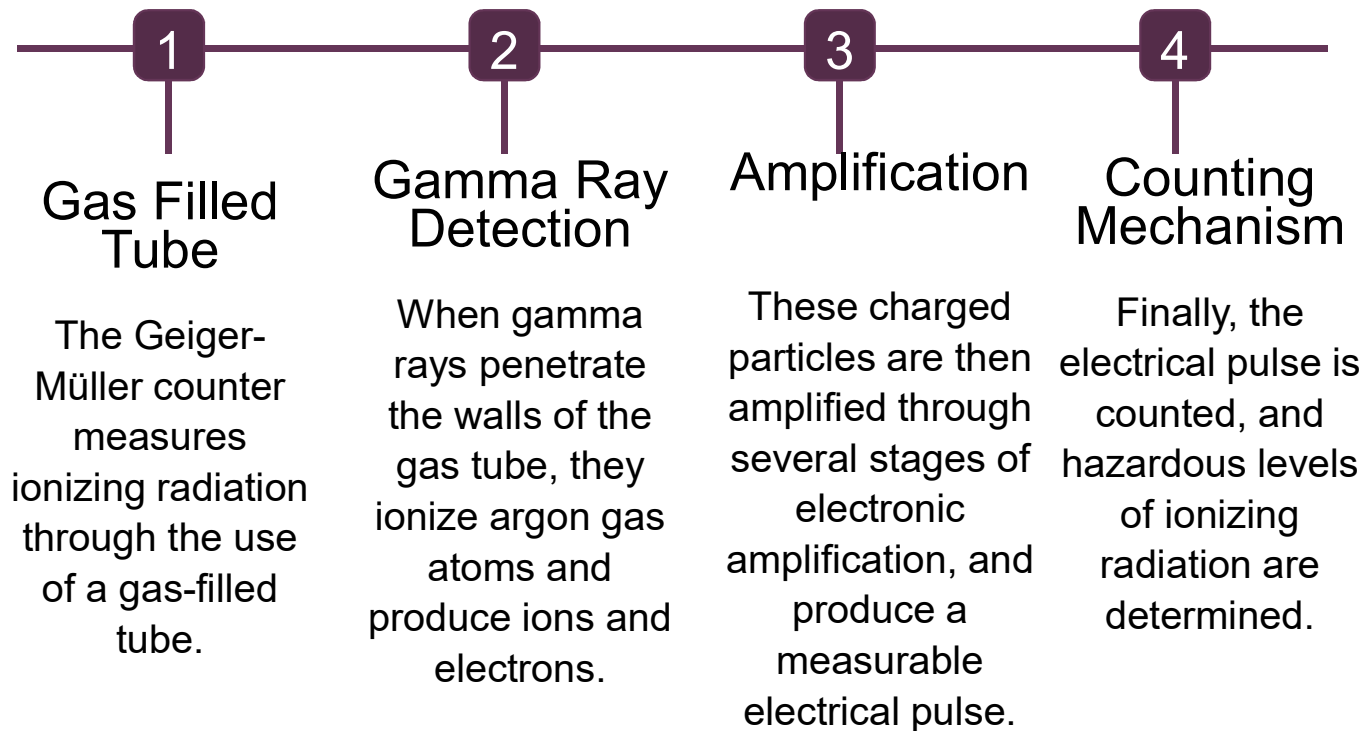


**Radiation monitoring**



# Working Principles of the Geiger-Müller Counter

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# Advantages and Disadvantages of the Geiger-Müller Counter

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## Advantages

Ease of use

Low cost

High accuracy

Fast response time

## Disadvantages

Saturates at high radiation levels

Cannot differentiate between types of radiation

Accuracy declines with higher radiation levels

Requires calibration over time



# Liquid Detectors



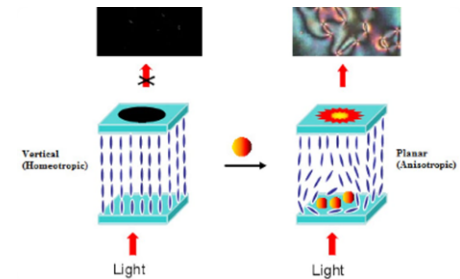
## Working Principle

Liquid detectors use a liquid scintillator or other liquid materials to detect radiation. When radiation interacts with the liquid, it produces scintillations or flashes of light, which can be detected and measured.



## Components

Liquid detectors consist of a scintillator material, a photomultiplier tube to detect the scintillations, and electronics to amplify and process the signal.



## Advantages and Disadvantages

Liquid detectors have high sensitivity, good energy resolution, and can be used in a variety of applications such as in medical imaging and particle physics experiments. However, they may be costly, require careful handling, and produce radioactive waste.

# Scintillation Detectors

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## 1 Principle

Converts ionizing radiation into flashes of light, which are then measured and counted. This interaction generates light in the ultraviolet to visible range.

Scintillators capture this light and convert it into an electrical signal that can be measured and analyzed

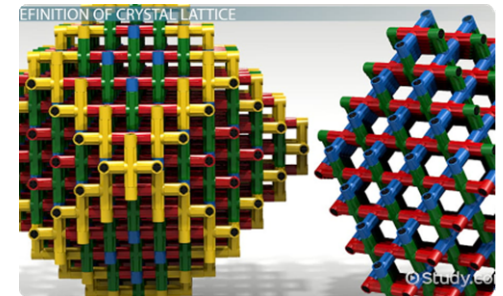
## 2 Types

There are organic and inorganic scintillators, each with its own properties and applications

Organic scintillators are made of complex molecules containing aromatic compounds that produce light when excited.

## 3 Examples

Sodium Iodide, Bismuth Germanate, Anthracene, NaI (TI) Scintillation Detector



# Pros and Cons of Scintillation Detectors

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## Pro: High Efficiency

Scintillation detectors can achieve high detection efficiencies for a wide range of radiation energies and types.

## Pro: Fast Response Time

Scintillation detectors have a fast response time and can capture the timing information of radiation events with excellent precision.

## Con: Temperature Sensitivity

Scintillators can be sensitive to temperature changes that affect their output, requiring careful calibration and operation.

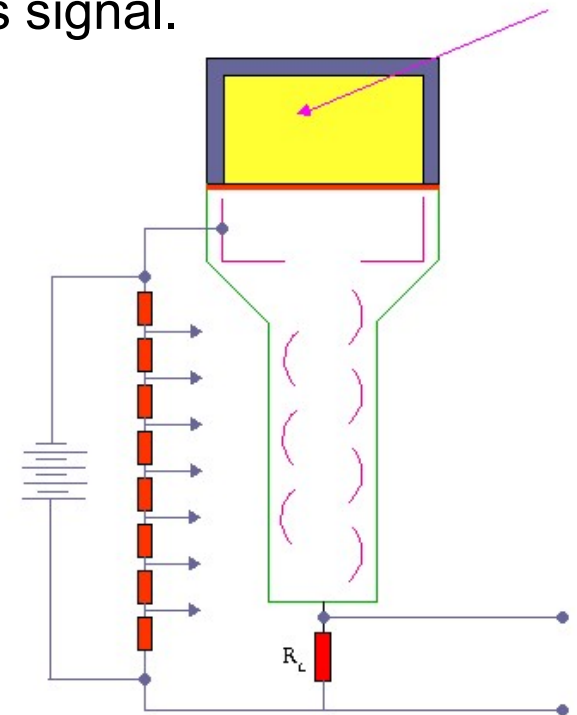
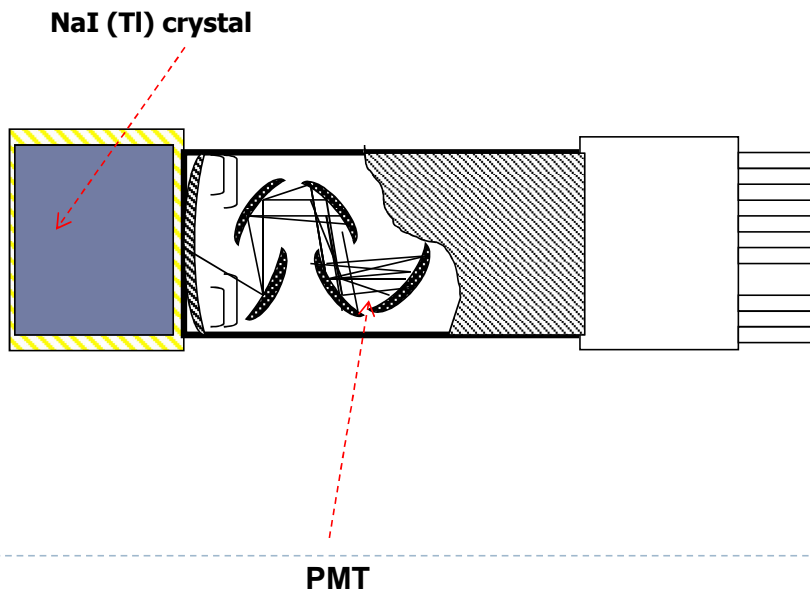
## Con: Radiation Damage

Scintillators can be damaged by the same radiation they are meant to detect, limiting their lifetime and sensitivity under high doses.



# Scintillation Detectors

It consists of a scintillator which generates photons in response to incident radiation, a sensitive photodetector (usually a photomultiplier tube (PMT), a charge-coupled device (CCD) camera, or a photodiode), which converts the light to an electrical signal and electronics to process this signal.



# Solid-State Detectors

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## Properties

- Uses a solid material such as silicon or germanium crystal
- Converts charged particles into electronic signals

## Applications

- Used in medical imaging such as PET and CT scans

## Image of Solid-State Detector

- High sensitivity and spatial resolution
- Excellent imaging

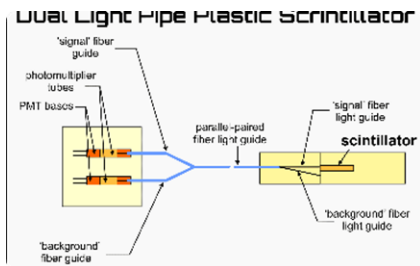
Silicon, Cadmium Zinc Telluride (CZT), Germanium, Diamond, and Sapphire detectors.

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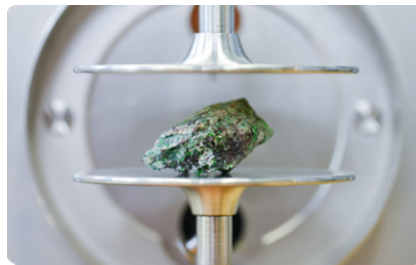
# Comparison with Other Radiation Detectors

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## Scintillation Detector

A scintillation detector detects ionizing radiation by using crystal materials.



## Ionization Chamber

An Ionization chamber detects and measures ionizing radiation by using an ion chamber filled with gas.



## Proportional Counter


A proportional counter detects particles of ionizing radiation and measures their energy levels, such as in mass spectrometry.





# Conclusion

| Detector Type | Advantages                                                                               | Disadvantages                                                                                    |
|---------------|------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Ionizing      | High sensitivity and can be used in a variety of applications                            | May require high voltage power supplies and may be sensitive to temperature and pressure changes |
| Gas-filled    | High sensitivity, good energy resolution, and can be used in high radiation environments | Requires high voltage power supplies and may be sensitive to temperature and pressure changes    |
| Liquid        | High sensitivity and good energy resolution                                              | May be costly, require careful handling, and produce radioactive waste                           |
| Solid-state   | High sensitivity and spatial resolution                                                  | May be costly and require specialized handling and processing                                    |
| Scintillation | High sensitivity and good energy resolution                                              | May require careful handling and processing                                                      |



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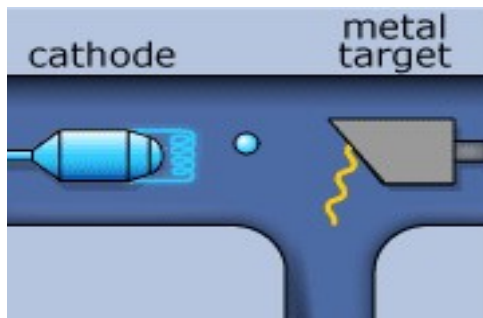
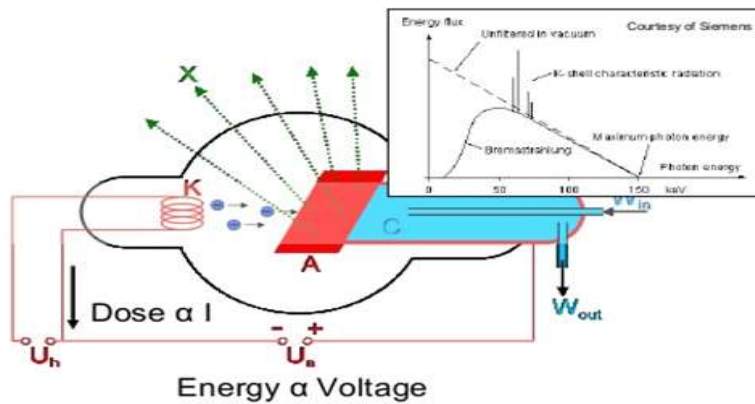
# **Medical Imaging devices**

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# X-rays

## X-ray – Generation



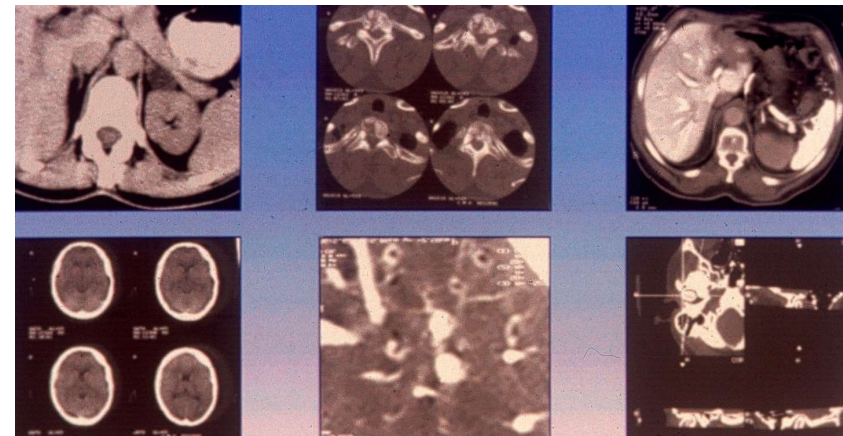
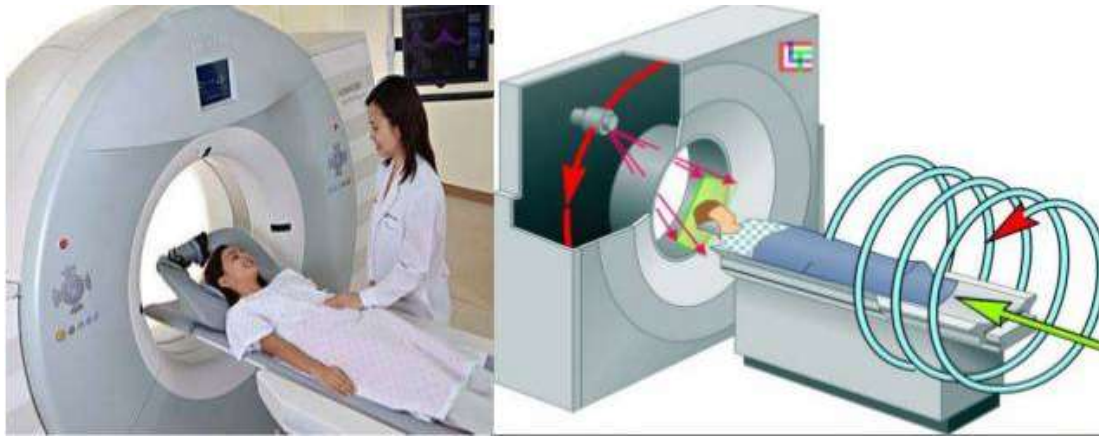
X-rays are a type of electromagnetic radiation that are used to create images of the inside of the body.



# MDCT Imaging

MDCT imaging is a type of computed tomography that uses multiple detectors to capture cross-sectional images of the body.

MDCT images are produced by rotating an x-ray tube around the body and using multiple detectors to measure the resulting x-rays. The images are then reconstructed using computer software.



A.M. Cormac, Sir G.N.Hounsfield 1979



# Linear Accelerator (LINAC)

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Linear accelerators are used to deliver high-energy radiation to cancerous tissue while sparing surrounding healthy tissue. The machines use electricity to accelerate electrons to near-light speeds, which creates high-energy photons that can penetrate tissue.



LINACs are used for external beam radiation therapy to treat cancerous tumors throughout the body, including the lung, prostate, breast, and head and neck.



LINAC, Y knife, X knife

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# Gamma Camera Imaging



# Principles of Operation

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## Scintillation Detection

The detector converts gamma rays into visible light, which is captured by the camera to form an image of the organ or tissue being studied.

1

2

3

## Gamma Ray Detection

The camera detects gamma rays emitted from the patient's body after being administered with a radioactive tracer. These rays are typically in the 100 keV to 2 MeV range.

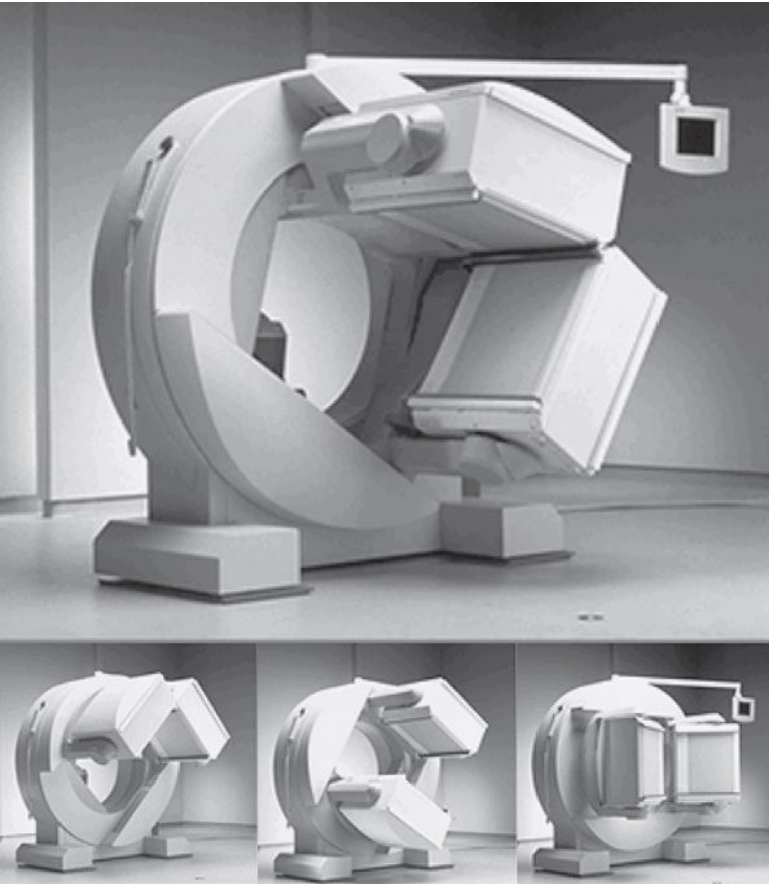
## Image Reconstruction

The camera uses sophisticated algorithms to convert the detected light into a high resolution 2D or 3D image. This information is then analyzed by physicians to make a diagnosis or determine treatment options.





# Gamma Camera Components



## Detector Head

- scintillator: single photoluminescent crystal, usually made from thallium-activated sodium iodide. it detects gamma rays emitted by the patient and converts them into an electrical signal.
- photomultiplier tubes
- preamplifiers
- electronics including: analog to digital converters, digital summing and positioning circuits and correction circuits

# Collimator

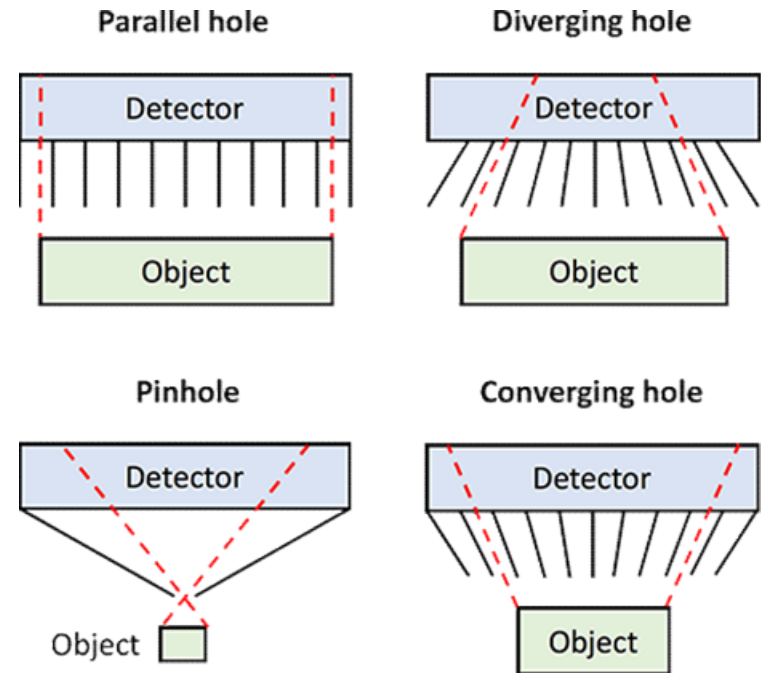
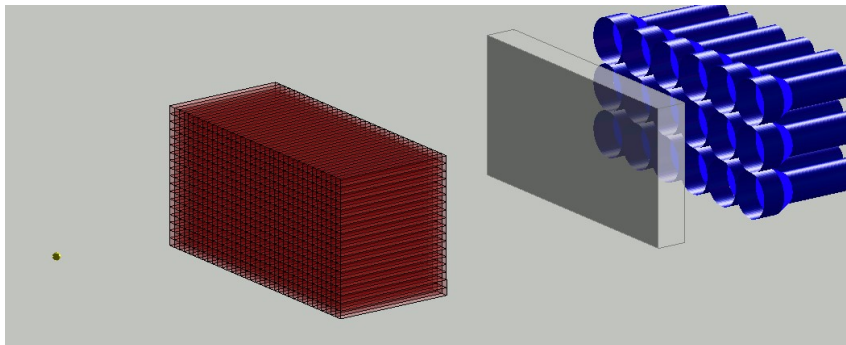
The collimator is a lead shield with small holes that direct gamma rays towards the detector head. It helps to improve image quality and reduce background radiation noise.

**Parallel hole**

**Pinhole**

**Fan beam (diverging)**

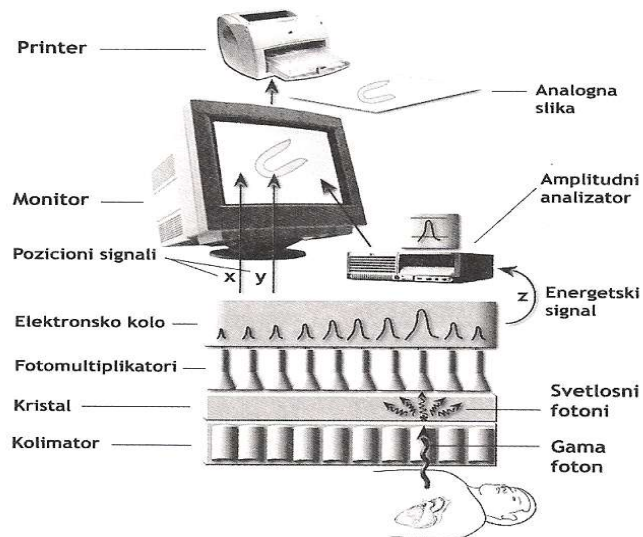
**Cone beam (converging)**



# Control Computer



The computer controls the movement of the detector head and processes the imaging data. It allows physicians to view, manipulate, and analyze the images captured by the camera.



## Advantages

- ▶ Image reconstruction
- ▶ Storage
- ▶ Telemedicine



\* Shown with the optional Scintibed™

# Advantages and Limitations

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## Advantages

- Safe, painless, and non-invasive
- Allows physicians to view internal organs and tissues in real time
- Can detect problems at a cellular level

## Limitations

- Expensive, clinical centers
- Can expose patients to a small amount of radiation
- Requires trained technicians to operate and interpret results



# SCINTIGRAPHY

## NUCLEAR MEDICINE IMAGING

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Scintigraphy (from Latin scintilla, "spark"), also known as a gamma scan, is a diagnostic test in nuclear medicine, where radioisotopes attached to drugs that travel to a specific organ or tissue (radiopharmaceuticals) are taken internally and the emitted gamma radiation is captured by external detectors (gamma cameras) to form two-dimensional images

In contrast, SPECT form 3-dimensional images and are therefore classified as separate techniques from scintigraphy, although they also use gamma cameras to detect internal radiation



# SCINTIGRAPHY

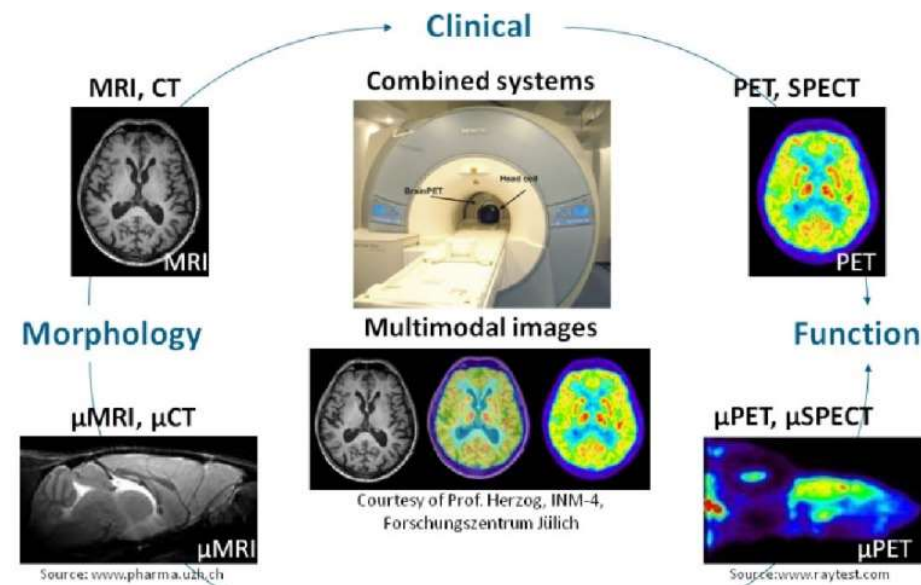
## NUCLEAR MEDICINE IMAGING

Scintigraphy is a molecular imaging technique that involves the use of radioisotopes to generate images of a patient's internal organs and tissues.

### Functional Imaging

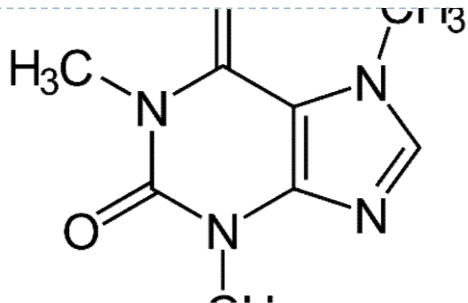
Track metabolic processes and biochemical activities in real-time without invasive procedures.

Scintigraphy is a safe and non-invasive diagnostic tool that can provide accurate and detailed images of the body's internal structures and functions.





# Radiopharmaceuticals



## Composition

Radiopharmaceuticals contain radioactive material and biologically active molecules that selectively adhere to specific disease sites in the body.

## Preparation

These substances are carefully prepared and quality-tested in labs to ensure that they are both safe and effective for clinical use.

## Injection

A radiopharmaceutical is injected into the patient's bloodstream, where it will travel to the intended organ or tissue being studied.



# Advantages of Scintigraphy

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## Increased Sensitivity

Scintigraphy can detect abnormalities much earlier than traditional imaging methods, allowing for earlier diagnosis and better outcomes.

## Non-Invasive

Unlike other diagnostic methods, scintigraphy does not require surgical or invasive procedures, reducing risks and ensuring a less painful and safer diagnosis experience.

## Functional and Anatomical imaging in one

Scintigraphy produces a high-resolution anatomical image combined with a functional image that displays metabolic activities effectively.



# Types of Imaging

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## Single-Photon Emission Computed Tomography (SPECT)

SPECT uses a rotating gamma camera to acquire images from different angles. It is used to study the function and structure of organs such as the brain, heart, and liver.

## Positron Emission Tomography (PET)

PET uses a gamma camera to detect positron emissions from the patient's body. It is used to study metabolic functions and diagnose cancer, dementia, and other diseases.

## Planar Scintigraphy

Planar scintigraphy captures 2D images of a patient. It is commonly used to study bone disorders and lung function.

## Hybrid Scanners

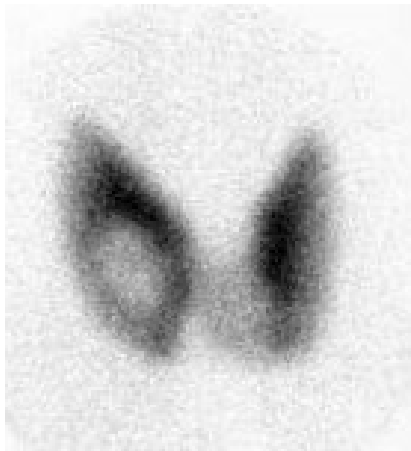
Hybrid scanners combine SPECT or PET with a CT scanner, providing both structural and functional information about the body.

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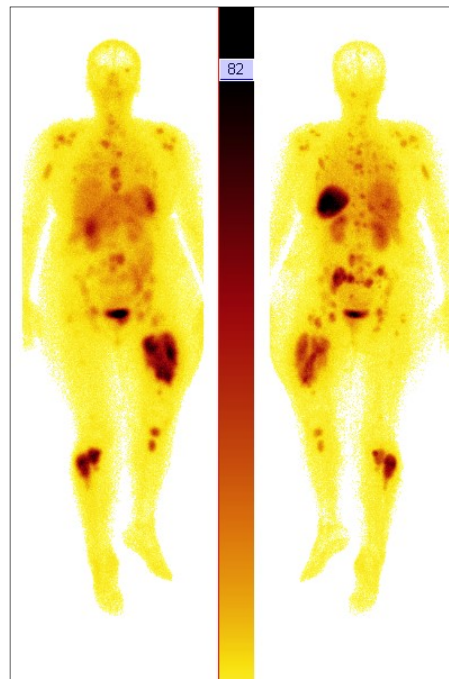
# Planar Scintigraphy

## NEGATIVE SCAN

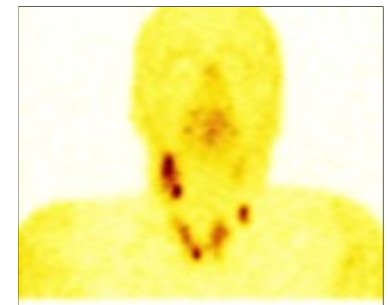
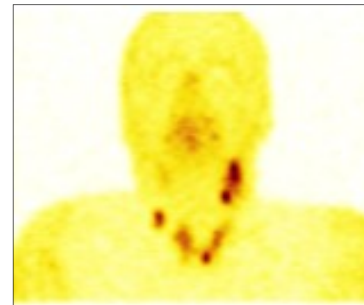


$^{131}\text{I}$

## POSITIVE SCAN



$^{131}\text{I}$ -MIBG

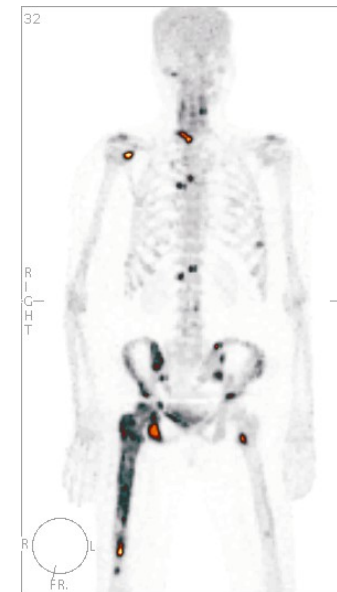


$^{99\text{m}}\text{Tc}$ -TEKTROTYD



# SINGLE PHOTON EMISSION COMPUTED TOMOGRAPHY (SPECT)

- Generation of 2D planar projections by rotating the detector around the axis of rotation (of the patient) or in some other combination depending on the construction of the camera and the type of study being performed.



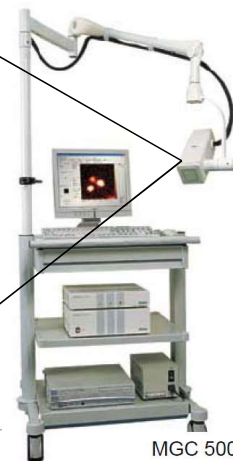
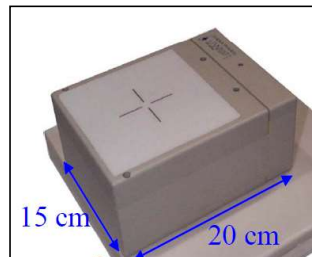
# Nuclear medicine imaging

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# Nuclear medicine imaging

“eZ-Scope-handheld”



MGC 500



Sentinella



Picture Frame is Actual Size of EZ Scope



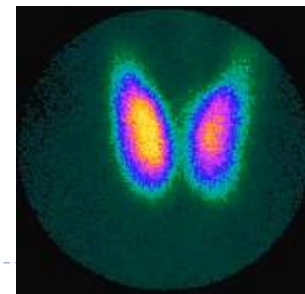
Thyroid Imaging



Pediatric Imaging

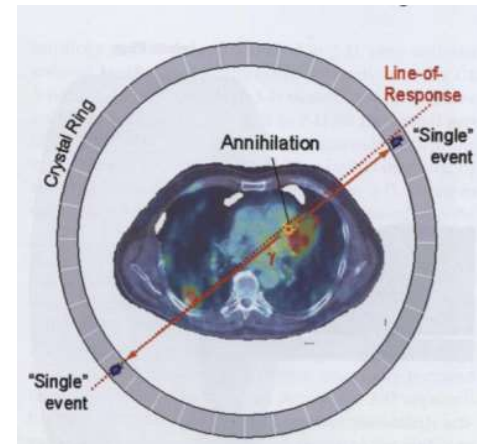
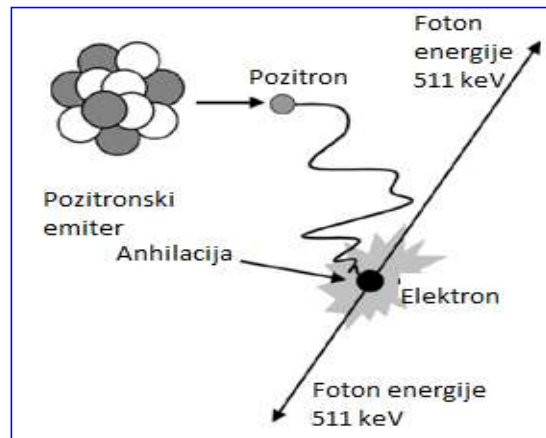


Small Animal Imaging



# Positron emission tomography (PET)

PET scans detect gamma rays emitted indirectly by a positron-emitting tracer injected into the body.



$^{11}\text{C}$   $^{13}\text{N}$   $^{15}\text{O}$   $^{18}\text{F}$

Annihilation photons are emitted approximately at an angle of  $180^\circ$  and are registered by the so-called detector rings. Thus, all the data are obtained simultaneously (cross sections), which later participate in the 3D reconstruction of the image.

# Hybrid imaging



**Prvi** BGO  
PET skener

## Metabolički imidžing

1978



## Prvi PET/CT hibridni sistem

## Morfofunkcionalni imidžing

1998



## Prvi SPECT/CT hibridni sistem

## Morfofunkcionalni imidžing

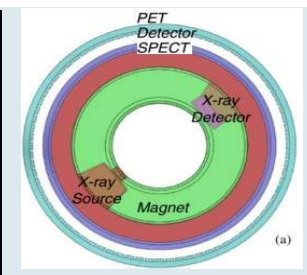
2003



**Prvi** time-of-flight WB  
PET-MRI

## Morfofunkcionalni imidžing

2010



**Prvi** All-in-one  
SPECT/PET/CT/MRI

**Lu<sub>1.8</sub>Gd<sub>0.2</sub>SiO<sub>5</sub> (Ce)  
detektor**

2013



## Hybrid imaging: SPECT-PET/CT

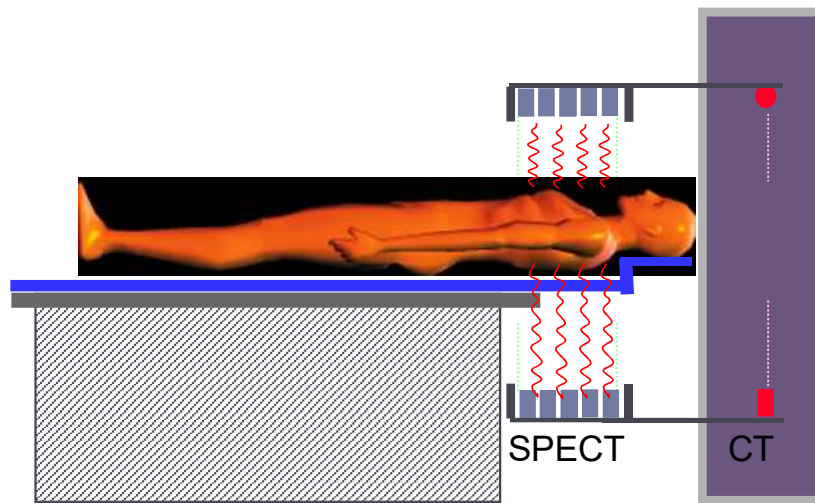
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SPECT/PET + CT > SPECT/PET i CT

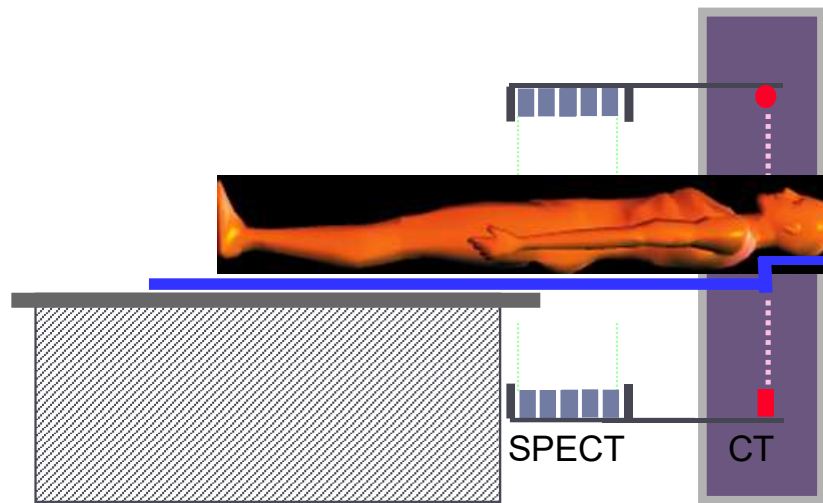
- ❖ combines the functional and molecular information from PET scans with the anatomical information from CT scans to provide detailed images of the body.
- ❖ have higher accuracy than either PET or CT scans alone; early detection with unprecedented details; and new therapies for cancer and other chronic diseases.
- ❖ offer increased accuracy in diagnosing cancer, tracking treatment progress, and planning radiation therapy. It can also help detect heart disease and neurological disorders.



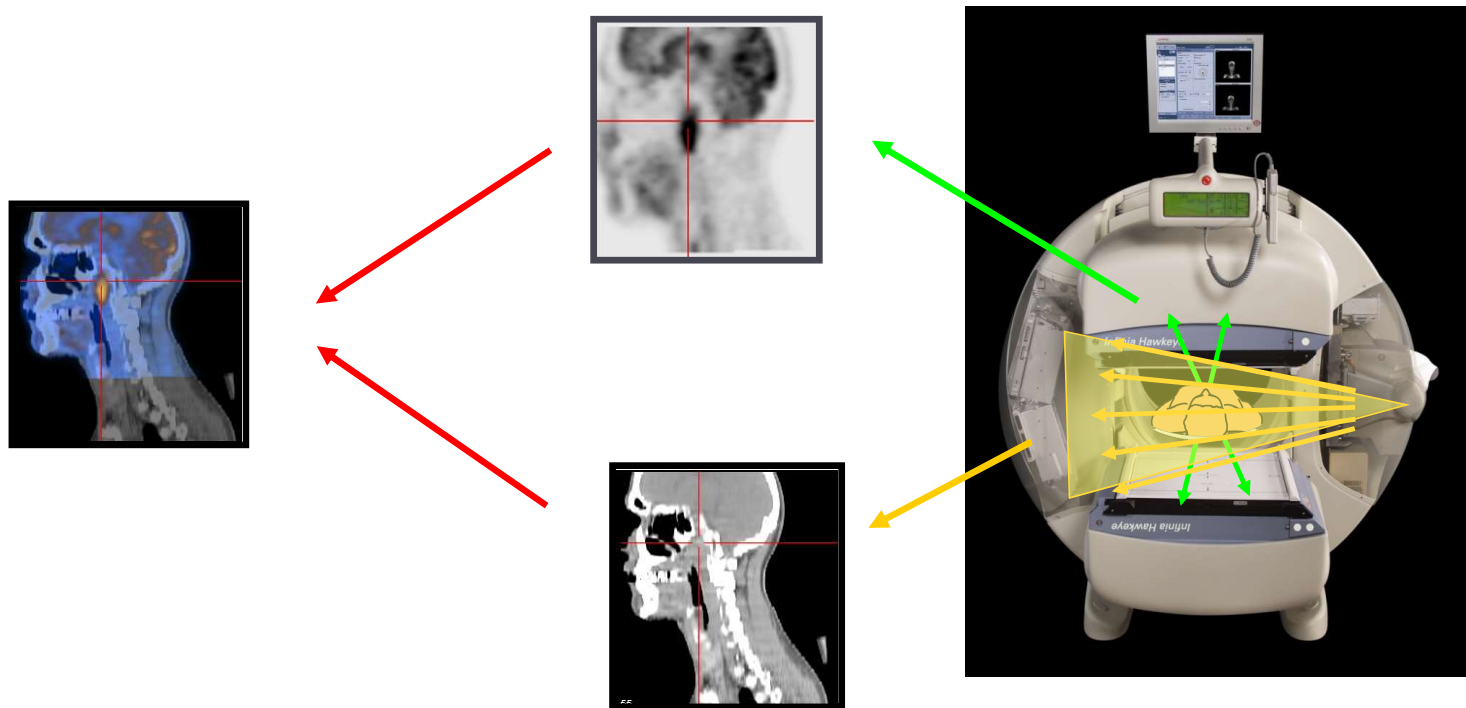
# Hybrid imaging: SPECT-PET/CT



# Hybrid imaging: SPECT-PET/CT

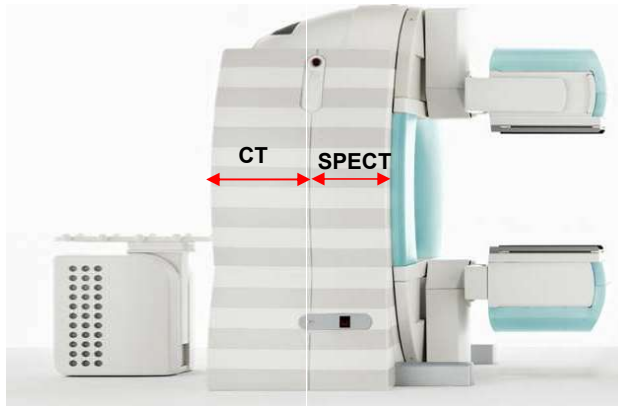


# Hybrid imaging: SPECT-PET/CT



# Hybrid imaging: SPECT-PET/CT

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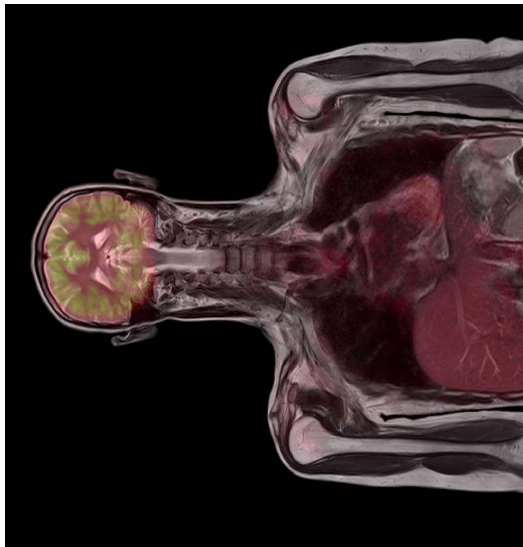
**Functional imaging SPECT/PET**

**+**

**Anatomic imaging CT**



# Hybrid imaging: SPECT-PET/CT



- Precise anatomical localization of functional changes (planar/SPECT/PET)
- Increased sensitivity
- Increasing specificity
- Improvement of attenuation correction
- ↓
- Early detection and monitoring of changes
- Therapy planning
- Therapy monitoring

# Hybrid imaging: SPECT-PET/CT

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## Philips PET/MR Approach



GEMINI TF PET/MR:

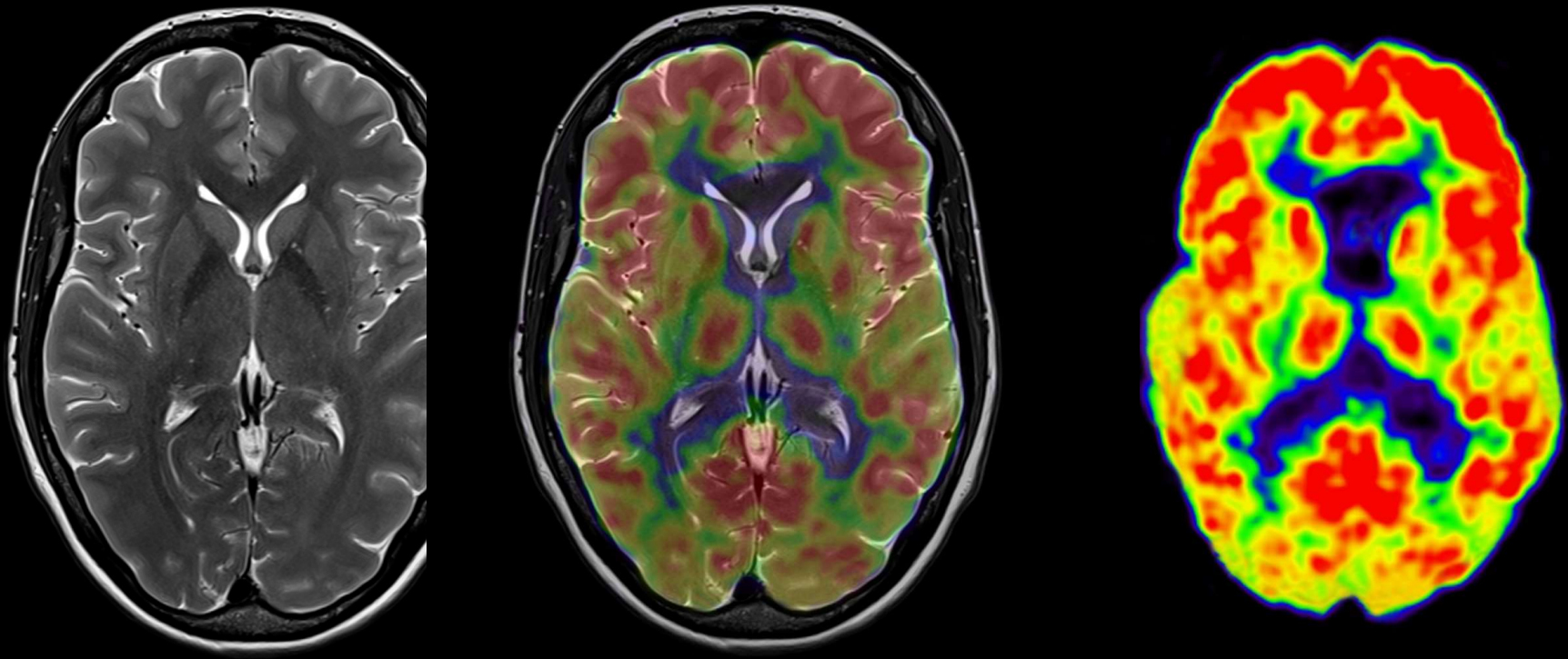
- PET inline with MR-System
- Whole Body Support
- Uncompromised imaging performance



Simultaneous PET/MR:

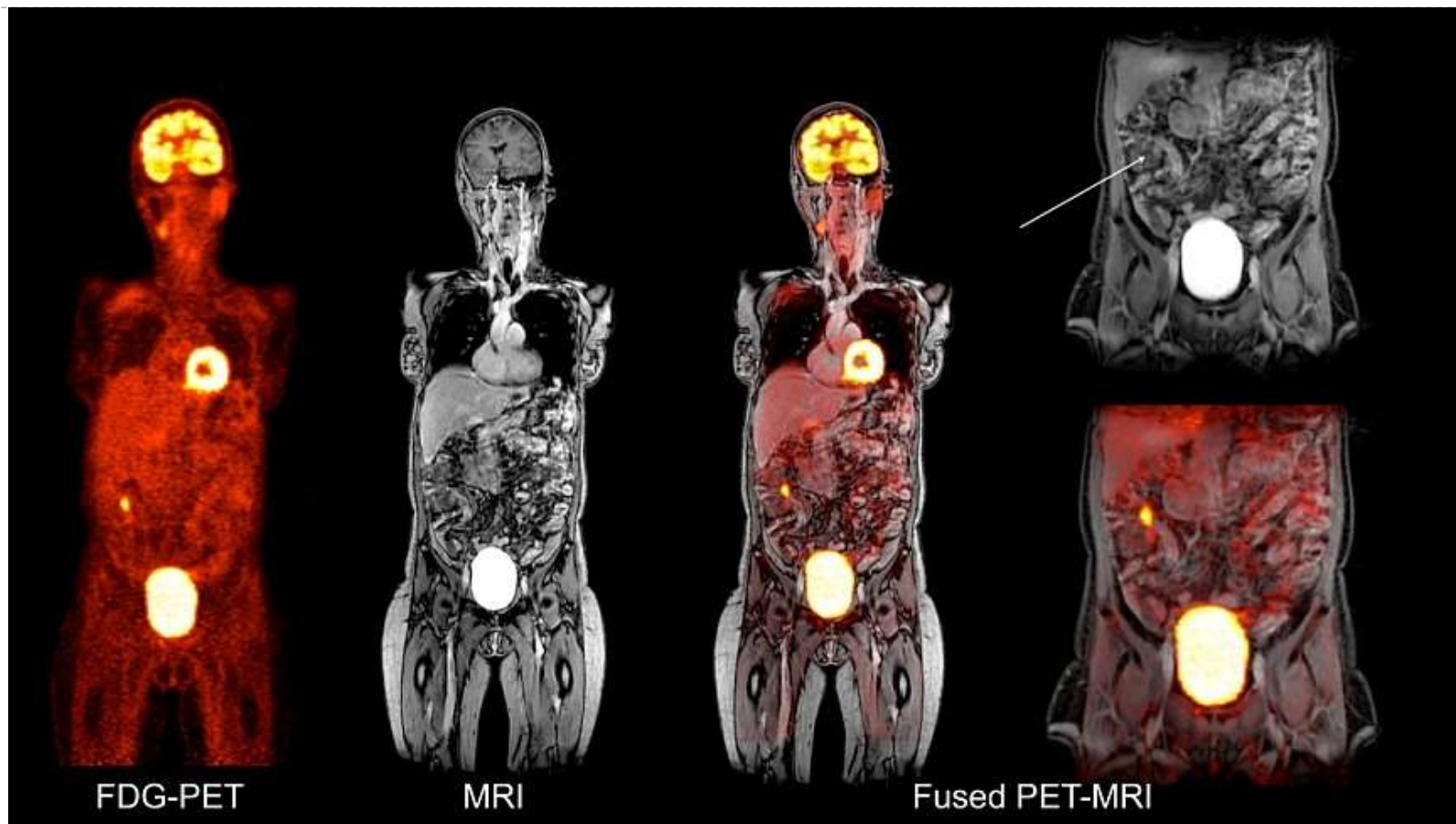
- Integration of PET detector into Achieva XR

## Hybrid imaging: SPECT-PET/MRI

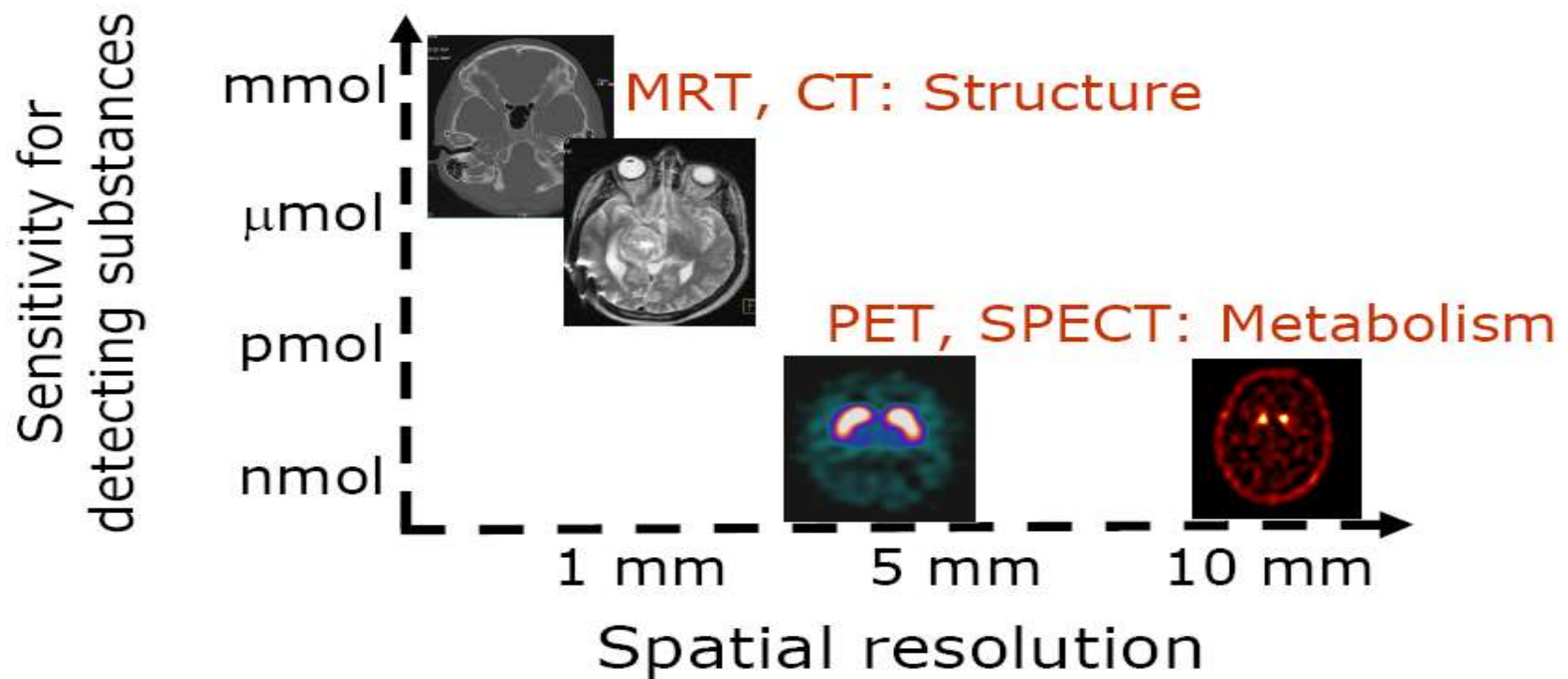




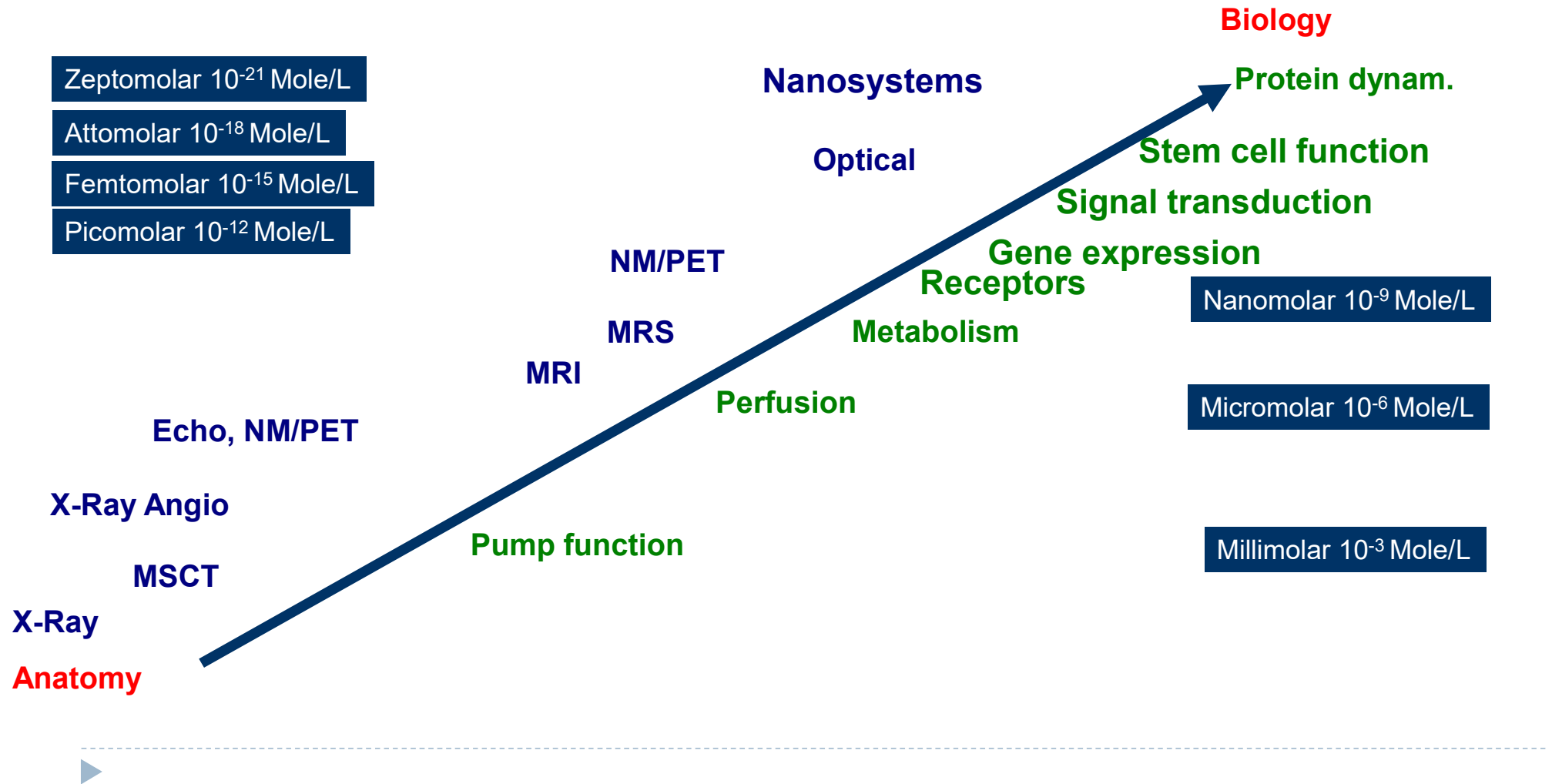
## Hybrid imaging: SPECT-PET/MRI



## Molecular und Morphological Imaging



**From anatomy to molecular imaging**  
*Imaging biological parameters*



# THANKS FOR YOUR ATTENTION

