Ionization Radiation Metrology: Health Sector Applications

المترولوجيا الاشعاعية وتطبيقاتها في القطاع الصحي

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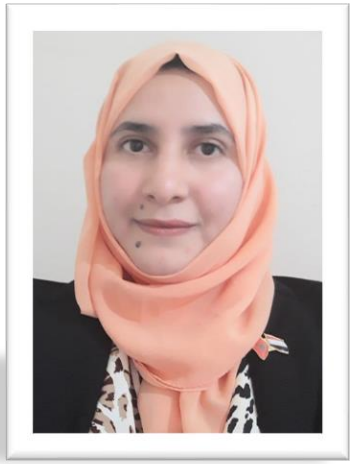
20 May 2021



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- ✓ Researcher, Trainer and Assessor , ISO 9001, ISO/IEC 17025, ISO 15189, occupational radiation safety
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- ✓ Auditor of ISO 9001, ISO/IEC 17025, according to ISO 19011.
- ✓ Teacher Assistants Sana'a University- Physics Dep- Faculty of science – YEMEN
- ✓ General Coordinator, YEMENI FORUM for Scientific Research and Sustainable Development
- ✓ Leader, Yemeni Young Professional Physicists Network YYPP
- ✓ Presidents of WOMEN in NUCLEAR - YEMEN Chapter
- ✓ Representative of N | woman & Youth Empowerment
- ✓ Secretary of National committee Metrology & Medical Devices and Supplies TC32.
- ✓ Member of GSO, ISO committees TC4 , TC11, ISO/TC 48, 12,213,19 & ISO/TC 85
- ✓ OIML Advisory group on matters of countries and economies with emerging metrology systems.
- ✓ OIML Main Contact of International Organization of Legal Metrology
- ✓ Ionization Radiation Metrology SSDL & PSDL Labs, Radioactivity environment measurements
- ✓ Diagnostic Reference Level DRL implementation , Nuclear Medicine Design and Shielding
- ✓ Quality infrastructure of quality and Metrology
- ✓ EGSnrc, PHITS & GAMOS/GEANT4 Monte Carlo codes
- ✓ Participation in a lot of international conferences
- ✓ Have many participation activates and paper

Happy World Metrology Day 2021

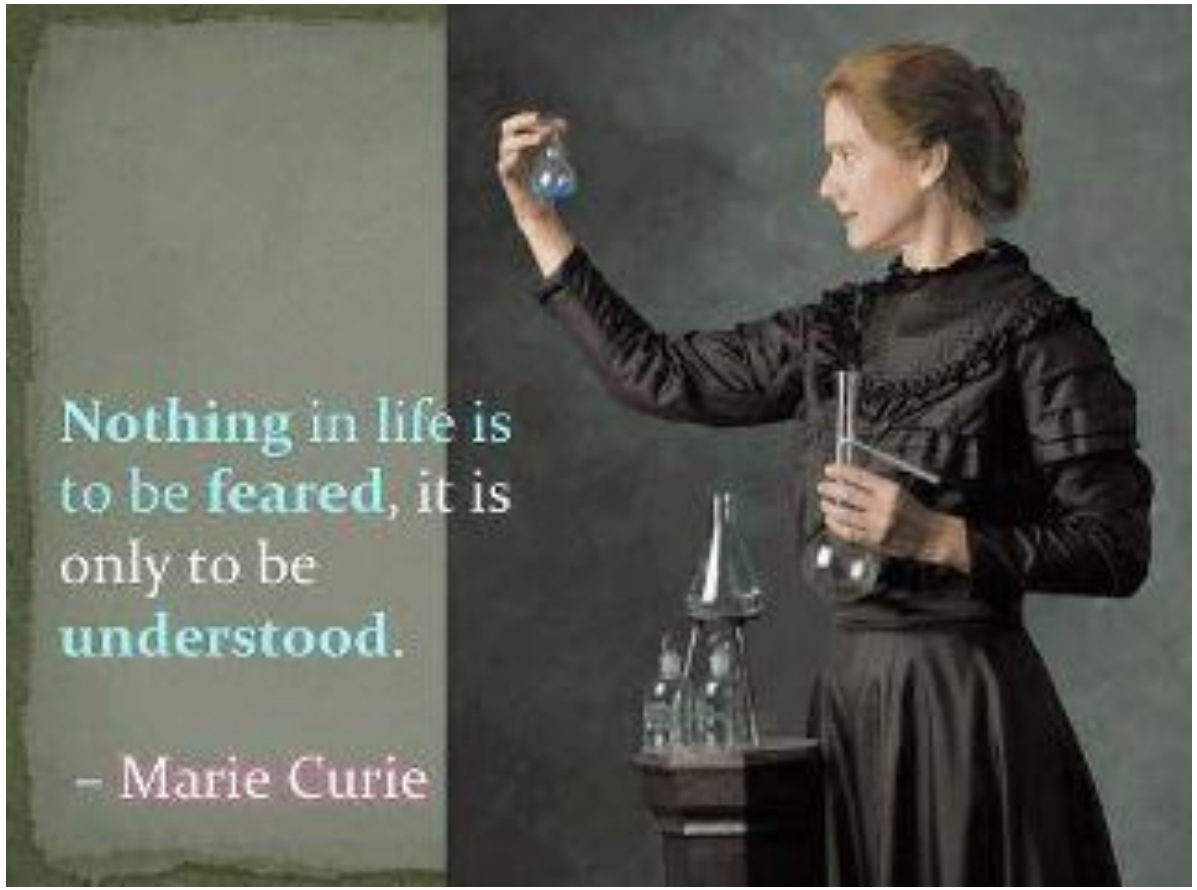
Radiation !

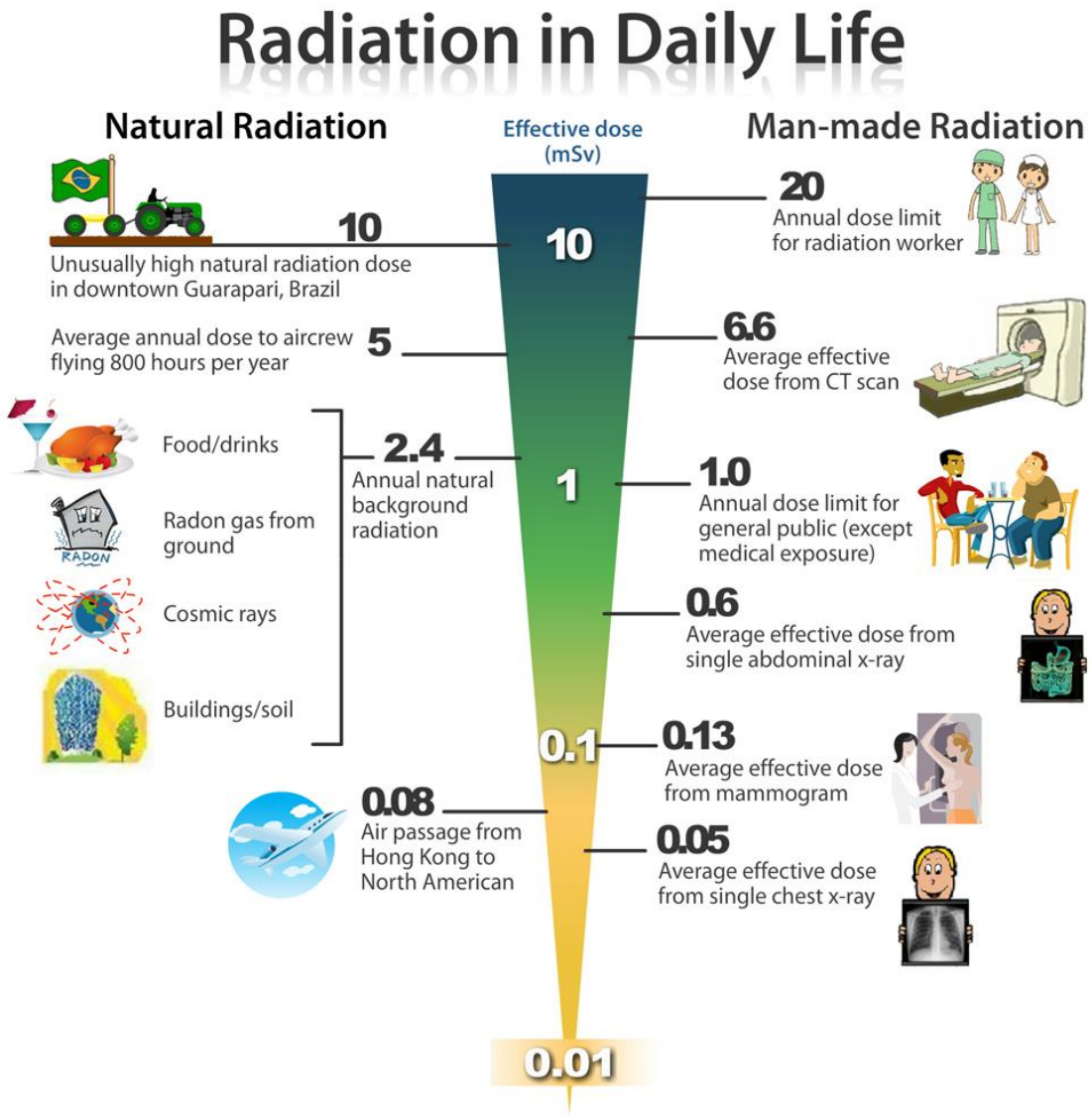
Nuclear!

Scare?!

Woman in Nuclear

Marie Curie was the first woman to win a Nobel Prize, in Physics, and with her later win, in Chemistry, she became the first person to claim Nobel honors twice. Her efforts with her husband Pierre led to the discovery of **polonium** and **radium**, and she championed the **development of X-rays**.





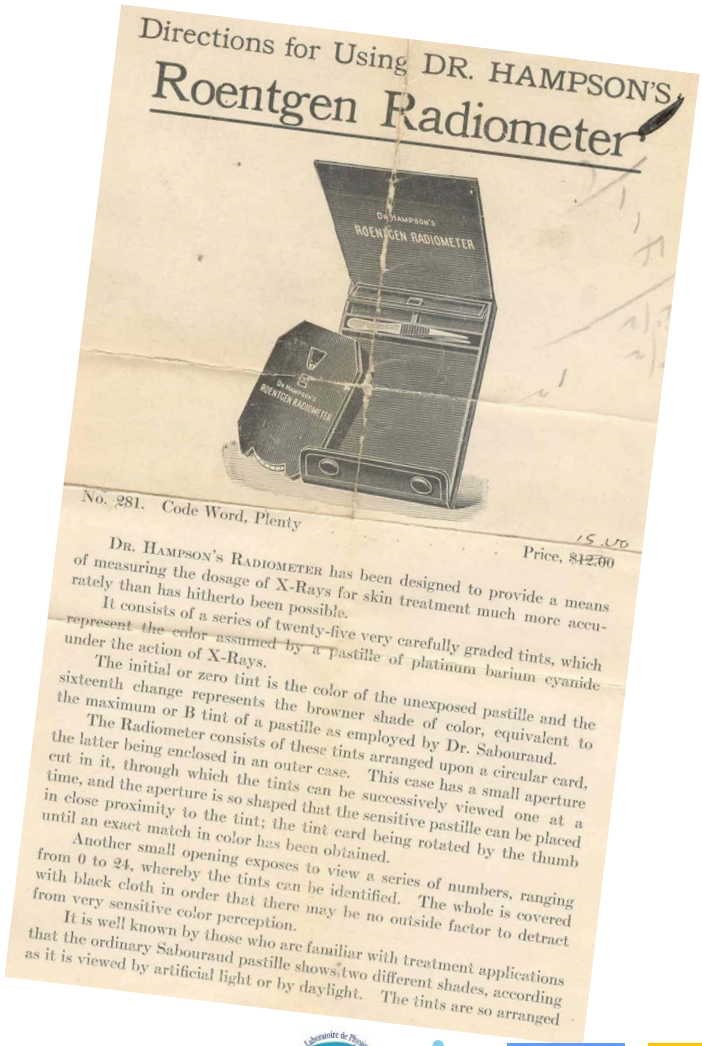
This diagram illustrates the examples of radiation in daily life, including **natural background radiation** as well as **artificial exposures of medical radiation** like X-ray and CT scan.
The annual natural background radiation, from cosmic rays and radon gas from ground, etc., has an effective dose of about **2.4 millisievert.**
As for man-made radiation, the average effective doses from single **abdominal x-ray and CT scan are 0.6 and 6.6 millisievert** respectively, while the annual dose limit for radiation workers is **20 millisievert**.

https://www.dbcp.gov.hk/eng/safety/knowledge.html

https://www.dbcp.gov.hk/eng/safety/knowledge_clip_image004.jpg

Dr. Hampson's Roentgen Radiometer (ca. 1910 – 1920)

1895 x-ray


Directions for Using DR. HAMPSON'S
Roentgen Radiometer

No. 281. Code Word, Plenty

Price, ~~$12.00~~ 15/-/-

DR. HAMPSON'S RADIOMETER has been designed to provide a means of measuring the dosage of X-Rays for skin treatment much more accurately than has hitherto been possible.

It consists of a series of twenty-five very carefully graded tints, which represent the color assumed by a pastille of platinum barium cyanide under the action of X-Rays.

The initial or zero tint is the color of the unexposed pastille and the sixteenth change represents the browner shade of color, equivalent to the maximum or B tint of a pastille as employed by Dr. Sabouraud.

The Radiometer consists of these tints arranged upon a circular card, the latter being enclosed in an outer case. This case has a small aperture cut in it, through which the tints can be successively viewed one at a time, and the aperture is so shaped that the sensitive pastille can be placed in close proximity to the tint; the tint card being rotated by the thumb until an exact match in color has been obtained.

Another small opening exposes to view a series of numbers, ranging from 0 to 24, whereby the tints can be identified. The whole is covered with black cloth in order that there may be no outside factor to detract from very sensitive color perception.

It is well known by those who are familiar with treatment applications that the ordinary Sabouraud pastille shows two different shades, according as it is viewed by artificial light or by daylight. The tints are so arranged

https://www.orau.org/ptp/collection/radiology/radiometerhampson.htm

Electromagnetic & Particulate Radiations

Radiation is described by its type and energy. The types of radiation fall into two main categories: particulate and electromagnetic.

•**electromagnetic radiation** consists of photons that have energy, but no mass or charge, such as **radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, and gamma radiation (γ).** A photon, as described by quantum theory, is a “particle” or “quantum” that contains a discrete quantity of electromagnetic energy which travels at a speed of light.

•**particulate radiation** consists of particles that have mass and energy, and may or may not have an electric charge, such as **alpha radiation (α), beta radiation (β),proton radiation and neutron radiation**.

Those radiation type above will be discussed in next section in detail. The most common unit of energy used to describe radiation is the **electronvolt(eV)**. **An electronvolt is the amount of kinetic energy an electron gains when accelerated through a potential difference of one volt**.

The conversion to SI units is 1 eV = 1.6e-19 Joules.

http://personal.cityu.edu.hk/liangdai/post/what_is_radiation/

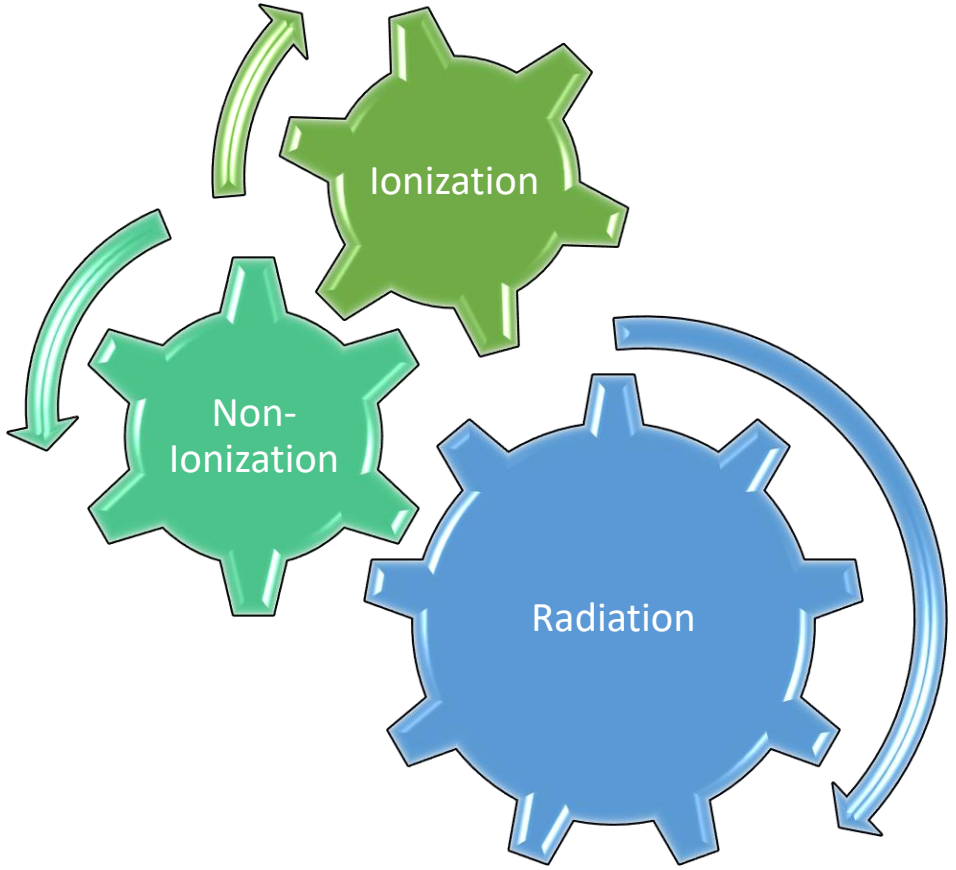
Ionization & Non ionization radiation

- **Ionizing radiation**

Medical diagnosis and treatment, nuclear power, radiography, gauges, safety signs, smoke detectors, sterilization of medical appliances, archaeological dating and baggage inspection

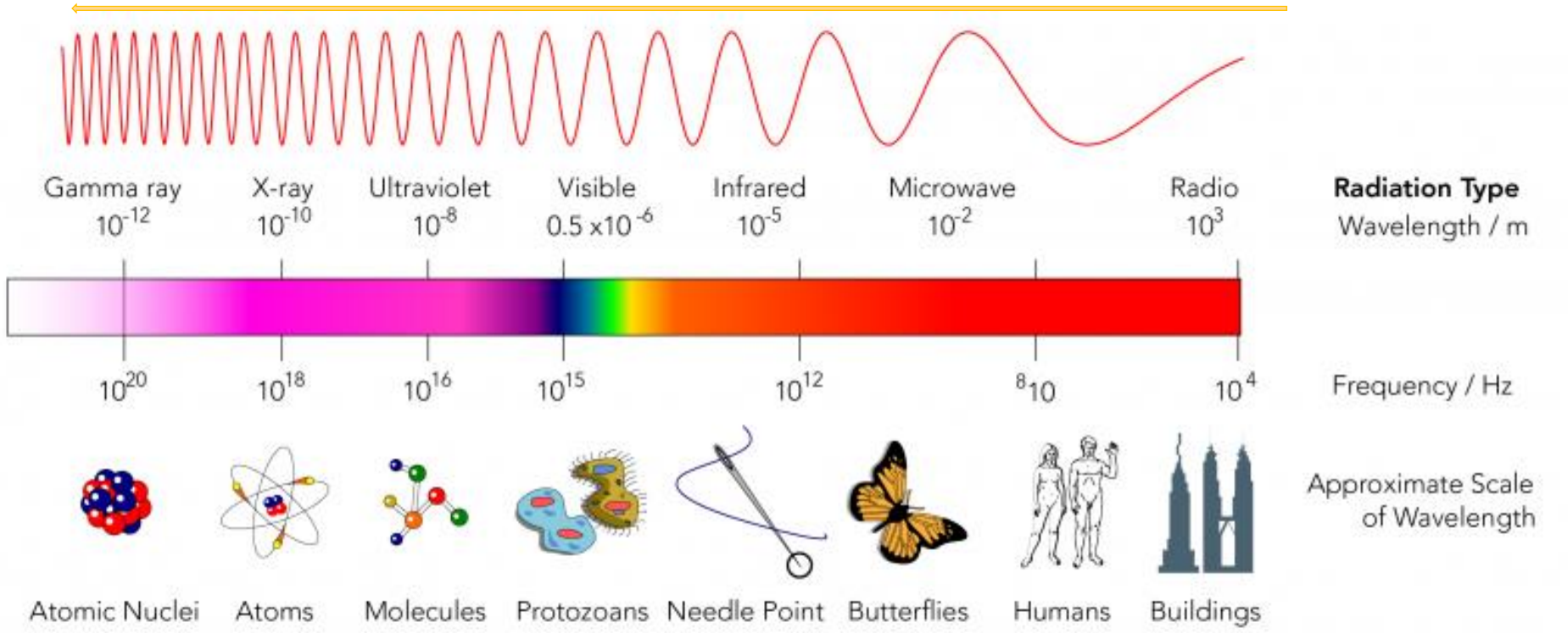
- **Non-ionizing radiation**

Lighting, heating, lasers, sterilization, sunbeds, radar, television, radio and electric power lines. **Low frequency electromagnetic radiations** are also emitted by a wide variety of products at home and in the workplace, from photocopiers to power lines, household appliances, and mobile phones to radios and computers.



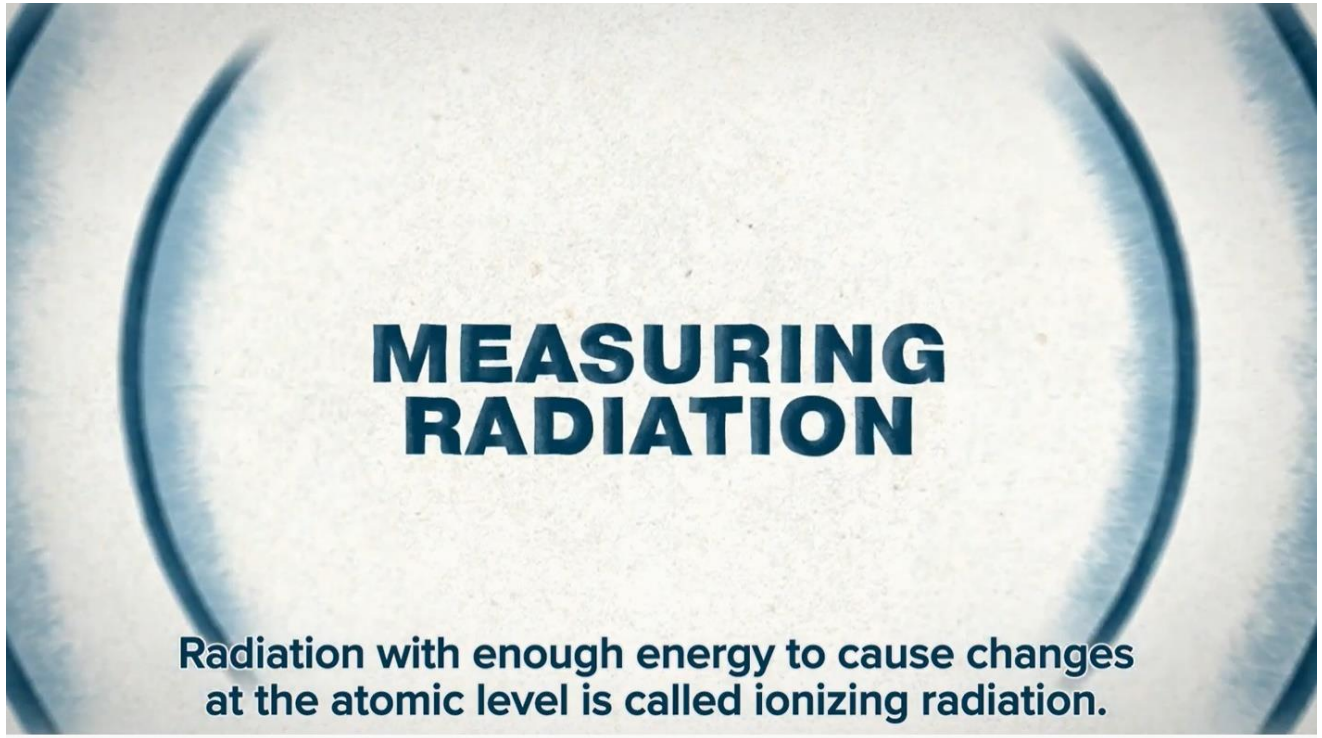
http://www.safety.hku.hk/radioiso/Q&a/Q&Awork.htm

Electromagnetic Spectrum



https://letstalkscience.ca/educational-resources/stem-in-context/what-if-you-could-charge-your-phone-using-radio-waves

What is Radiation?



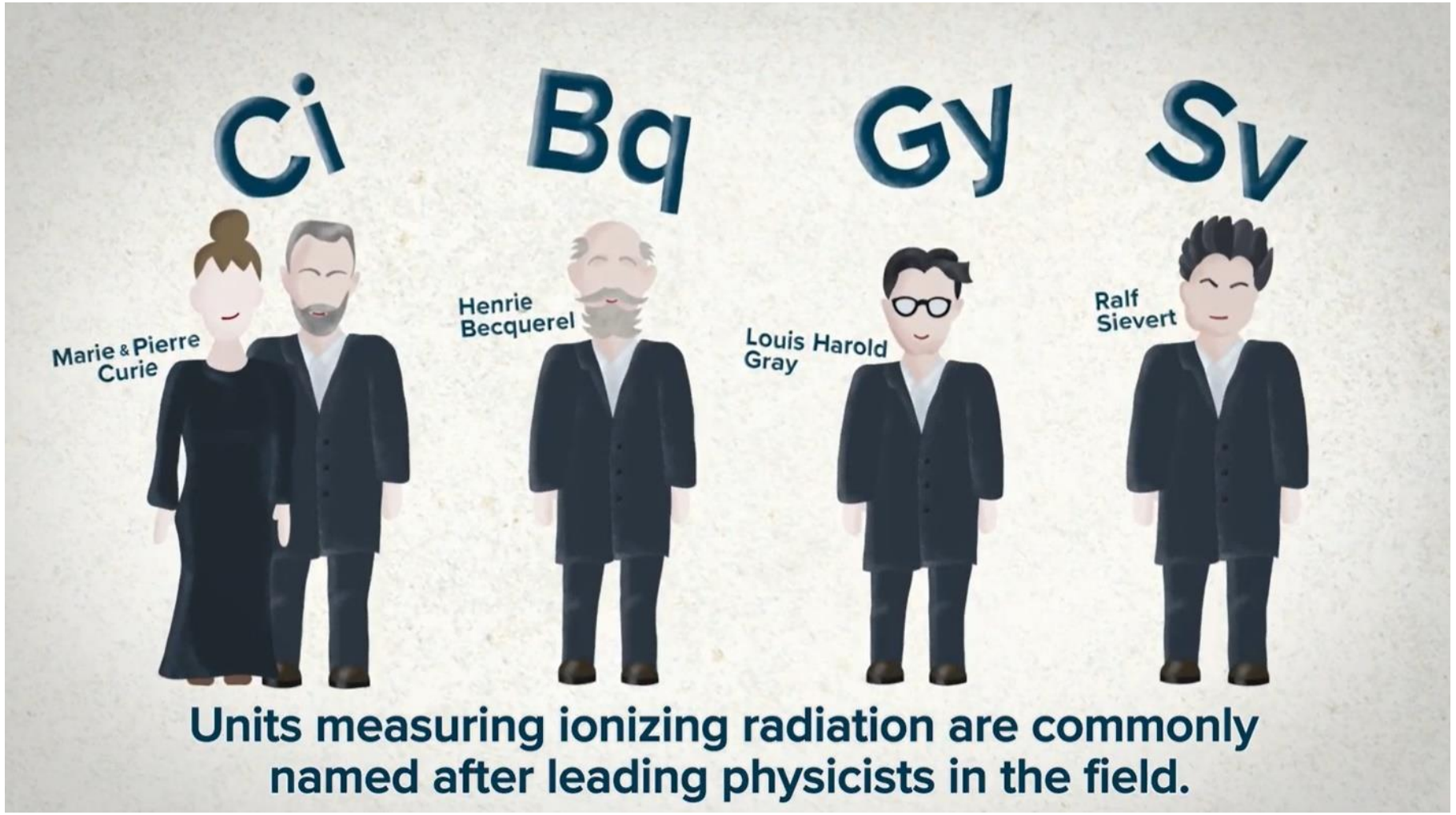
https://www.youtube.com/watch?v=qwGqR-m_0Z8

What is Radiation?

In physics, radiation is defined as **energy that travels through space or matter in the form of a particle or wave.** It can be produced in one of two ways: by **radioactive decay of an unstable atom (radionuclide),** or by **the interaction of a particle with matter.** Some attributes of radioactive decay are spontaneousness and randomness.

The type of radiation emitted depend on the specific radionuclide. Radiation emission as the result of an interaction depends on both the incoming particle and the material it hits, and is theoretically predictable if enough information is known.

Units


Ci
Bq
Gy
Sv
Marie & Pierre Curie
Henrie Becquerel
Louis Harold Gray
Ralf Sievert
Units measuring ionizing radiation are commonly named after leading physicists in the field.

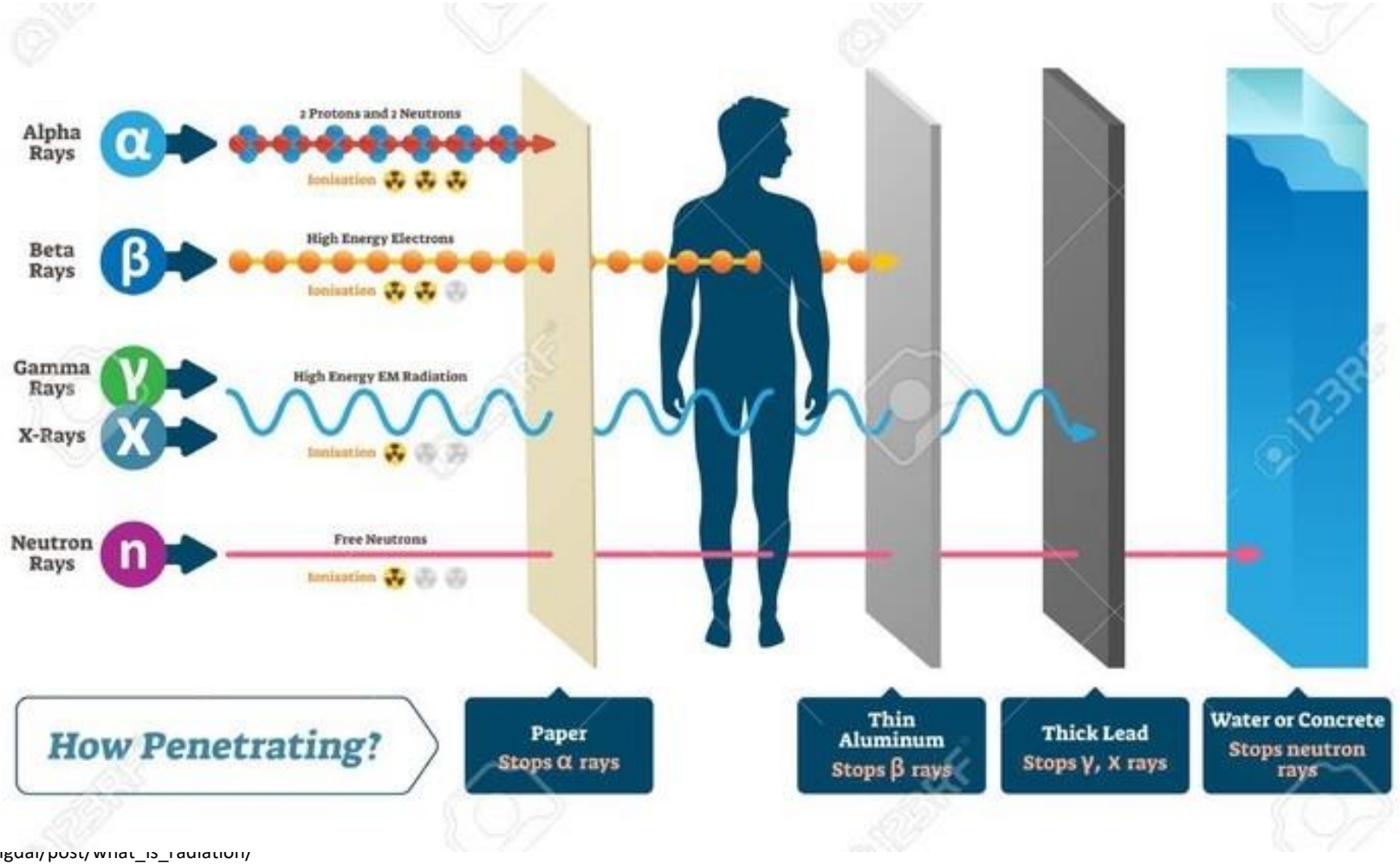
Radiation Unit

(1852-1908)

Becquerel
Derived unit

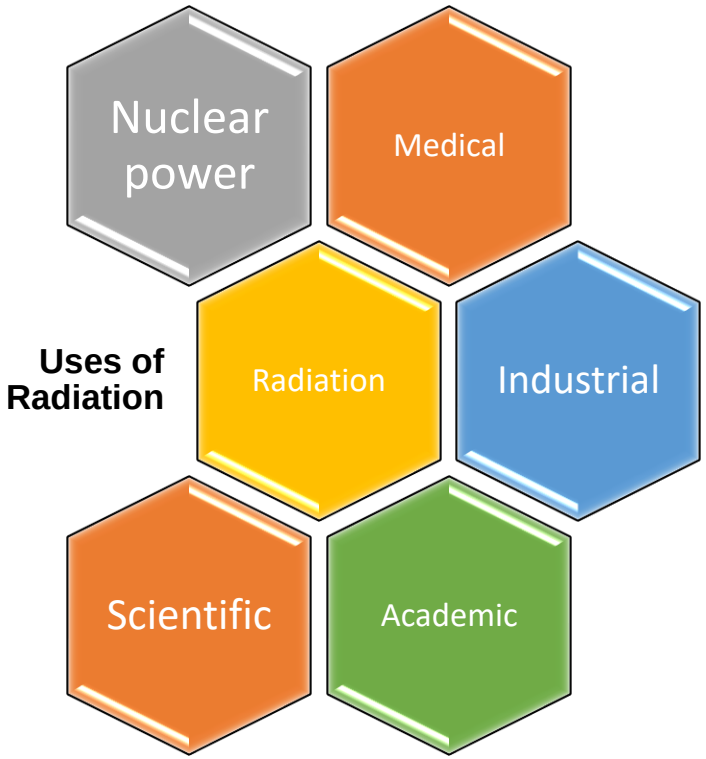
1 Ci = 3.7 × 10 ^{10} Bq

Types of Radiation



http://personal.cityu.edu.hk/liangdai/post/what_is_radiation/

Ionization Radiation application



Uses of Radiation

Although scientists have only known about radiation since the 1890s, they have developed a wide variety of uses for this natural force. Today, to benefit humankind, radiation is used in medicine, academics, and industry, as well as for generating electricity. In addition, radiation has useful applications in such areas as agriculture, archaeology (carbon dating), space exploration, law enforcement, geology (including mining), and many others. For additional information, see the following topics on this page:

- Medical Uses
- Academic and Scientific Applications
- Industrial Uses
- Nuclear Power Plants

https://www.nrc.gov/about-nrc/radiation/around-us/uses-radiation.html

Metrology in Medical

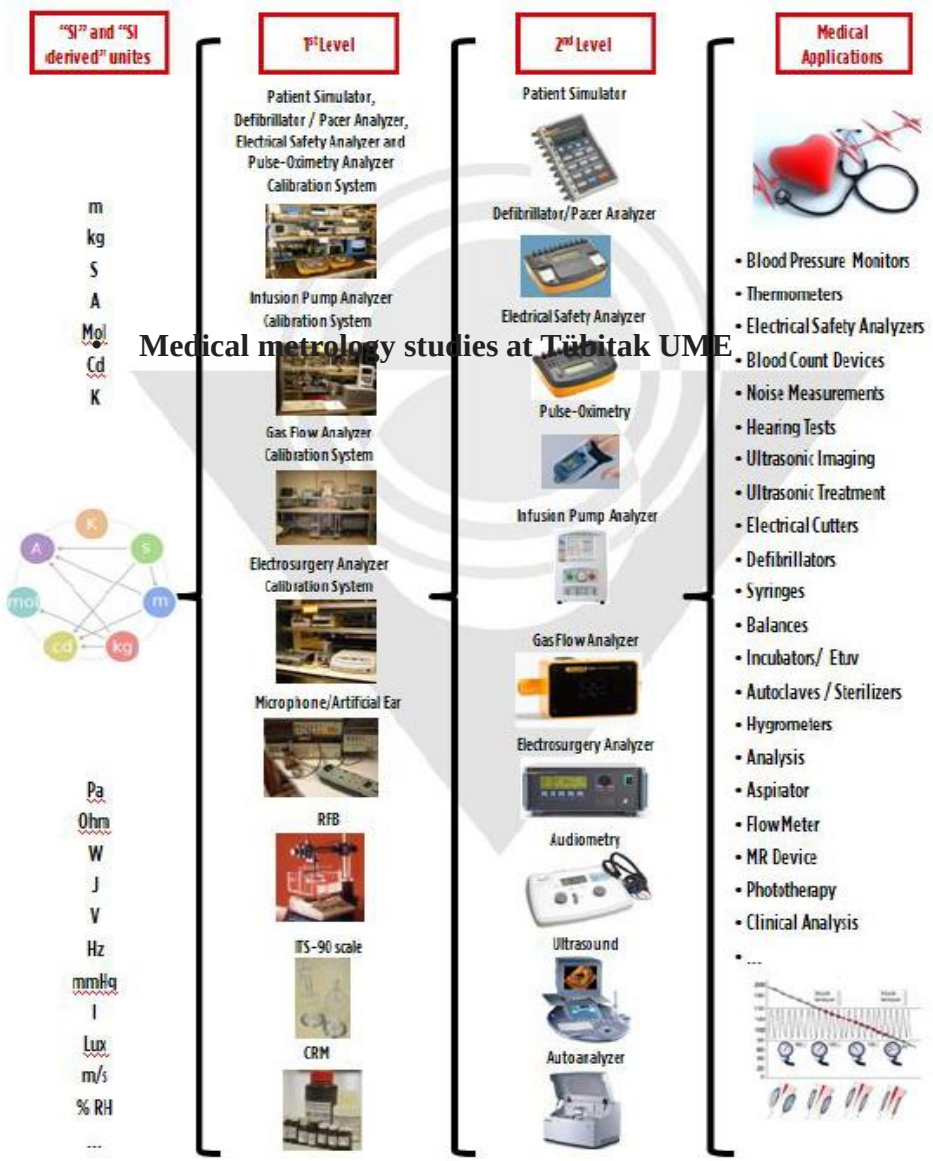
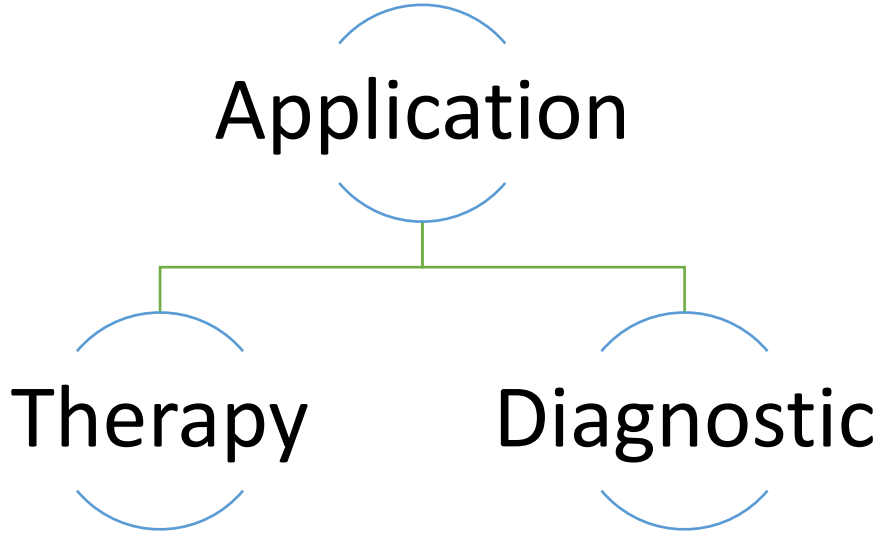
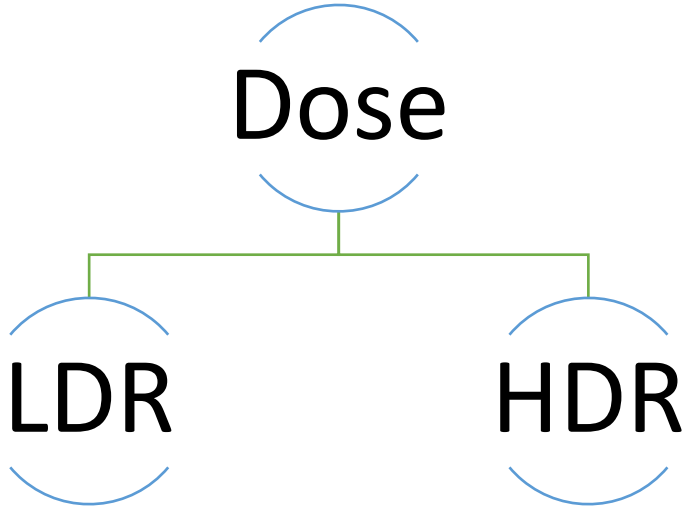


Figure 6. Measurement and calibration

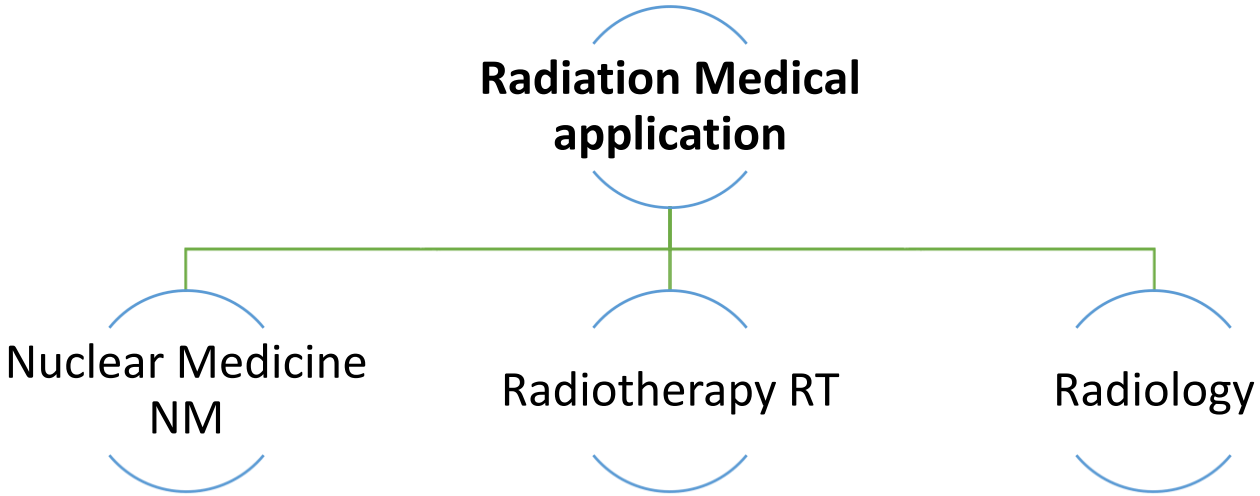
Medical metrology studies at Tübitak UME

Radiation application in Medical Sector

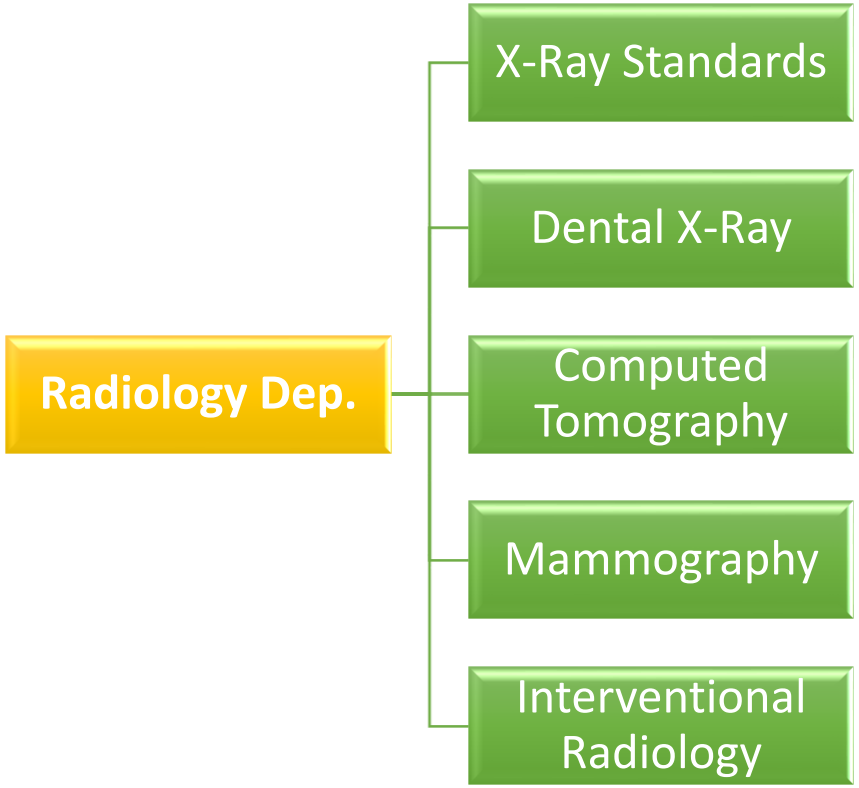




Radiation application in Medical Sector



Radiology – Diagnostic



X-Ray Standards

http://futurexray.com/en/products-services/04-x-ray-protection-room/

Dental X-ray

https://ortorad.pl/en/dental-x-ray/

Dental X-ray

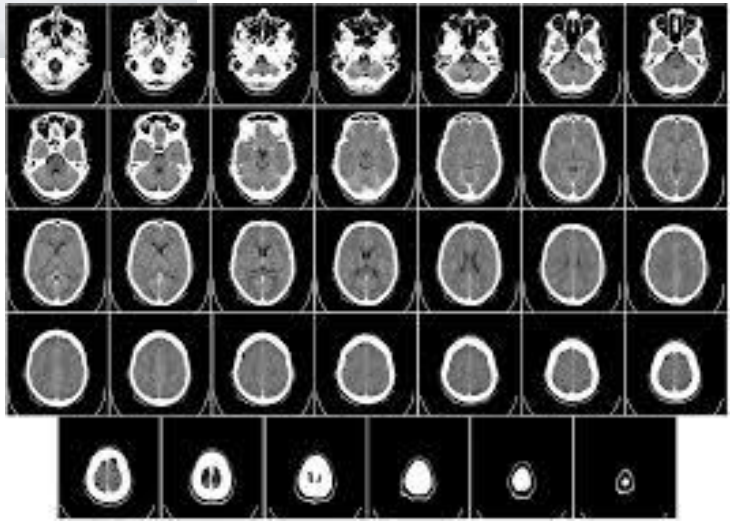
- **X-ray panoramic image (Panoramic / Panorama)**

Used by dentists to define an endodontic, implantological, surgical and orthodontic treatment plan. Often referred to as a “tooth panorama” or as a panoramic image.
Pantomographic dental x-ray enables early detection of pathological changes in the bones of the maxilla and mandible, as well as in the temporomandibular joints and maxillary sinuses.

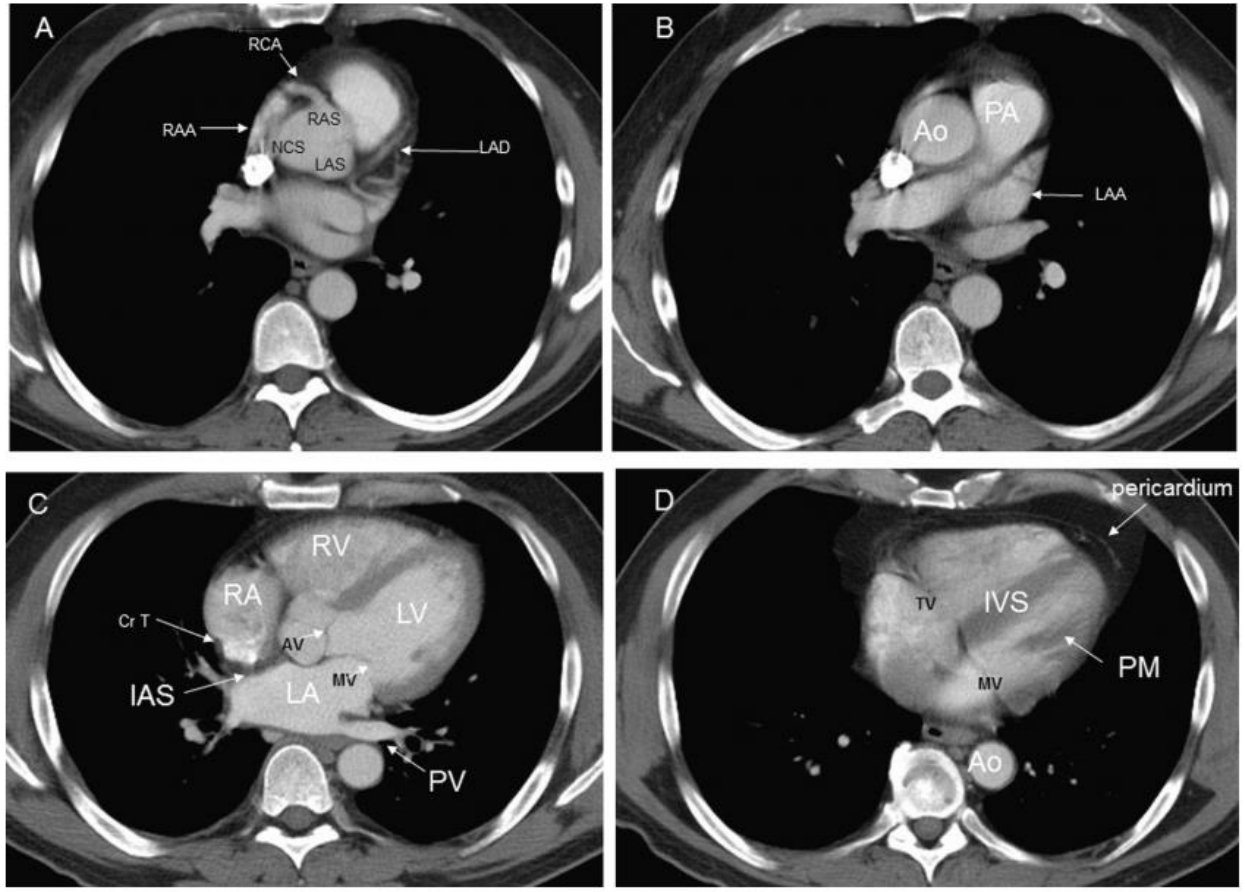
https://ortorad.pl/en/dental-x-ray/

Computed Tomography (CT) scan

- Whether you're visiting the emergency room after a rough spill from your mountain bike or visiting your health clinic for a routine cancer screening, it's likely that the doctor will request internal images to accurately assess your health.
- One of the most common ways to capture internal body images is with a computed tomography (CT) scan.
- CT scans, also called CAT scans, use a rotating X-ray machine to create cross-sectional, or 3D, images of any body part, according to the National Institute of Biomedical Imaging and Bioengineering (NIBIB). They provide a painless, noninvasive and fast way for doctors to examine bones, organs and other internal tissues.



Computed Tomography (CT) scan Cardiac



Interventional Radiology

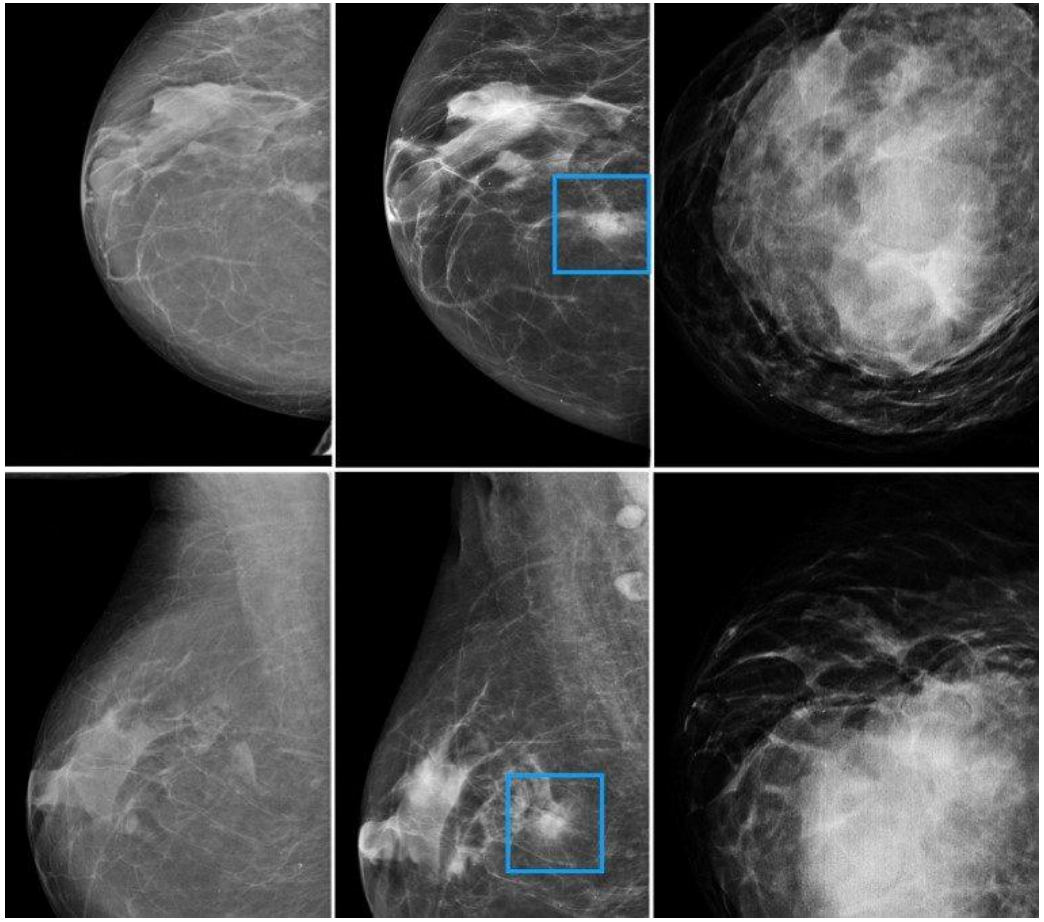
1- مضخم الصورة 2- الذراع القوسية 3- أنبوب الأشعة
4- وحدة تخزين الصورة ومعالجتها

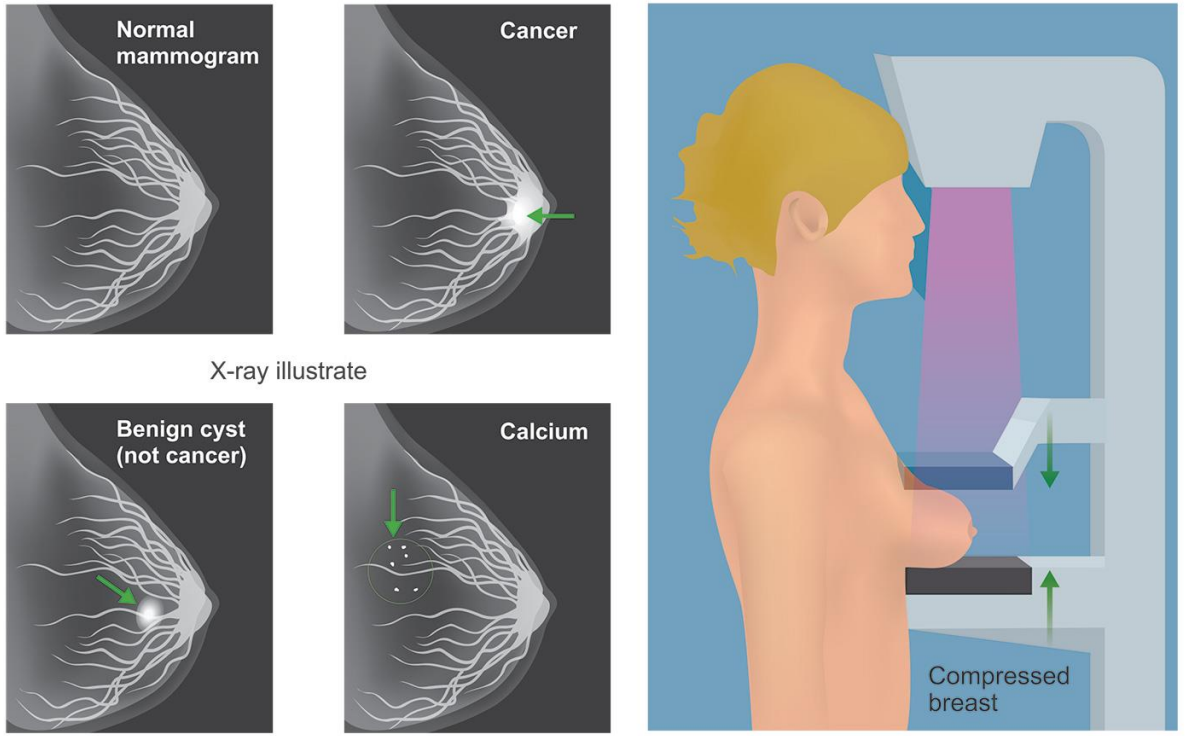
الشكل (1): جهاز التنظير والتصوير بالأشعة السينية المتحرك

1- الحامل السقفي 2- طاولة المريض 3- شاشات المراقبة
4-الذراع المتمفصلة 5- القوس الحاملة 6- أنبوب الأشعة
7- كاشف الأشعة الرقمي

الشكل (2): جهاز التنظير والتصوير بالأشعة السينية الثابت ذو الذراع المقوسة، مع طاولة العمليات

Mammography

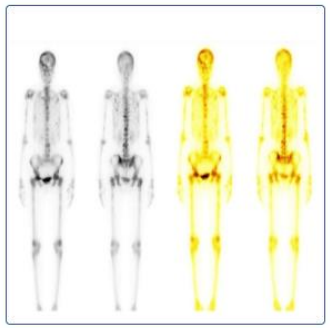


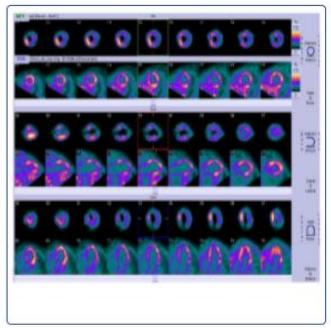


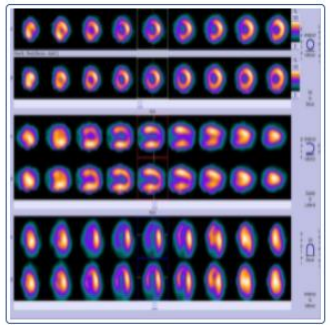
- In mammography, each breast is compressed horizontally.
- During a screening mammogram, the breast is placed between two plastic plates.
- The plates then are briefly compressed to flatten the breast tissue.
- Two views usually are taken of each breast.

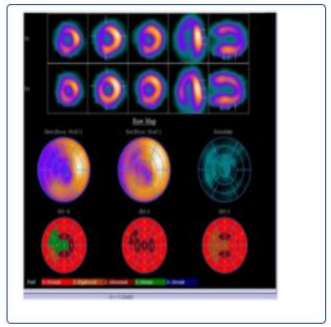
Nuclear Medicine NM

Diagnostic & Therapy









https://www.medicalexpo.com/prod/mie-america/product-100661-713085.html

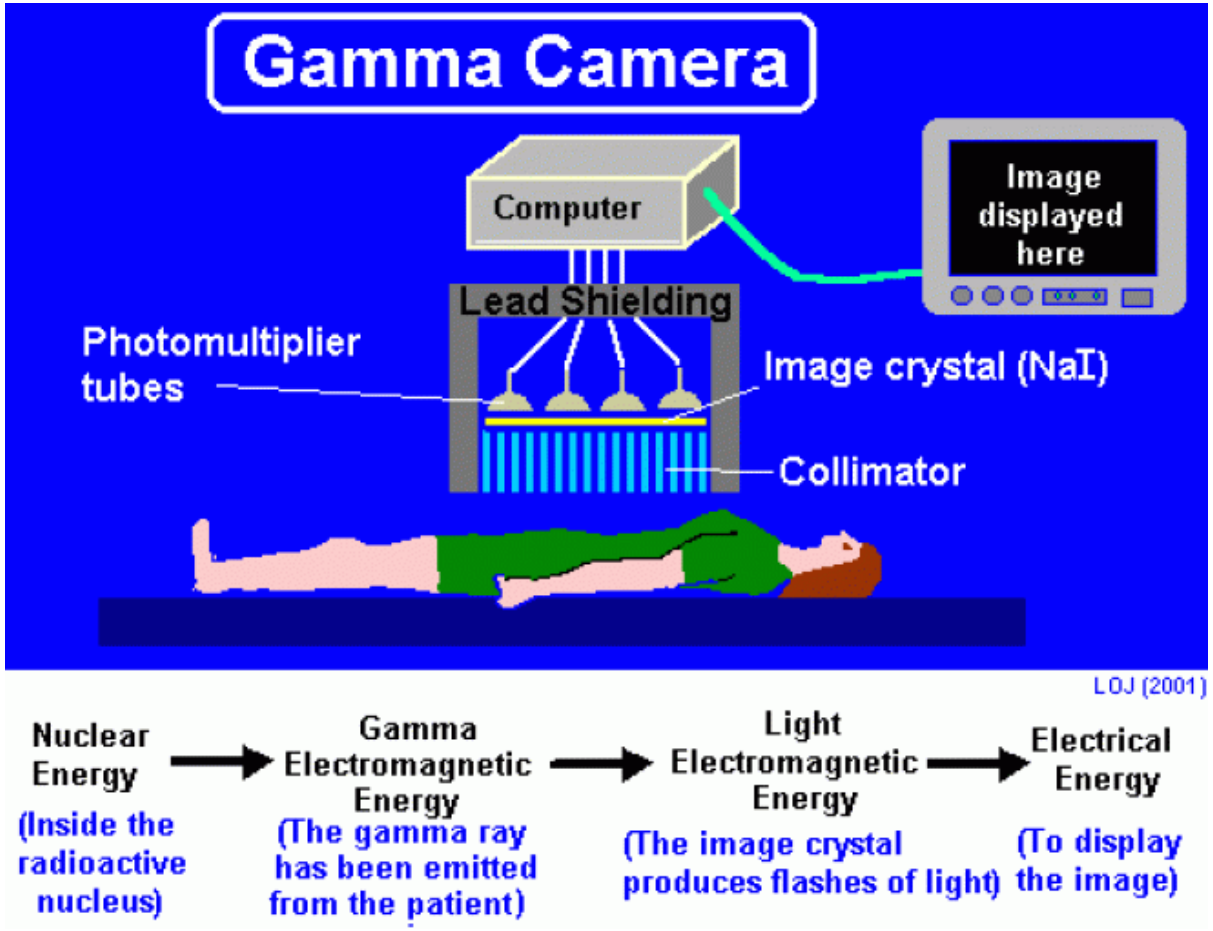
Gamma Camera to PET

Steps in the development of Gamma Cameras:

- 1896 Henri Becquerel discovered radiation
- Georg von Hevesy discovered element hafnium

Pioneers in the development of Gamma Cameras:

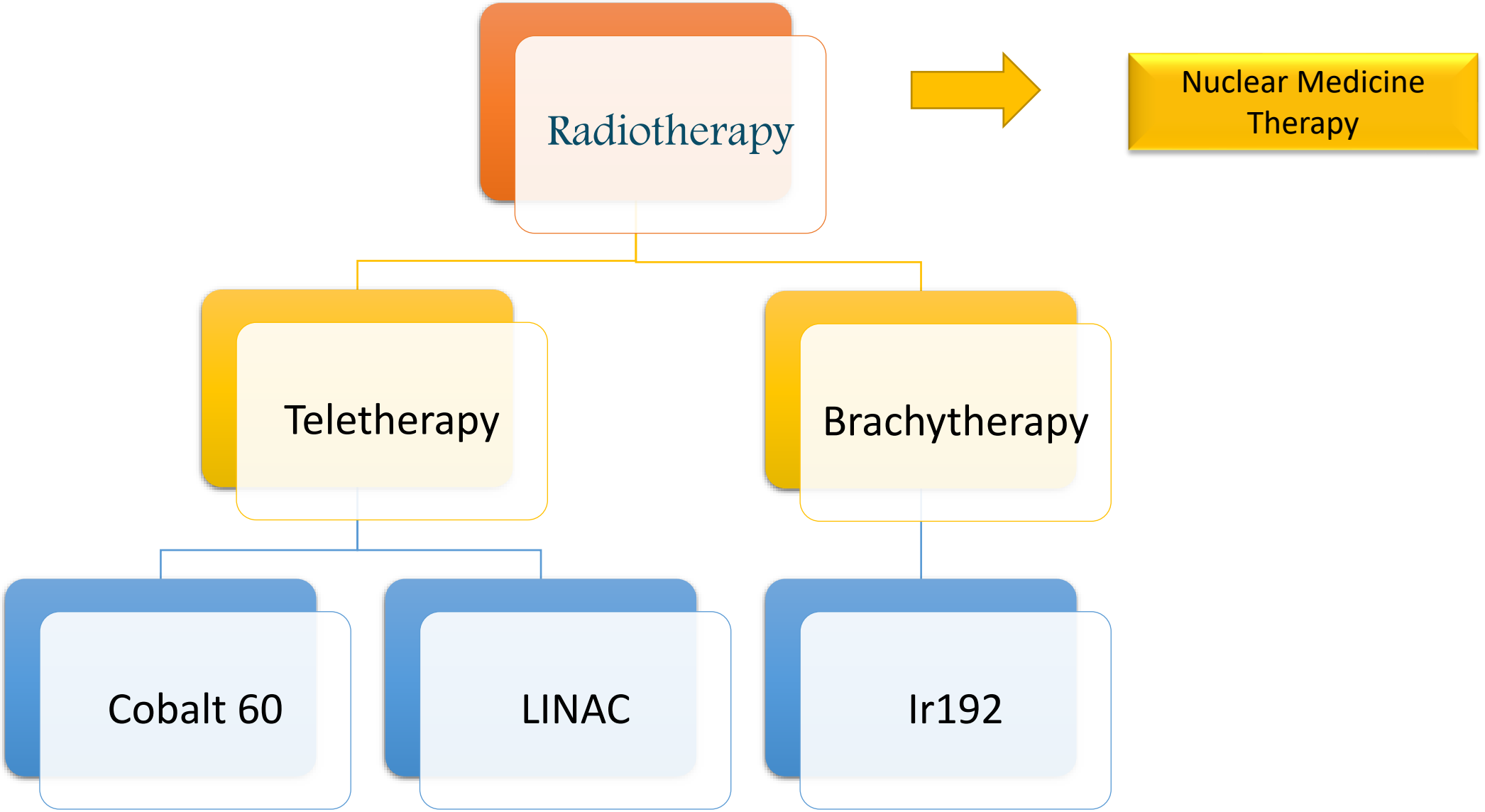
- 1943 George Hevesy received Nobel Prize for nuclear tracer theory
- Ernest Lawrence – Developed precise method for measuring the e/m ratio of the electron
- Hal Anger – Developer of gamma camera – revolutionized medicine



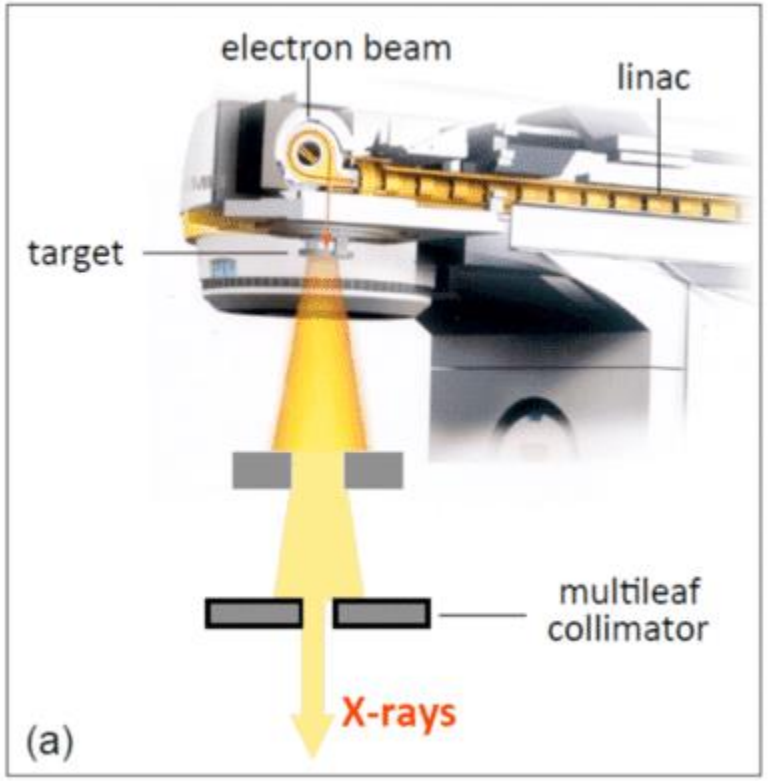
Gamma Camera to PET

- 1972 Gamma Works released its first NM imager with digital processing
- 1990 Foundation of Mediso Ltd.
- 1994 Manufacturing of the first Mediso gamma camera
- 1996 Release of the first SPECT camera Nucline™ X-Ring-R
- 1998 Mediso acquired the NM profile of Gamma Works
- 2000 Launch of the Nucline™ SPIRIT DH-V variable angle dual head camera
- ISO 9001 and MDD certification of the company
- 2006 Manufacturing of the first Mediso preclinical SPECT/CT
- 2007 Production of the first Mediso clinical SPECT/CT
- Mediso takes on NM clinical diagnostic service profile acquiring ScanoMed Ltd.
- 2008 Launch of AnyScan® multimodality clinical imaging family

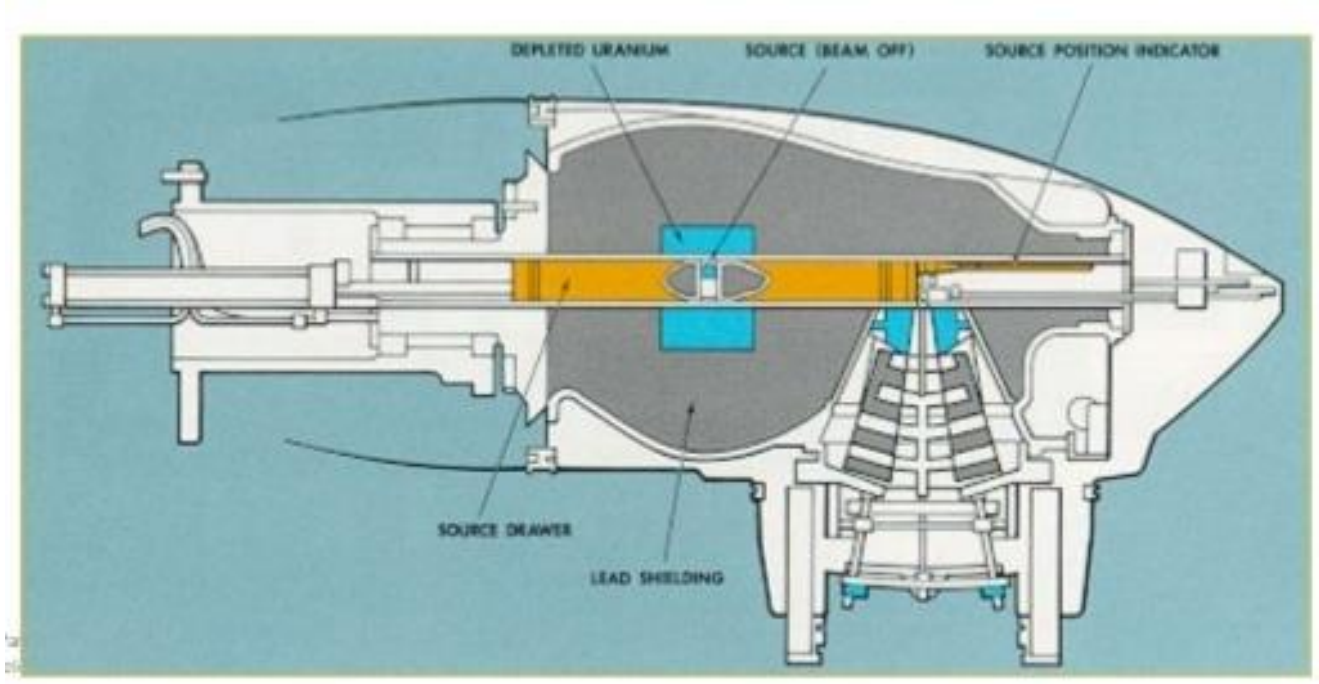
Frost & Sullivan 2008 European Medical Imaging Entrepreneurial Company of the Year Award
2009 New Mediso product launch of NanoPET™ /CT preclinical PET-CT
Inauguration of Mediso Reference Multimodality Diagnostic, Research & Training Centre
2011 Launch of nanoScan® preclinical PET/MRI
2012 Launch of nanoScan® Family complete preclinical SPECT/PET/CT/MRI imager portfolio
Frost & Sullivan 2012 European Preclinical Imaging New Product Innovation Award
2013 New member of nanoScan® Family: nanoScan® SPECT/CT/PET
2014 First installation of MultiScan LFER 150
2015 Introduction of AnyScan® TRIO Family based on triple detector SPECT
2016 First installation of nanoScan® PET/MRI 3T with 3 Tesla MRI


Radiotherapy
Nuclear Medicine Therapy
Teletherapy
Brachytherapy
Cobalt 60
LINAC
Ir192

Medical Linear Accelerator (LINAC)



Cobalt 60 Unite

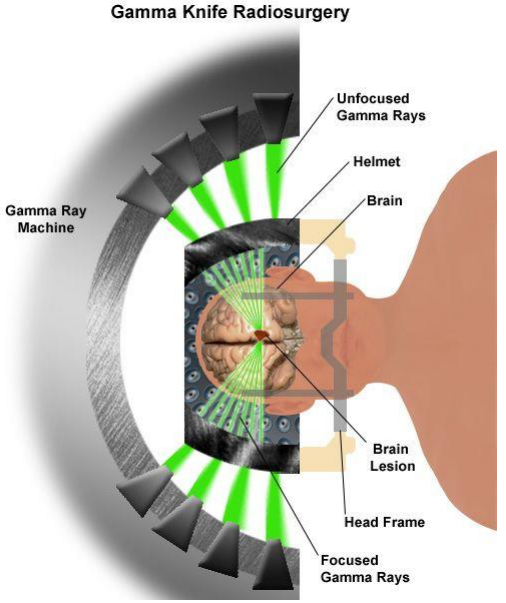


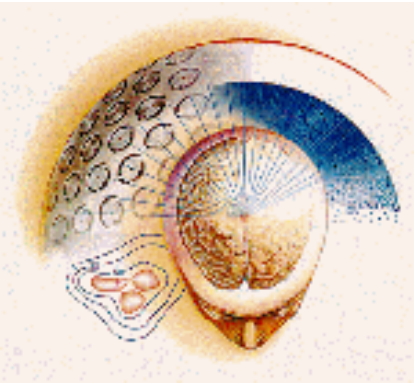
LINAC Vs Cobalt-60

LINAC	Cobalt 60 machine
Continuing progress in technology, design & utility	New machines have improved beam capabilities.
6MV – adequate penetration to treat very vast majority of tumors	Does not give ideal depth dose, but adequate for palliative therapy.
Platform that allows for advanced curative treatment.	Primarily used for palliative treatment.
Upgradeable for advanced treatment modalities to improve the accuracy & quality of treatment.	Continuously depleting sources mean longer treatment times – compromised treatment efficiency & quality. Cumbersome exchange & disposal of sources
Standard of external beam therapy in Developed Countries.	

Gamma Knife

- The Leksell Gamma Knife is an alternative or adjunct to conventional brain surgery. The principles behind the development of the Gamma Knife were first conceived by a Swedish neurosurgeon, Lars Leksell, during the 1950s. He envisioned a multisource Gamma ray emitter that would be able to focus very accurately on an intracranial target and thus replace open surgery for some conditions. In 1967, the first Gamma Knife unit was put into clinical use in Karolinska and this was a 179 cobalt 60 source.



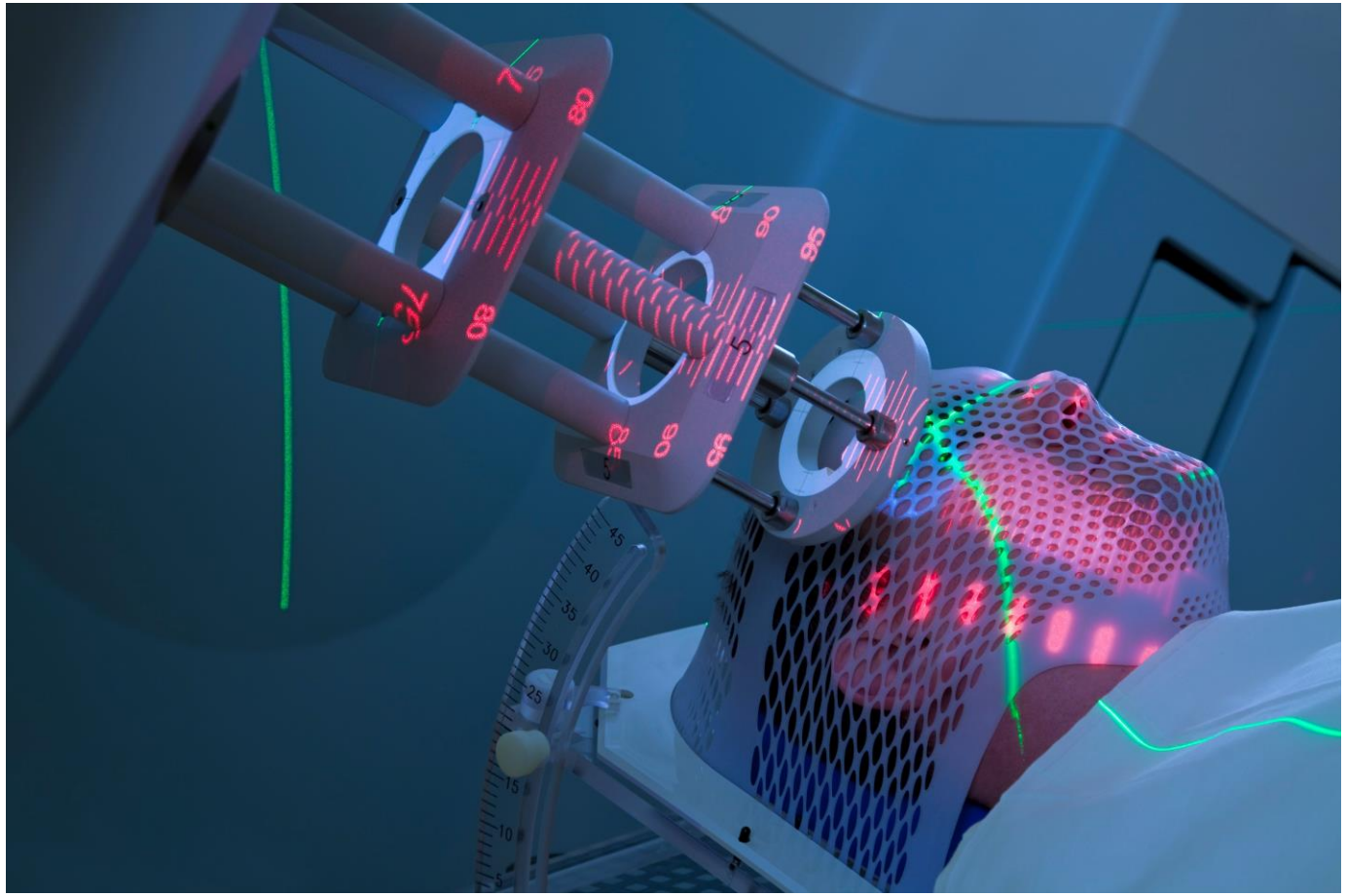


Proton Therapy

What is proton therapy?

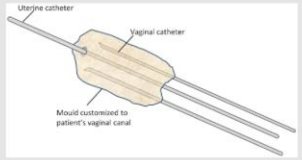
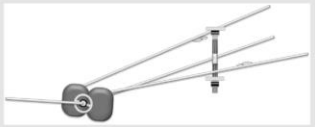
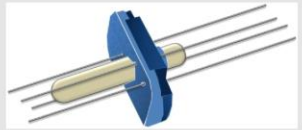
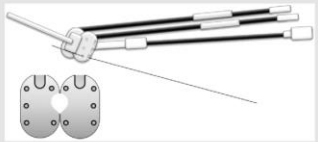
Proton therapy, also known as proton beam therapy, is a form of radiation treatment used to destroy tumor cells. Instead of using x-rays like regular radiation treatment, it uses protons to sends beams of high energy that can target tumors more precisely than X-ray radiation.

When treating a patient, doctors and physicists work together to focus the proton beam on the exact size and shape of the tumor. The beam kills the tumor cells layer by layer, sparing surrounding healthy tissue.



Brachytherapy

Table 1 Overview of MRI- and CT compatible applicators used in image-based brachytherapy

Applicator	Features
	Henschke applicator ■ Titanium models compatible for 1.5 and 3T MRI available ■ Intracavitary tandem and ovoid dosimetry ■ Adjustable ovoid separation and shielding ■ LDR source loading available
	Vaginal mold ■ MRI-compatible for 1.5T ■ Cervicovaginal impression constructed that is used to fabricate acrylic mold ■ Positioning of sources dictated by anatomy of patient and topography of tumor ■ No vaginal packing required; patient can be ambulatory without risk of displacement
	Rotterdam applicator ■ MRI-compatible for 1.5T and 3T ■ Visibility and reconstruction have been validated with inter-rater variability of 0.7 mm ■ Vaginal cylinder attachment components available for targeting vaginal disease
	Syed-Neblett interstitial template ■ Models compatible for 1.5T and 3T MRI available ■ Interstitial catheters with central tungsten alloy obturators placed through a central vaginal obturator and through a disposable template ■ Models using intrauterine tandem available
	Utrecht Applicator ■ MRI-compatible for 1.5T, 3T, 6T and others ■ Combined intracavitary/interstitial ■ Modification of Fletcher system ■ Ovoids can serve as tandems for delivery of10 interstitial channels ■ Angled at 15° to align approximately with angle of uterine tandem ■ Clinically validated for average dosimetric gain for HR-CTV D90 of 4.4 $Gy_{\alpha/\beta\ =\ 10}$

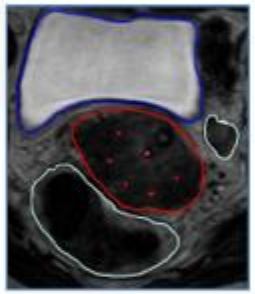
(continued on next page)

The workflow of IGABT

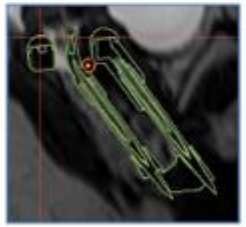
Applicator choice and insertion

3D imaging

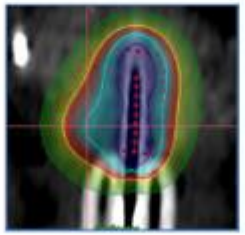
Contouring



Applicator reconstruction



3D dose planning



Dose delivery

During the last decades, image guided adaptive brachytherapy (IGABT) was introduced as a mean of tailoring treatment to tumor response and variations in individual anatomy

Brachytherapy

Figure 6 Coronal view of the Xoft Henschke applicator.

https://www.wjgnet.com/1949-8470/full/v9/i4/148.htm

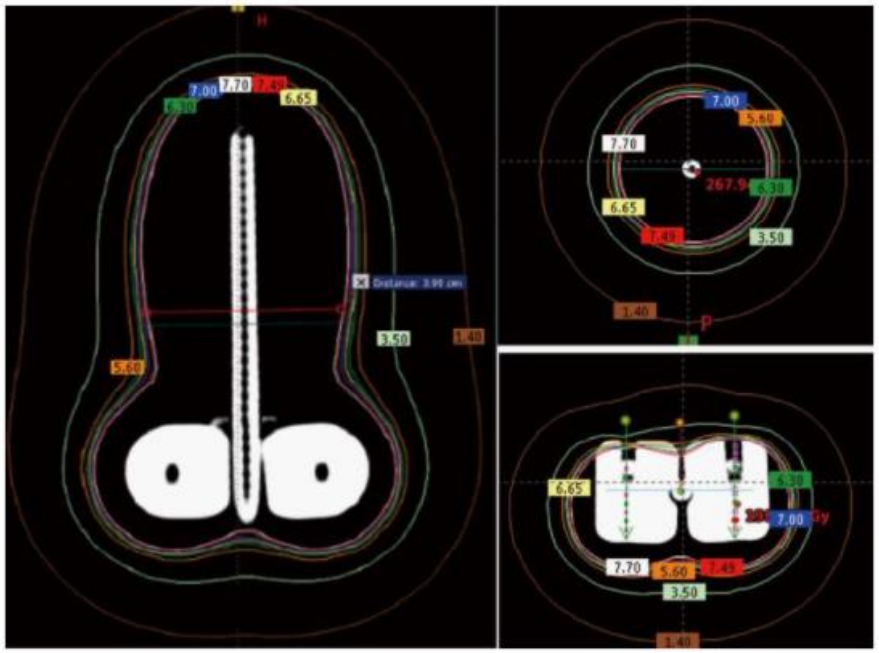
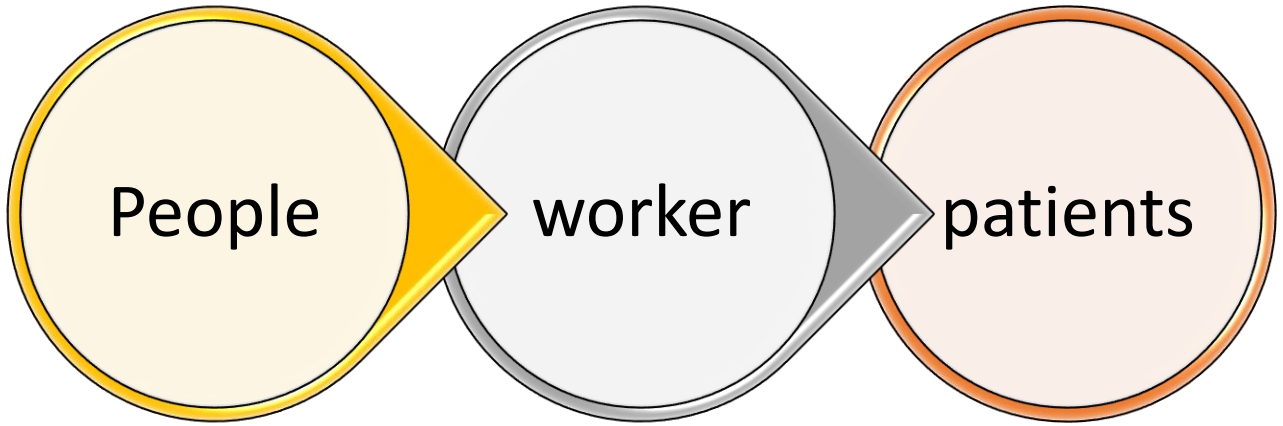
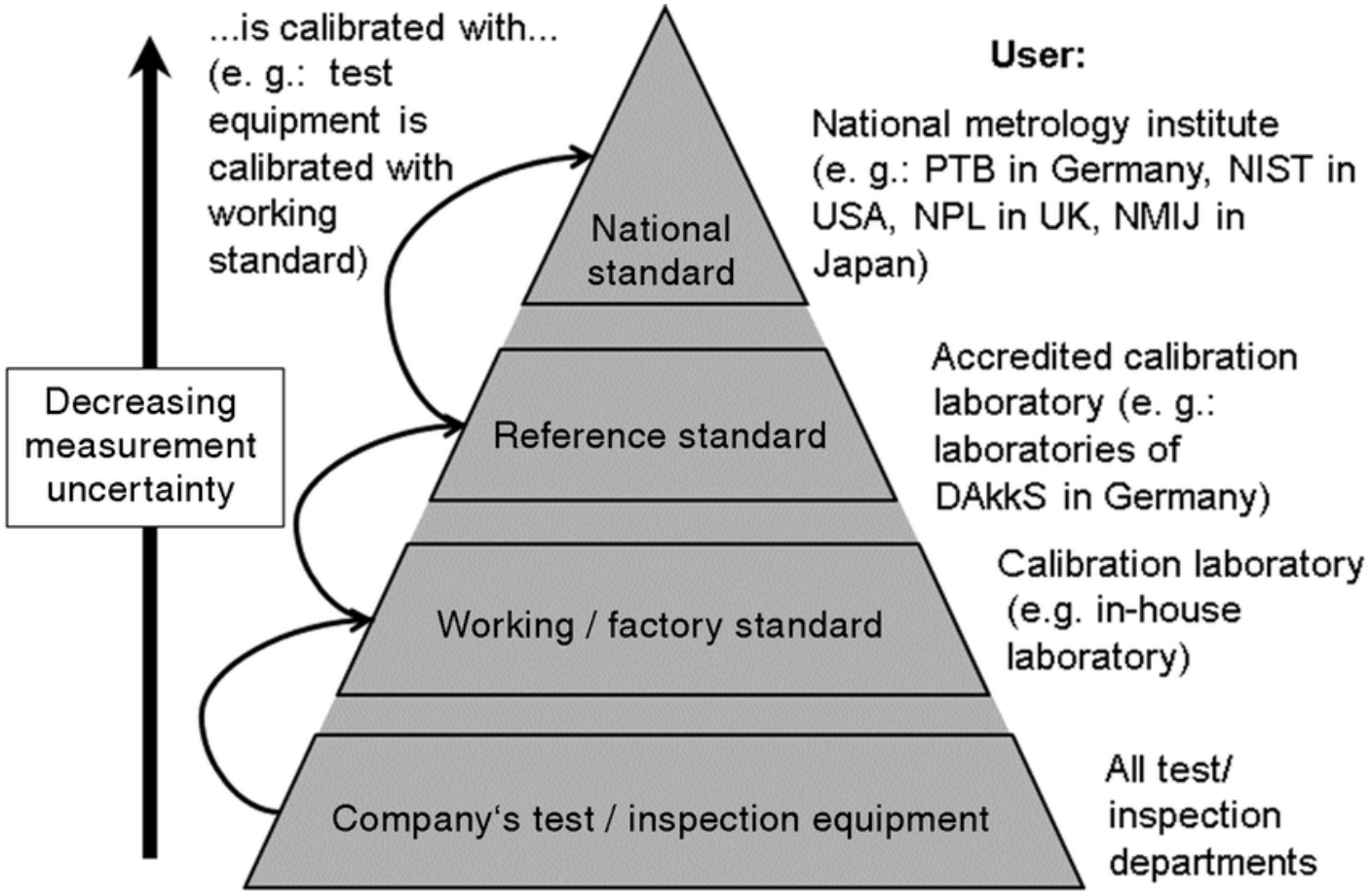


Figure 5 Simulation of a Tandem and Ovoid applicators planned in a Brachyvision software for a predefined Xoft X-ray source dwell positions.

Radiation protection




...is calibrated with... (e. g.: test equipment is calibrated with working standard)
Decreasing measurement uncertainty
National standard
Reference standard
Working / factory standard
Company‘s test / inspection equipment
User:
National metrology institute (e. g.: PTB in Germany, NIST in USA, NPL in UK, NMIJ in Japan)
Accredited calibration laboratory (e. g.: laboratories of DAkkS in Germany)
Calibration laboratory (e.g. in-house laboratory)
All test/ inspection departments

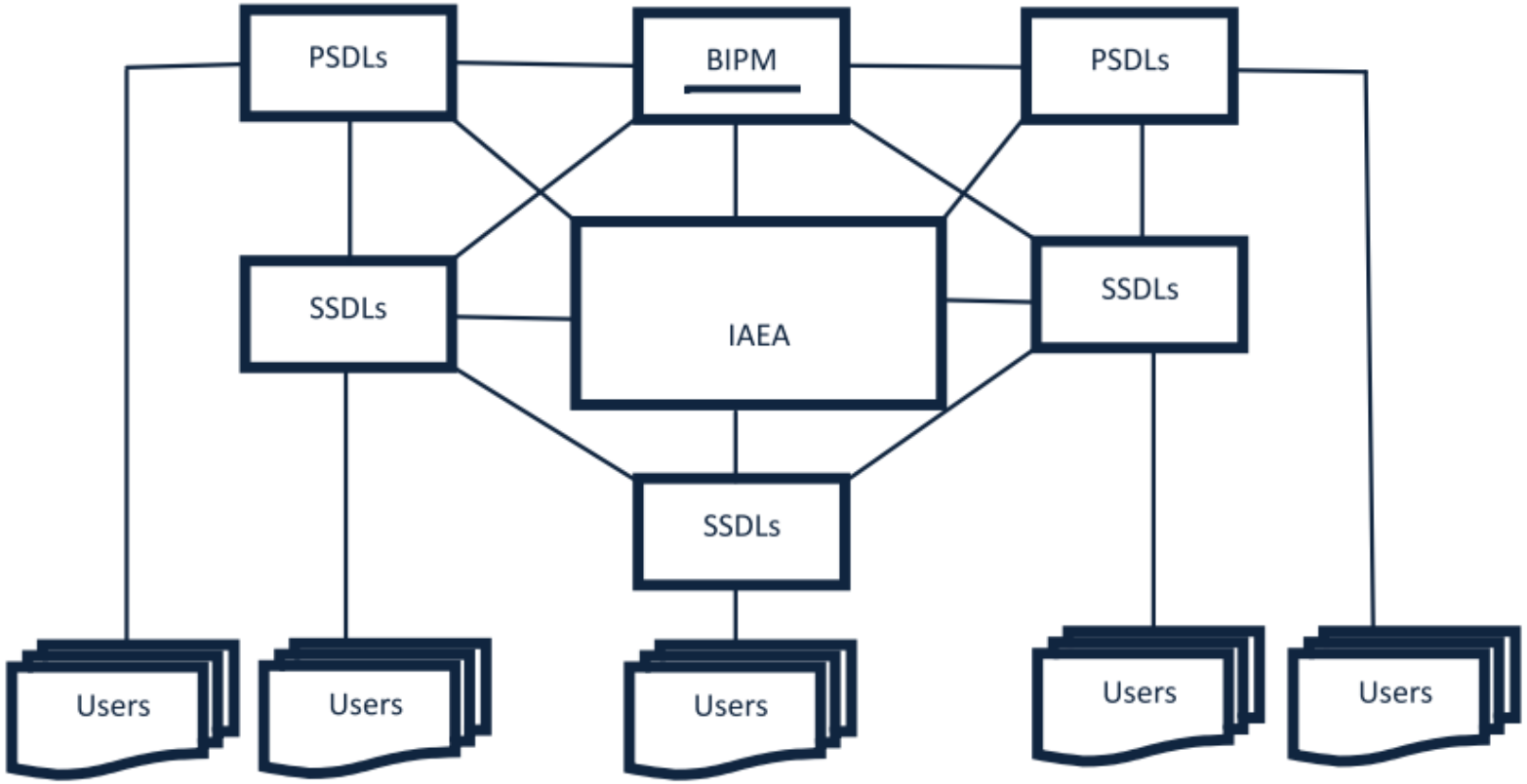
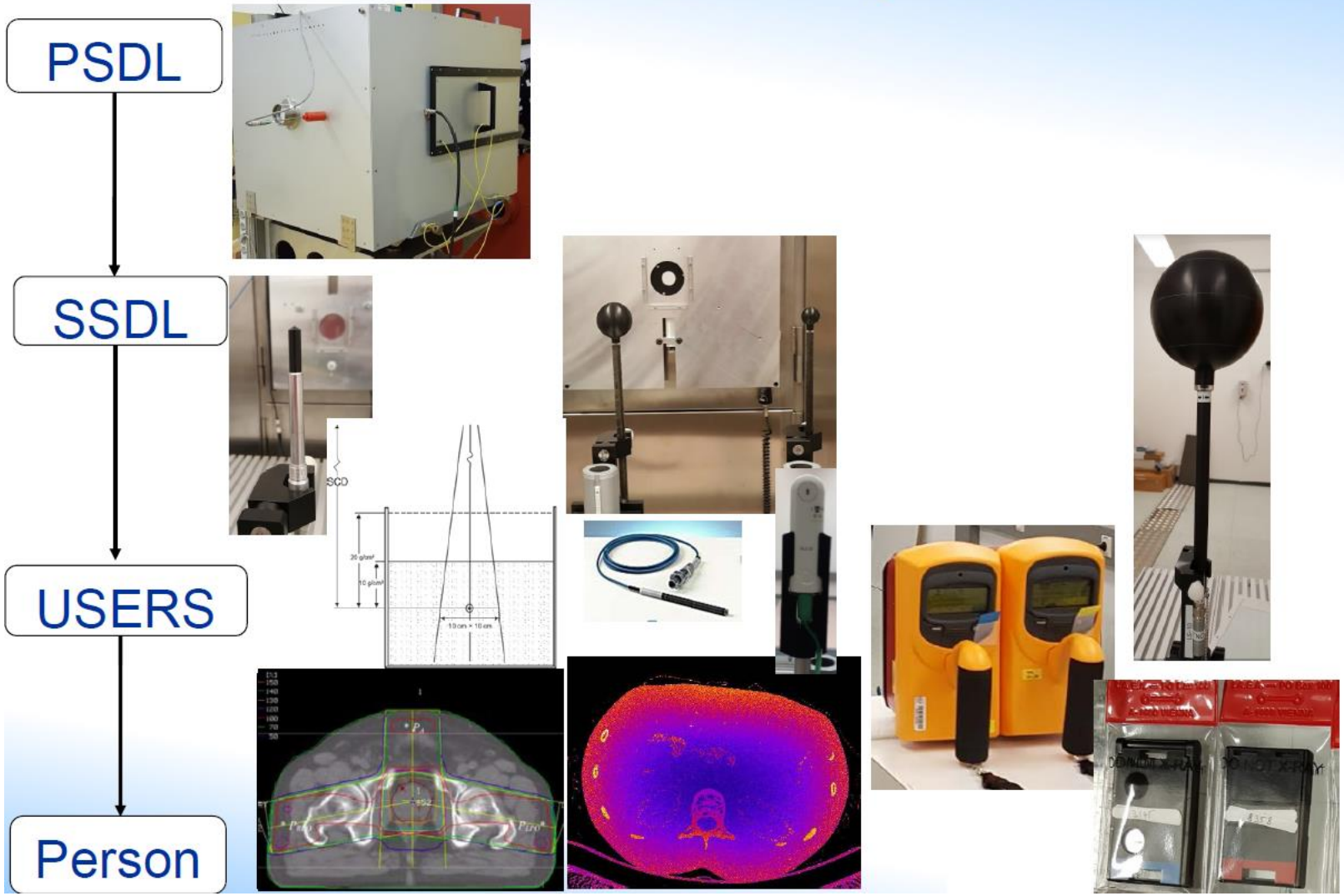
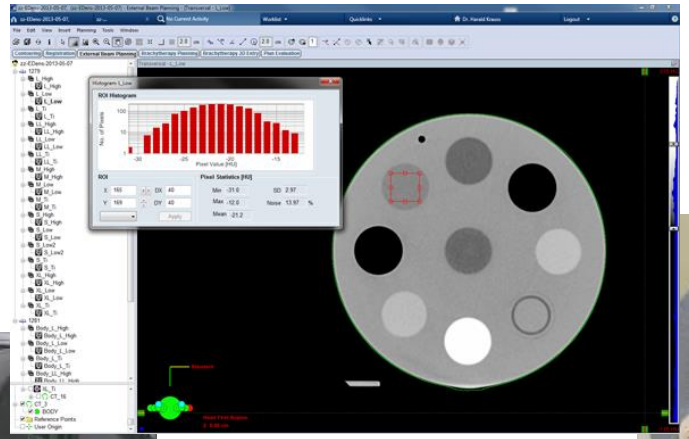
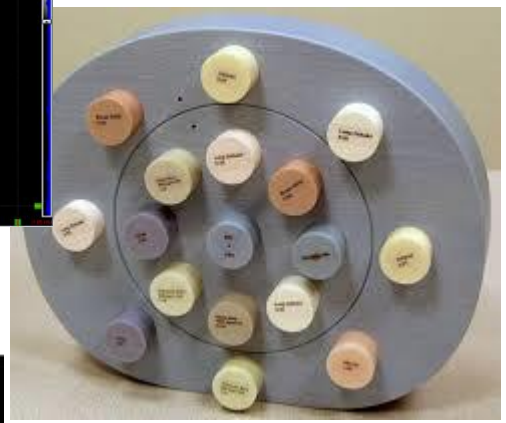


Figure II.1. Global metrological links of the international measurement system [26].

International measurement system

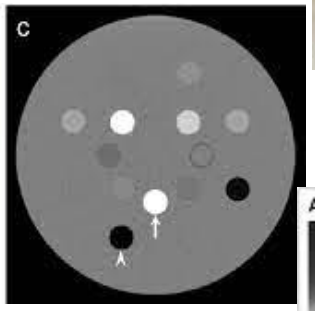


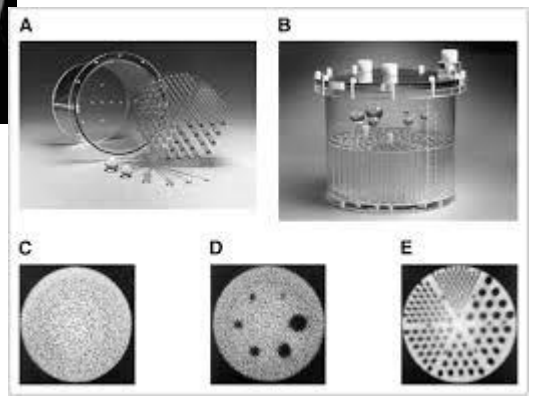




CIRS 062 Phantom

PMMP Phantom





Australian Government
Australian Radiation Protection and Nuclear Safety Agency

External beam radiotherapy

Hospitals calibrate their linac output for radiotherapy with a **dosemeter**

Electrometer

Ionization chamber

Thanks for Attention!

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