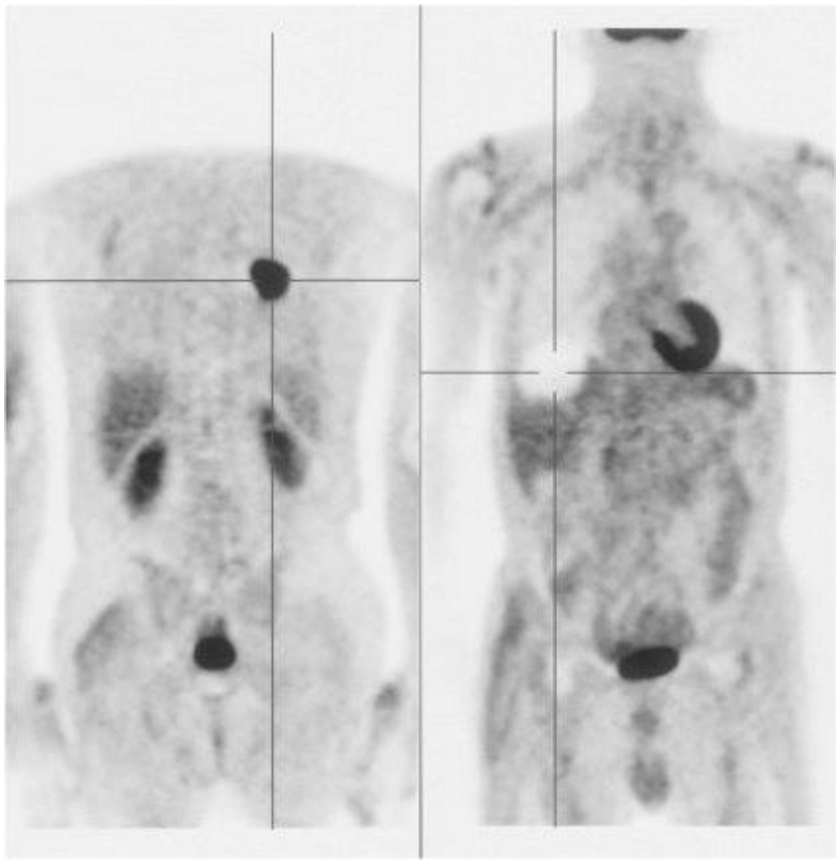
جامعة الانبار
كلية العلوم التطبيقية – هيت
قسم الفيزياء الحياتية

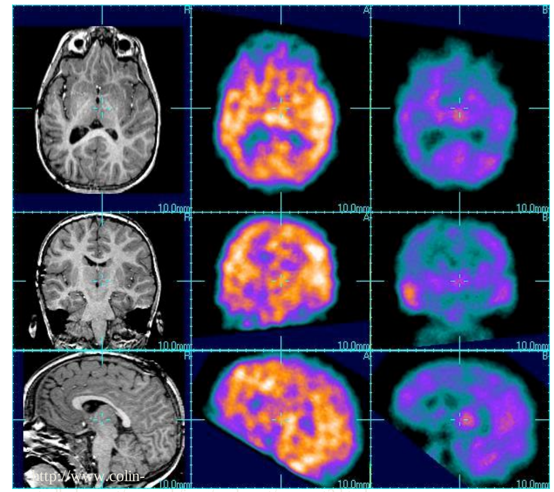
الاجهزة الطبية

Gamma Camera Imaging

Mohammed Qasim Taha

Nuclear Medicine





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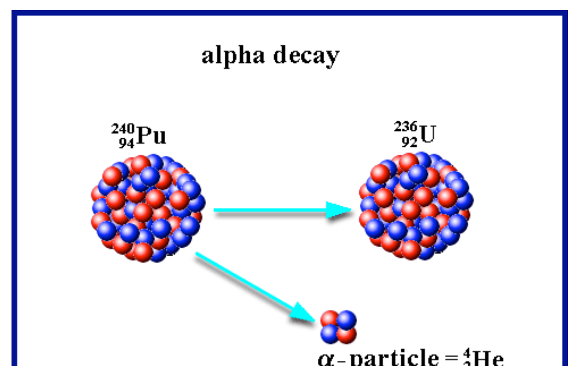


http://www.mwit.ac.th/~Physicslab/applet_04/atom2/Alphae.gif

Background Image courtesy of Dr. Bill Moore, Dept. of Radiology, Stony Brook Hospital

Gamma Camera

- Is a device used to image gamma radiation radio-isotopes this technique is called also scintillation camera.

- Gamma camera is used to view and analyze images of the human body or the distribution of the medically ingested, injected or inhaled radionuclides.

Nuclear Medicine *– Gamma Ray Imaging*

• The ionizing radiation employed in most diagnostic nuclear medical imaging is no different from that employed in x-ray imaging.

• Both involve the detection of photons emerging from the patient’s body however it depends on where the source is located with respect to the patient.

• X-rays are high energy photons that originate in an ***extra-nuclear*** source.

• However, the gamma rays used in nuclear medicine are ***intra-nuclear*** or produced by the decay of unstable atomic nuclei.

***Nuclear Medicine** – Gamma Ray Imaging*

- Ernest Rutherford (1897) discovered that the emissions of certain radioactive elements could be detected using a zinc sulfide screen, producing tiny flashes of light called scintillations.

- Applied medically it become possible to use that isotopes could be introduced into a patient, where the photons emitted could be identified by newer scintillation detectors, and an image could be produced of the distribution of the isotope within the body.

Nuclear Medicine– Gamma Ray Imaging

• The basics of using gamma rays to image is nuclear medical technique called a gamma camera.

• The gamma camera consists of three basic parts

1. Collimators
2. Scintillation detector (Scintillator or Photomultiplier tube (PMT)).
3. Electronics & computer elements

http://www.paec.gov.pk/kiran/images/800by600/dual-head-gamma-camera.jpg

The Gamma Camera

• The gamma camera was invented by H. Anger in the1960s and is often referred to as the Anger camera

• An Anger camera consists of a collimator, placed between the detector surface and the patient, and the collimators are made out of a highly absorbing material such as lead. This suppresses gamma rays that deviate substantially from the vertical and acts as a kind of "lens". The simplest collimators contain parallel holes.

• Depending on the position of the radiation event, the appropriate phototubes are activated. The positional information is recorded onto film as an analogue image or onto a computer as a digital image.

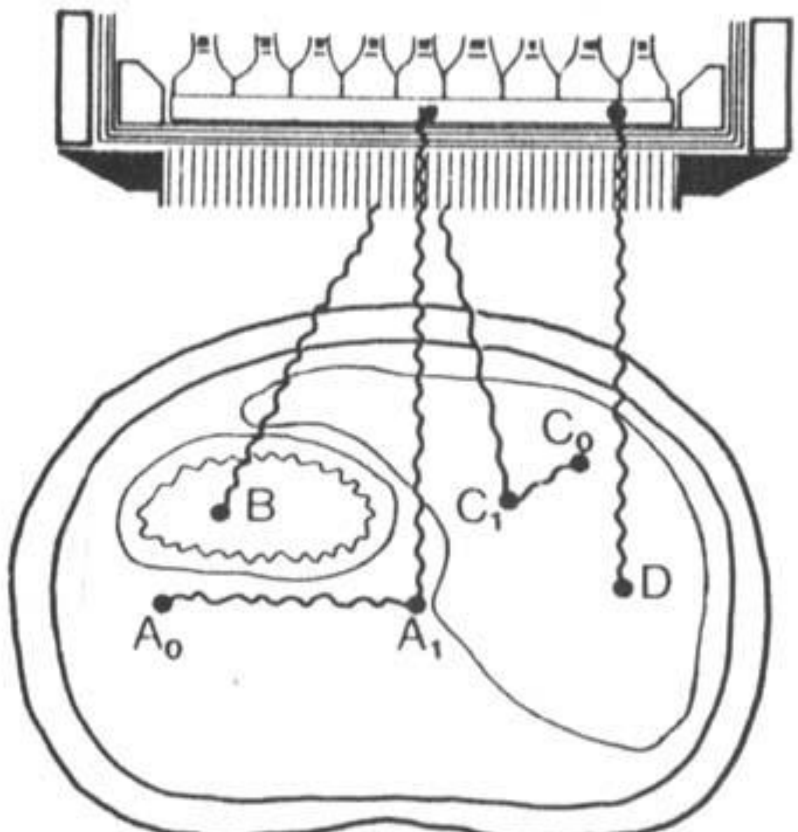
• This set-up yields relatively accurate positional information. The intrinsic resolution of two radiation sources placed immediately on the crystal surface without the collimator is in the order of 1 mm.

Gamma Camera Components

1-Collimators

The collimator provides an interface between the patient and the detector surface scintillation crystal by allowing only those photons traveling in an appropriate direction.

Collimators



Collimators

- Types of collimators
- A) By the accepted energy.
- B) By the geometric shape.
- C) By the resolution.

Collimators

- By the accepted energy

Low Energy Collimator

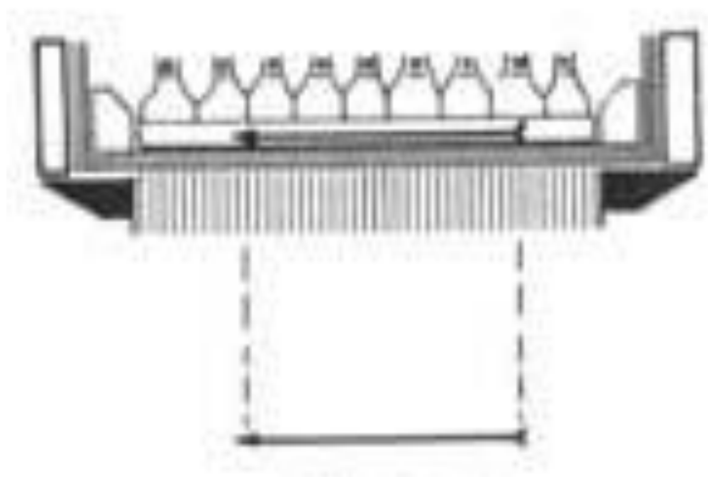
High Energy Collimator

Medium Energy Collimator

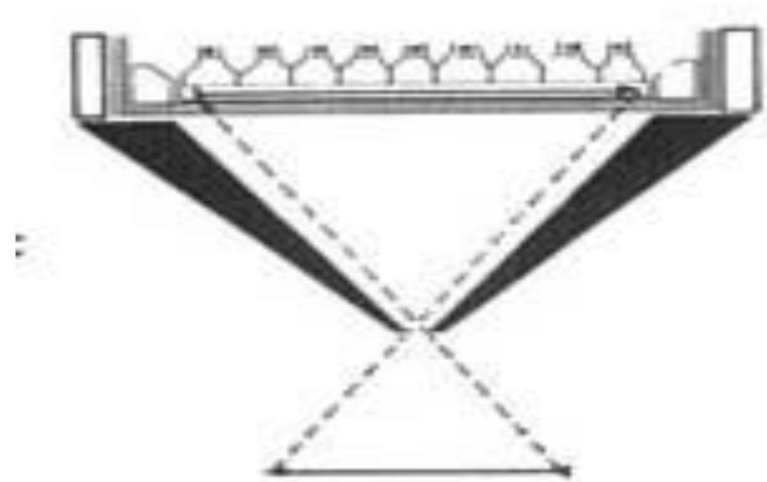
Collimators

- By the geometric shape.
  - **Parallel-Hole**
  - **Pin-Hole Collimator**
  - **Converging collimator**
  - **Diverging collimator**

Collimators

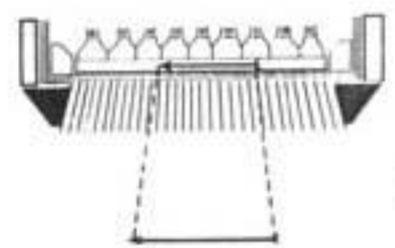


Parallel-Hole

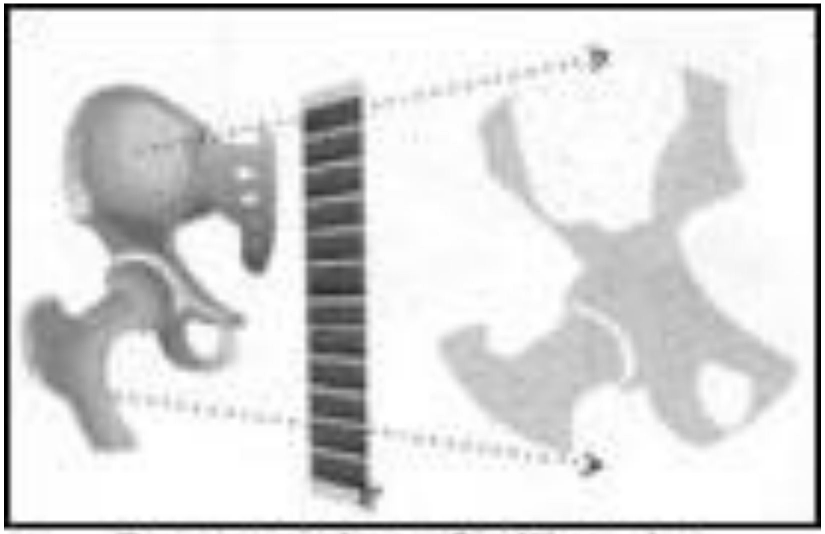


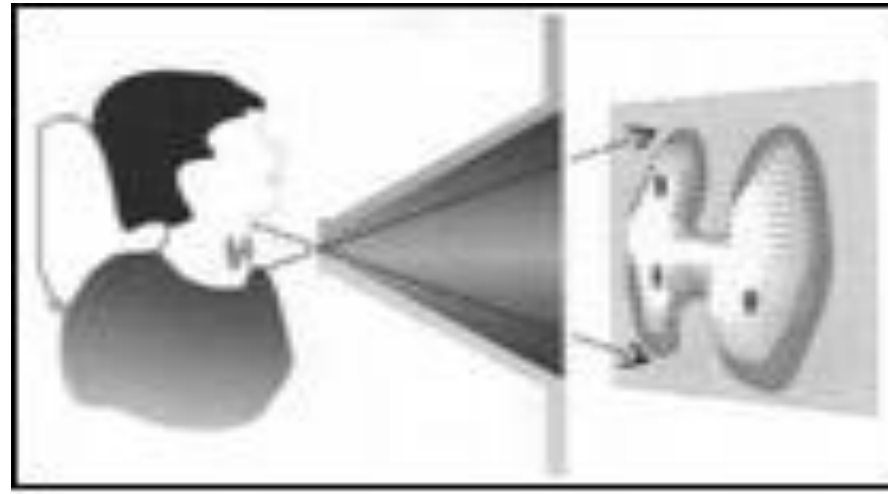
Pin-Hole (more resolution & magnification) hip,thyroid

Converging لتكبير الصورة وتحديد أفضل للأعضاء



Diverging للتصغير في حالة المريض البدين


Converging Collimator


Pinhole Collimator

Detector Surface Crystal

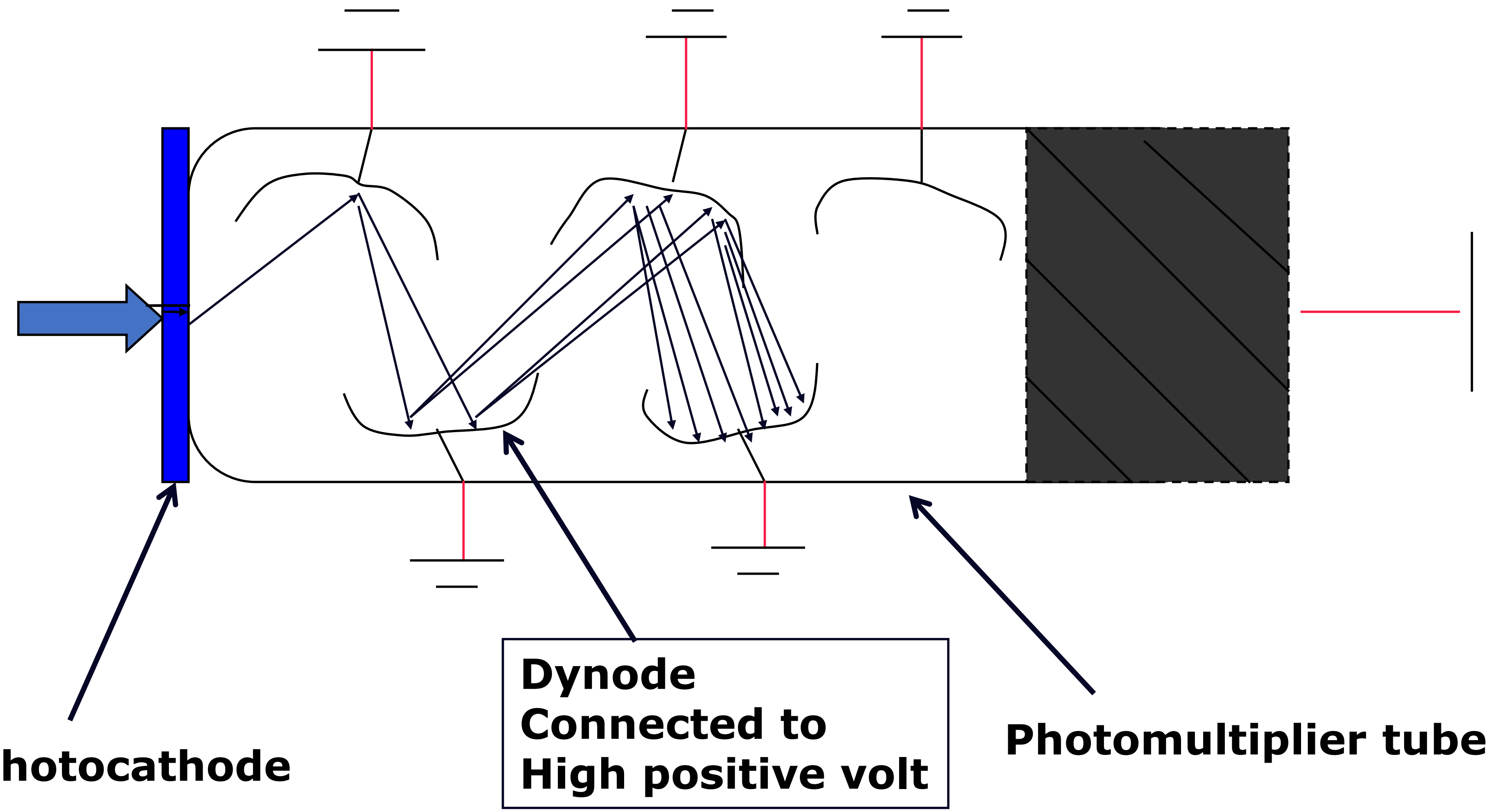
- The Na-I (Tl) crystal is sodium iodide doped with thallium ions
- The Na-I (Tl) crystal is stationary.
- The crystal transform the gamma-ray photon ------> Light photon

Detector Surface Crystal

- Any damage to the crystal results in an inoperable scintillation camera and requires costly replacement of the crystal.

- The large surface area, as well as the hygroscopic and brittle nature of the crystal, calls for constant care to avoid puncturing the housing or otherwise damaging the crystal.

Photomultiplier tube



Photomultiplier Tube PMT functions

1. The Photocathode transform the light photon → electron.

2. The PMT multiplies the electron to be a significant detected signal.

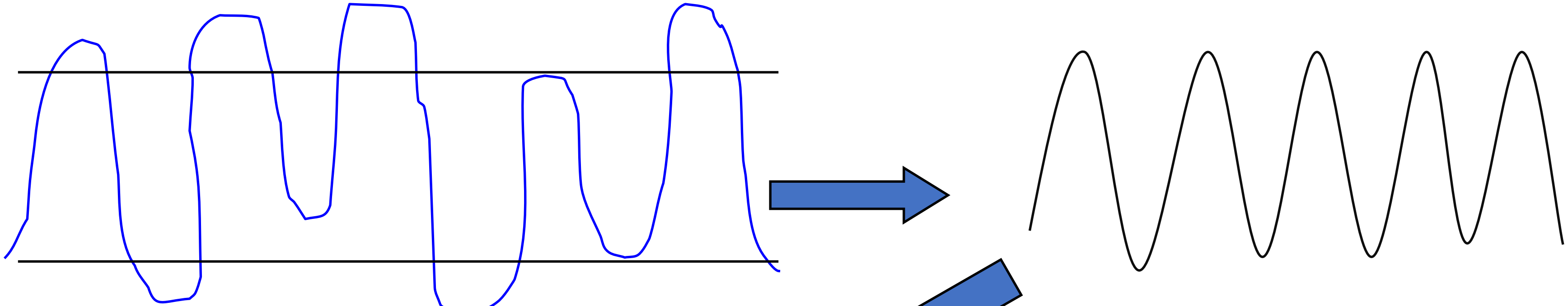
Advantages of Gamma Camera

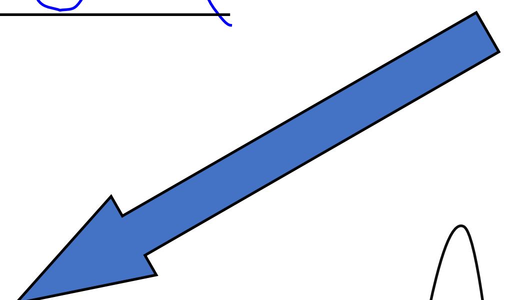
1. The imaging time is only 1-2min.

2. It can distinguish 2 sources about 5mm apart.

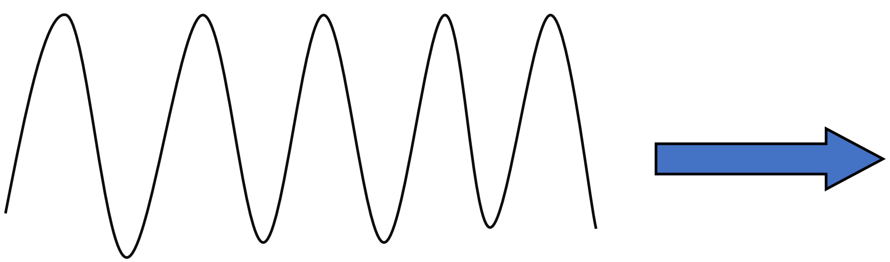
Other circuits

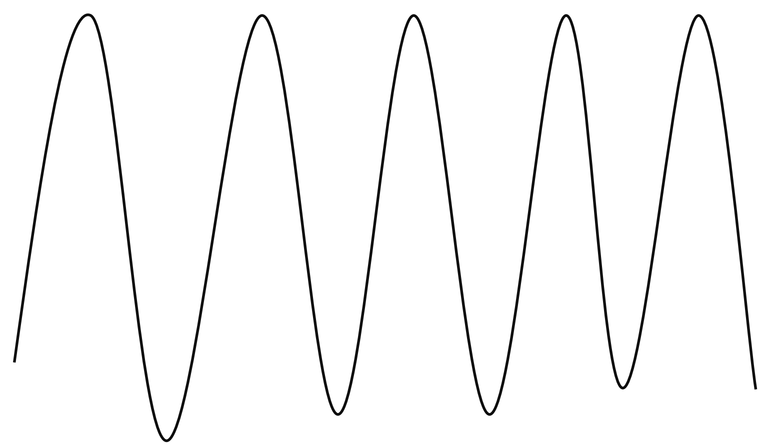
- 1)Pre-Amplefier

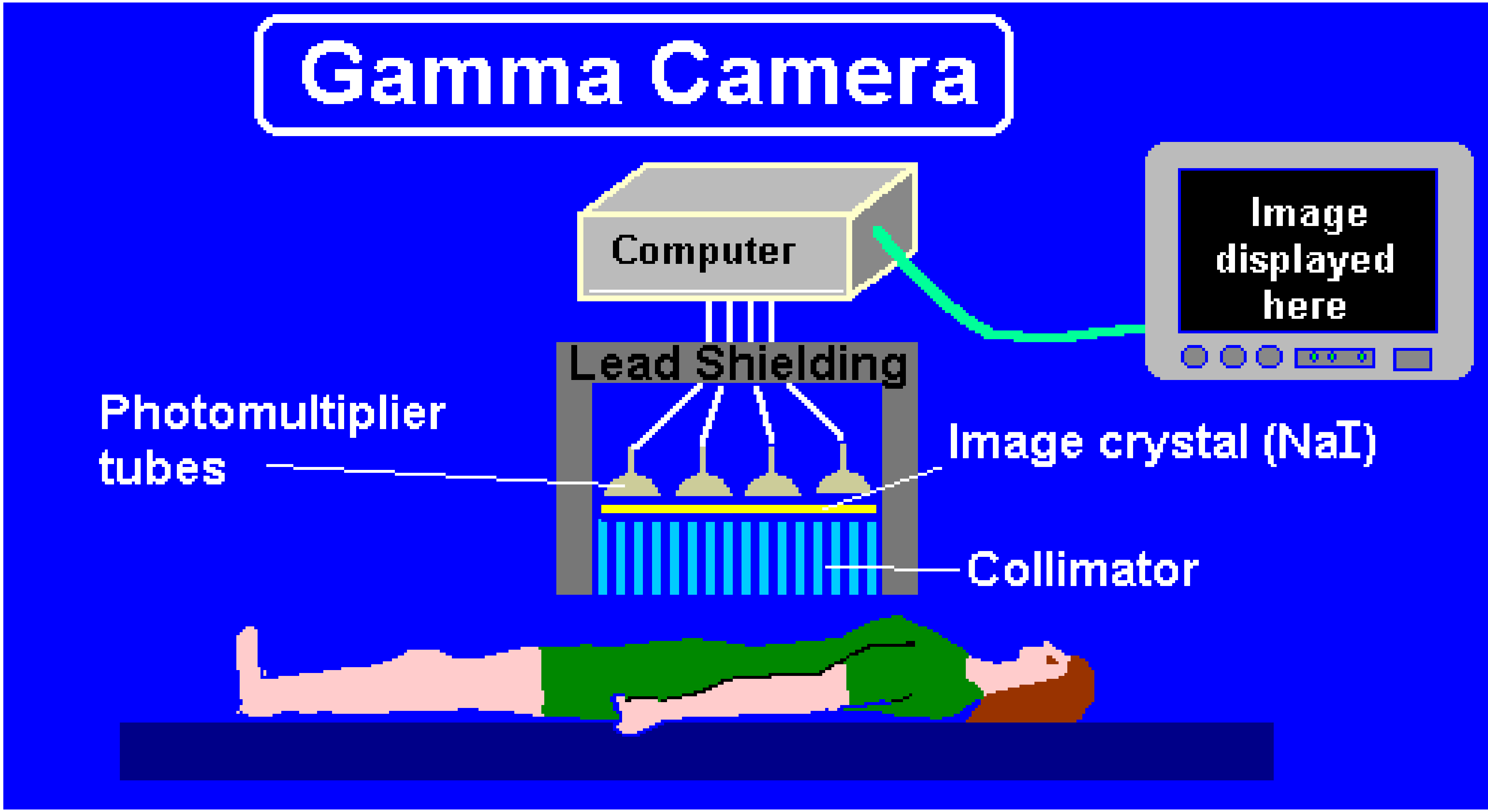




- 2) Amplifier





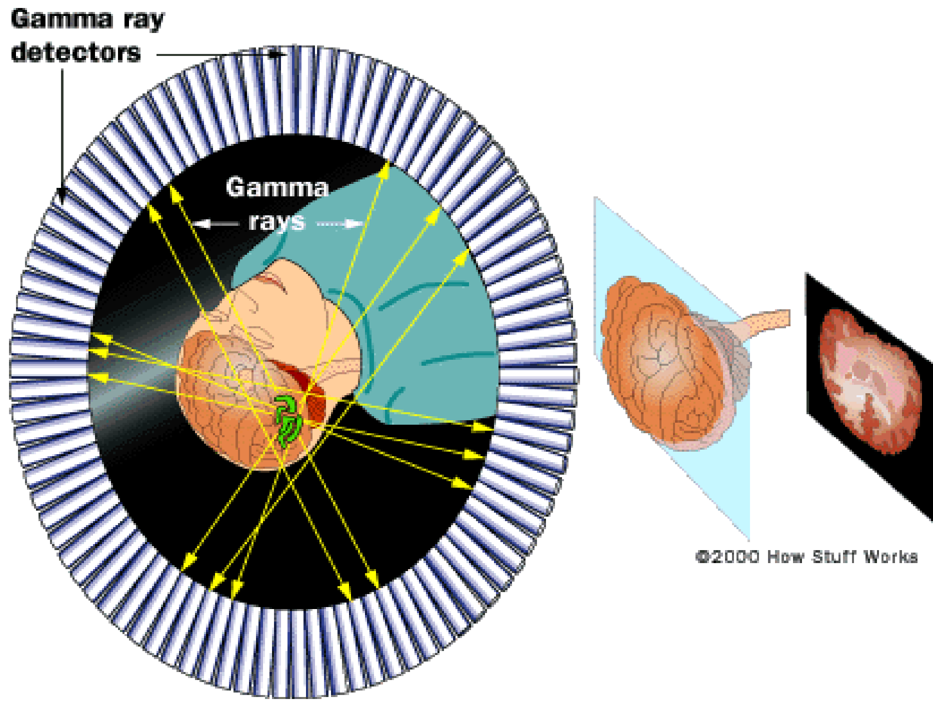


LOJ (2001)

Nuclear Energy (Inside the radioactive nucleus) → **Gamma Electromagnetic Energy** (The gamma ray has been emitted from the patient) → **Light Electromagnetic Energy** (The image crystal produces flashes of light) → **Electrical Energy** (To display the image)

Slices Imaging in GAMMA Camera

Collectively, the different projections contents represent the basic raw data, which is then mathematically reconstructed to yield the transverse section images



Types of Gamma Camera

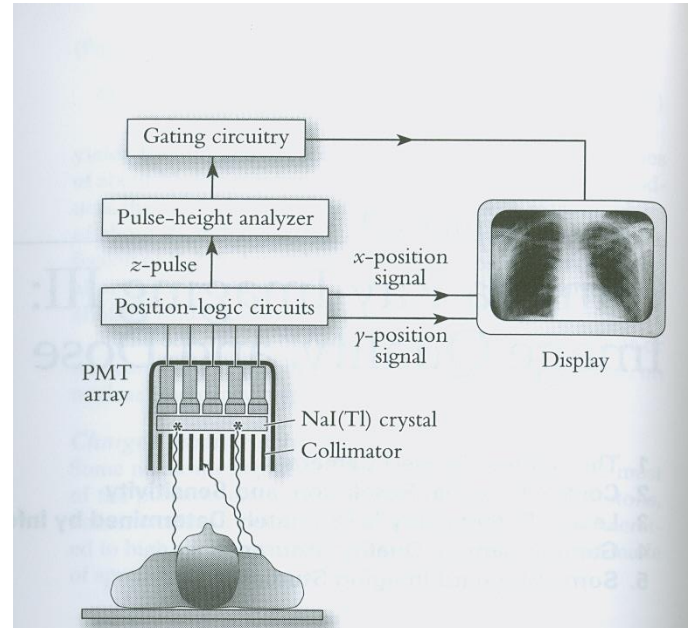
- Dual head scanner

- Single head SPECT

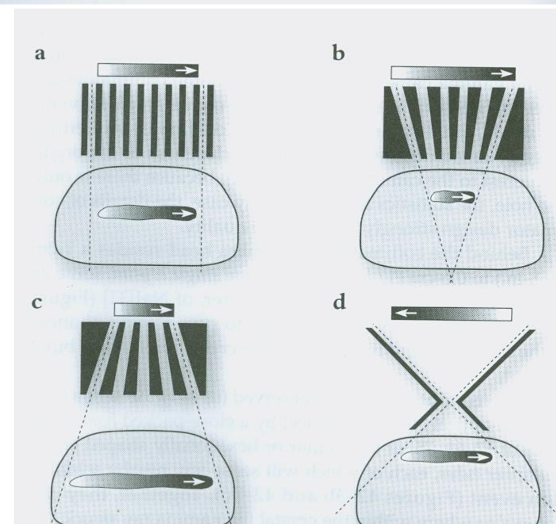
The Gamma Camera

-Collimators

- In an ordinary photographic camera a lens diverts light rays by refraction to form an image on the film or detector.
- For gamma rays, the image is formed by a component called a collimator
- The collimators are usually made out of a thick sheet of a heavy material usually lead, that is perforated like a honeycomb by long thin channels.
- The collimator forms an image by selecting only the rays traveling in (or nearly in) a specific direction, in which the channels are oriented.
- Gamma rays traveling in other directions are either blocked by the channel walls or miss the collimator entirely.



Wolbarst, Physics of Radiology, Ch. 42



Wolbarst, Physics of Radiology, Ch. 42

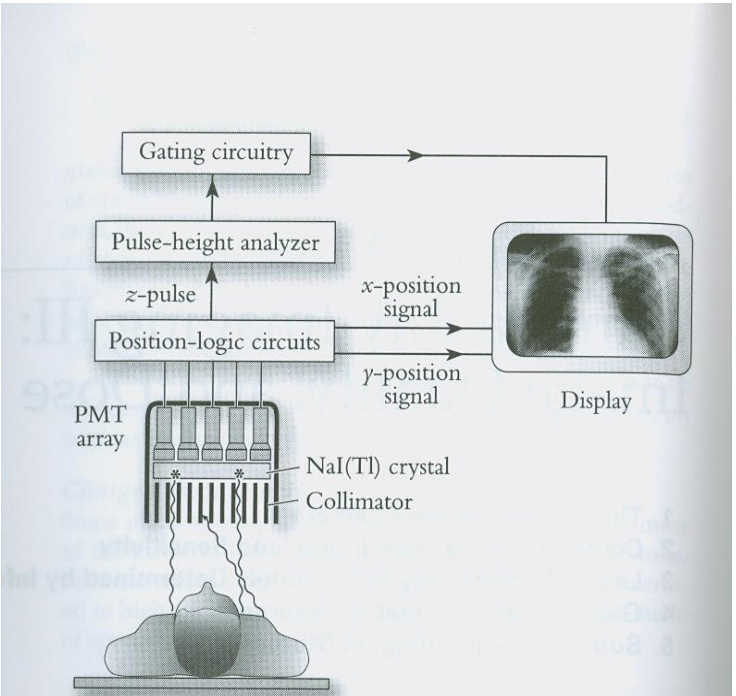
The Gamma Camera - Collimators

Collimators can be classified with respect to their photon energy and resolution/sensitivity.

1. Low-energy, or "technetium," collimators, are "all purpose" collimators (LEAP) or "low energy high resolution" (LEHR), image gamma rays less than 200 keV in energy.
$^{99*}Tc$, ^{201}Tl , ^{123}I and ^{57}Co

2. Medium-energy, or "gallium," collimators for gamma rays 200–300 keV in energy.
^{67}Ga and ^{111}In

3. High-energy, or "iodine," collimators for gamma rays greater than 300 keV in energy. ^{131}I



Wolbarst, Physics of Radiology, Ch. 42

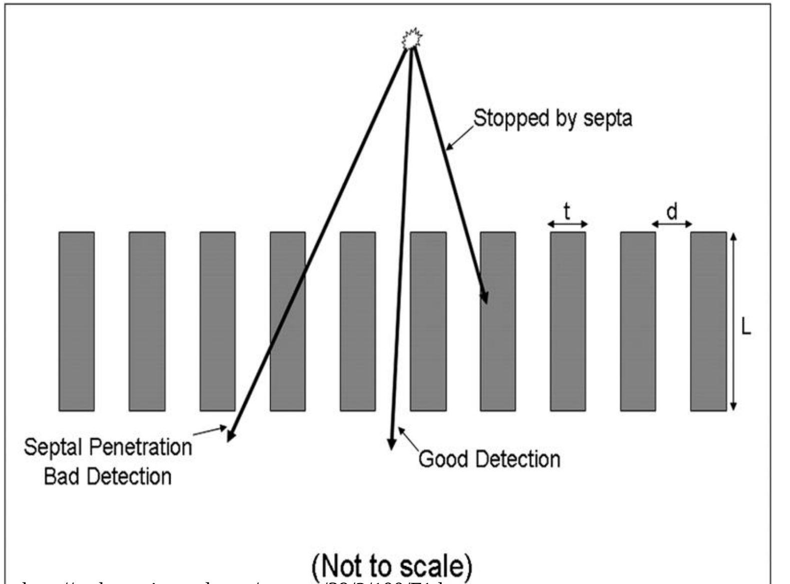
The Gamma Camera –Parallel Collimators

•The collimator preferentially selects the direction of the incoming radiation.

• Gamma rays traveling at an oblique angle to the axes of the holes will strike the lead walls (septa) and not reach the crystal to be detected.

• This allows only radiation traveling perpendicular to the crystal surface to pass and contribute to the resulting image.

• A certain fraction (about 5%) of photons striking the septa will pass through them and reach the crystal; this phenomenon, which degrades image quality, is known as *septal penetration*.



http://tech.snmjournals.org/content/39/2/100/F1.large.jpg

***The Gamma Camera** -Detectors*

- The detectors are generally made of a reflective material so that light emitted toward the sides and front of the crystal are reflected back toward a photomultiplier tube and get counted.

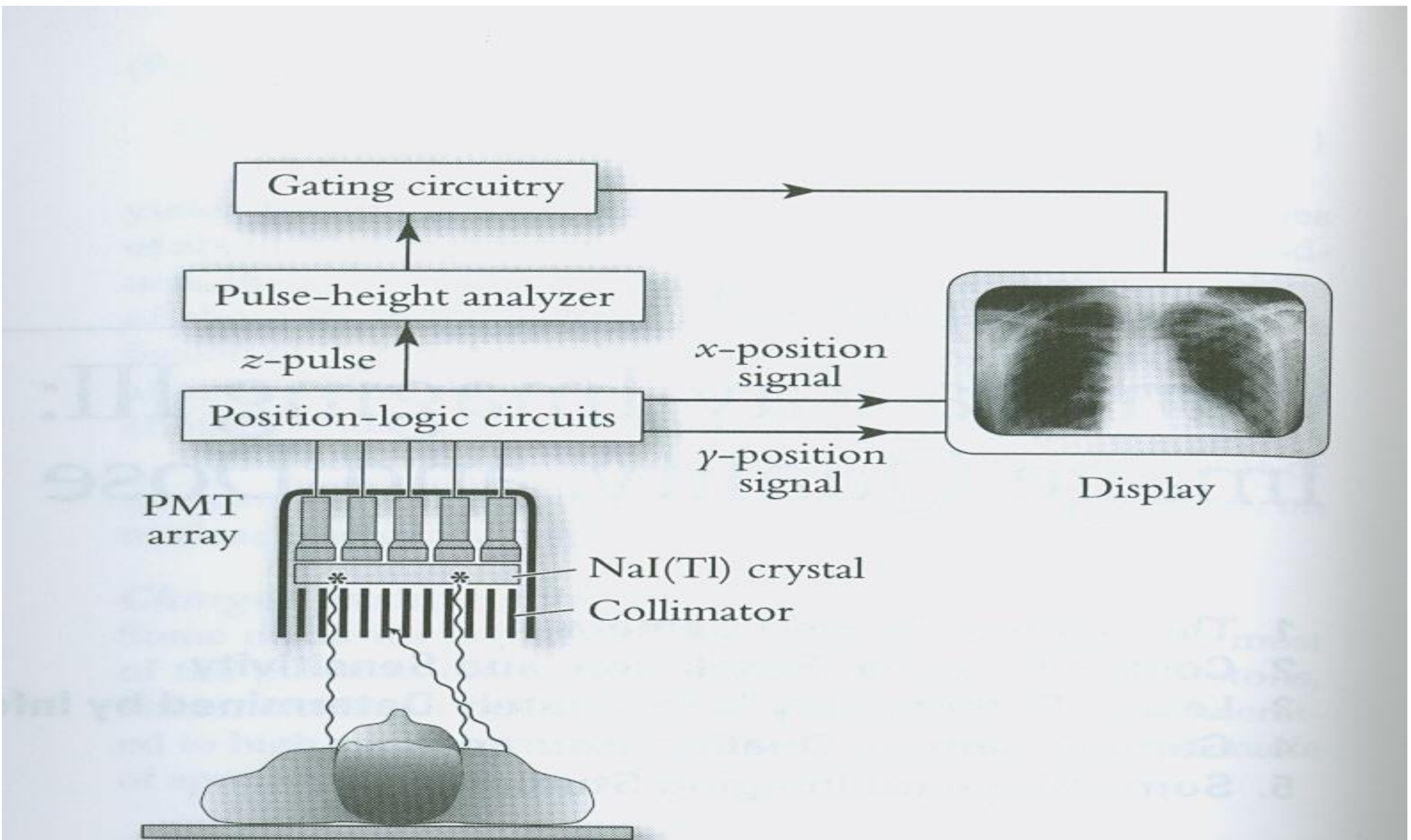
- This maximizes the amount of light collected and therefore the overall sensitivity of the detector.

- This also ensures that the amount of light detected is proportional to the energy of the absorbed gamma ray photon.

Fiber optic light pipe:

• Interposed between the back of the crystal and the entrance window of the PMT (thin layer of transparent optical gel).

• It optically couples the crystal to the PMT and thus maximizes the transmission (>90%) of the light signal from the crystal into the PMT.

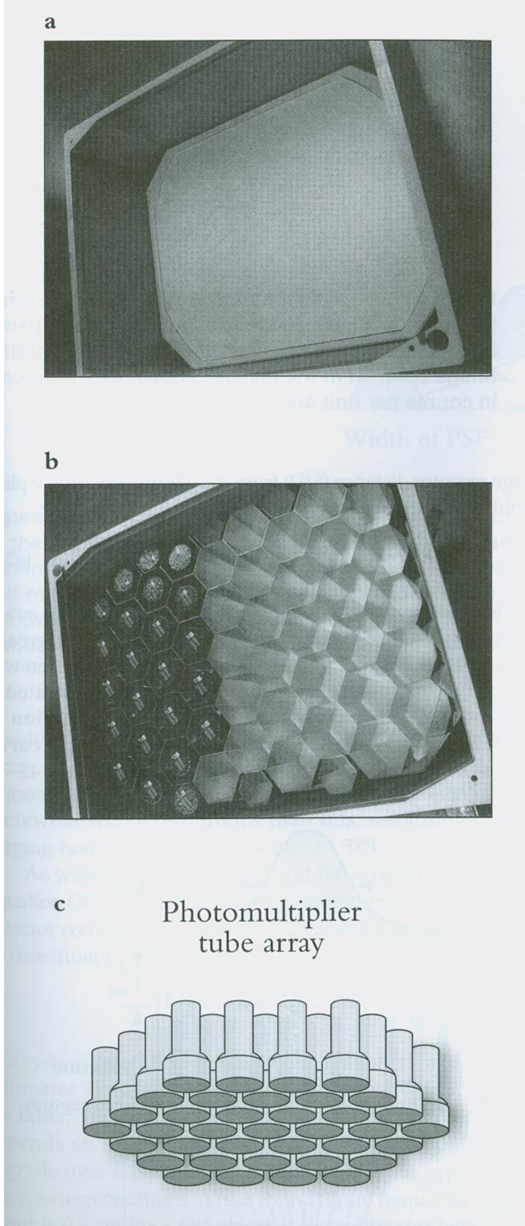


Wolbarst, Physics of Radiology, Ch. 42

The Gamma Camera-Detectors

Crystals vary in thickness from 1/4" - 1"

- ¼" provides best resolution but lowest sensitivity.
- 1" provides the highest sensitivity but coarsest resolution mostly used for imaging the photons of ^{18}F.
- 3/8"provides the optimum balance between sensitivity and resolution and is the most widely used for general gamma camera imaging. ~95% of the photons from ^{99}Tc are absorbed in a 3/8" crystal.
- The light signal is spread out among the PMTs in a two-dimensional array on the back of the crystal.
- These photons are detected by (PMTs). PMT produces a cascade of electrons, which yields a measurable electrical current.

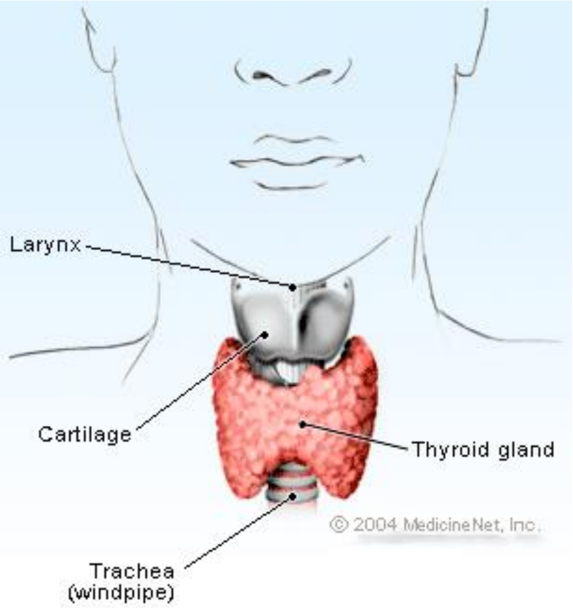


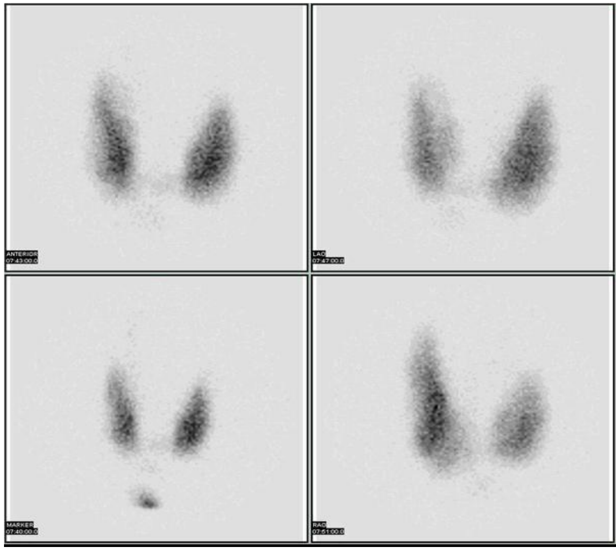
The Gamma Camera -Thyroid Imaging

• The thyroid is a gland that makes and stores essential hormones that help regulate the heart rate, blood pressure, body temperature, and the rate of chemical reactions (metabolism) in the body.

• It is located in the anterior neck. The thyroid gland is the main part of the body that takes up iodine.

•In a thyroid scan, iodine is labeled with a radioactive tracer, and a special camera is used to measure how much tracer is absorbed from the bloodstream by the thyroid gland. If a patient is allergic to iodine, technetium can be used as an alternative.





The Gamma Camera -Osteosarcoma

• Osteosarcoma is the most common cancerous bone tumor in kids. The average age at diagnosis is 15 and both sexes are just as likely to get this tumor until the late teen years, when it is more often seen in boys.

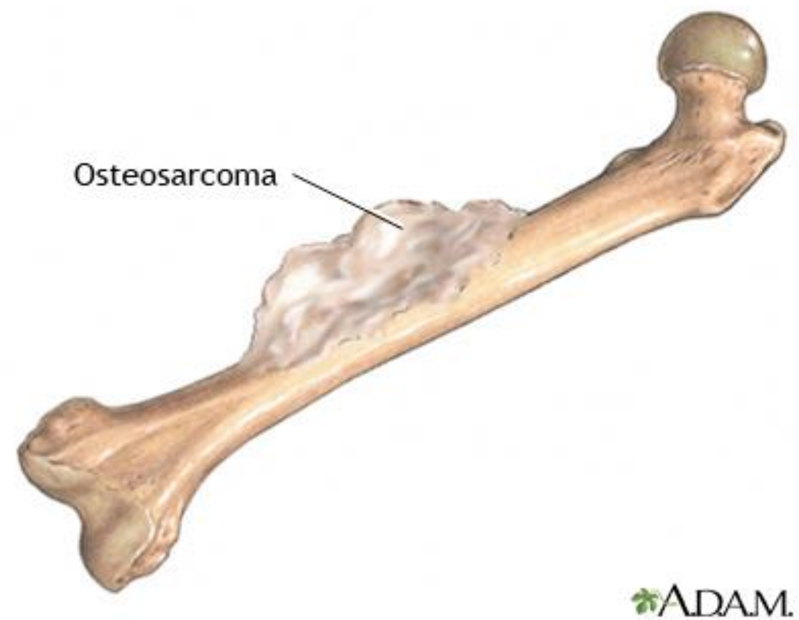
• Osteosarcoma is also more commonly seen in people over age 60.

• Osteosarcoma tends to occur in the bones of the:

Shin (near the knee)

Thigh (near the knee)

Upper arm (near the shoulder)



• This cancer occurs most commonly in larger bones and in the area of bone with the fastest growth rate and Osteosarcoma can occur in any bone.

The Gamma Camera-Osteosarcoma

How is an Osteosarcoma detected:

1. X-ray – used to confirm the presence of a tumor in the bone

2. Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) scans are used to determine the extent of the tumor

3. Radionuclide Bone scan – uses primarily a Gamma Camera to confirm primary sites and identify any additional sites of bone involvement

4. Positron Emission Tomography (PET), gamma camera, or a Single Photon Emission CT (SPECT) scan -- to find small tumors or check if treatment is working effectively

5. Biopsy -- to remove tissue from the tumor for microscopic examination by an expert pathologist

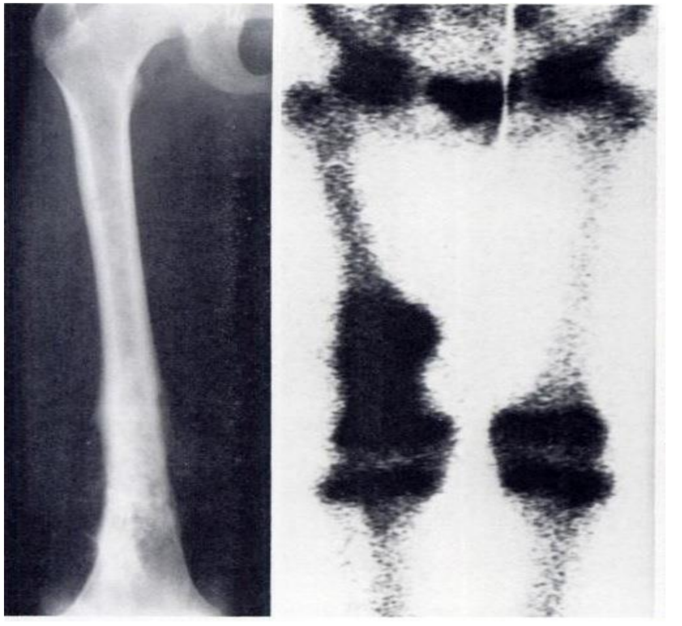


Image of the right femur using an x-ray and part of a whole body gamma camera imaging of a pyrophospate radiolabeled using ^{99m}Tc.

The left is an image of a suspected osteosarcoma

The right is a the gamma camera image showing uptake in both knees as well as the lower part of the femur.

The Gamma Camera

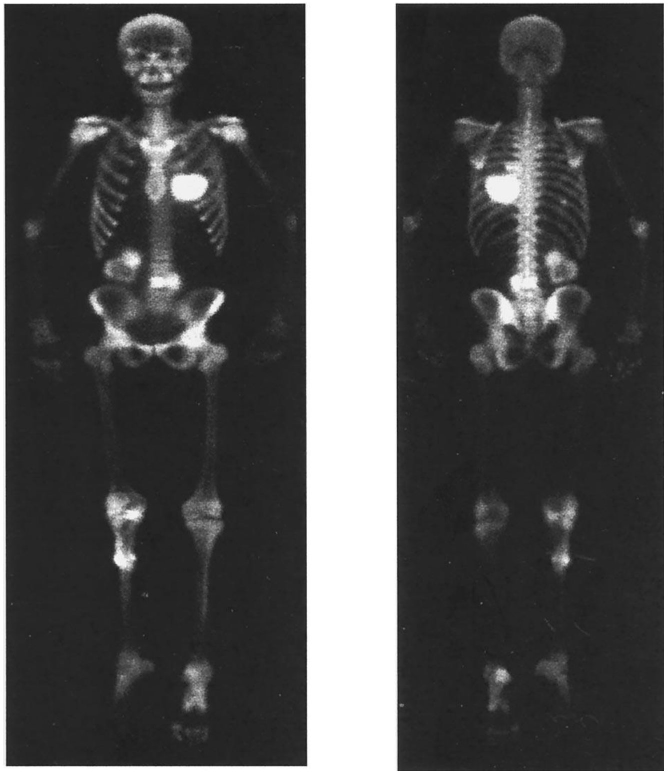
-Osteosarcoma

• The bone scan is a well established procedure in Nuclear Medicine.

• Areas of bone injury or bone destruction are usually associated with ongoing bone repair and consequent increased metabolic activity and calcium turnover.

• The radionuclides which mimic the metabolic behavior of calcium will localize in this region of bone repair in increased concentration relative to normal bone. In the past ^{85}Sr and ^{18}F were the primary radionuclides used.

• However, various phosphate compounds labeled with ^{99m}Tc are mostly the radionuclides of choice



http://jco.ascopubs.org/content/20/1/189.full.pdf+html

• Technetium is metastable and decays by emitting a 140 keV gamma ray with a physical half-life of 6 hours and a biologic half life of 1 day.

$$^{99m}\text{Tc} \rightarrow {}^{99}\text{Tc} + \gamma$$

Osteosarcoma

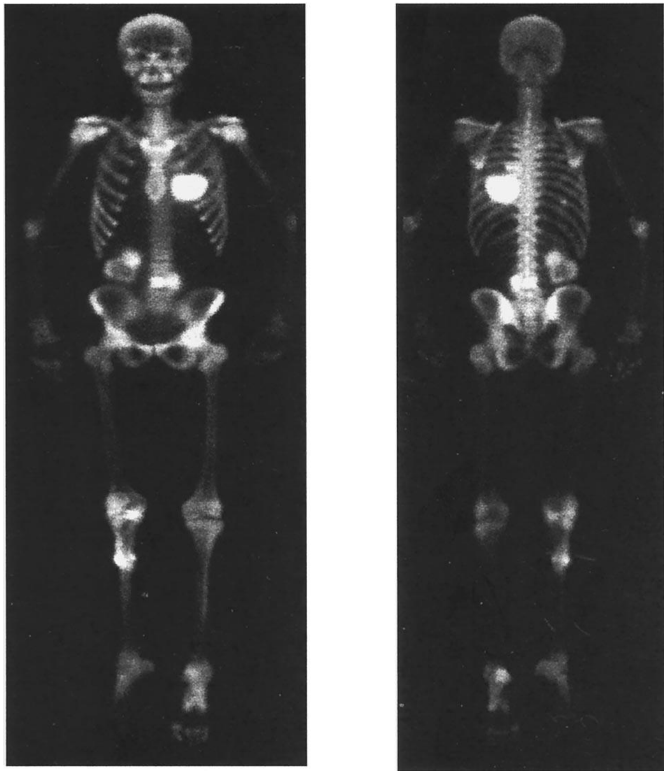
•However not all bone scans are done with ^{99m}Tc.

• Here is a gamma camera image of a bone scan that was done with ^{153}Sm (Samarium.)

• Samarium is a bone-seeking radiopharmaceutical that provides both diagnostic (gamma ray emitter) and therapeutic (beta emitter) irradiation to osteoblastic bone metastases.

• The injected radionuclide is ^{153}Sm-EDTMP (^{153}Sm ethylene diamine tetramethylene phosphonate), has a high bone uptake due to the phosphorus concentration in the bones.

Note the more avid radioisotope uptake of the left chest mass adherent to the pericardium compared with the spine and right renal metastases.



•Variable uptake of ^{153}Sm-EDTMP in metastatic osteosarcoma

• Anterior and posterior gamma camera imaging 24 hours after administration of 3 mCi/kg.