Ministry of Higher Education
and Scientific Research

UNIVERSITY OF ANBAR
Applied Science College – Heet
Dept. of Biophysics

Medical Devices

Fourth Stage- Lecture 10

LASIK

Dr.Nasrin Nadher Jamil


VisuMax

What is LASIK?

LASIK is a type of surgery in which a laser is used to reshape the eye. This helps some people with vision problems see better. LASIK is an acronym for "Laser-Assisted in SItu Keratomileusis".

LASIK is the most commonly performed laser eye surgery to correct vision problems, myopia (nearsightedness), hyperopia (farsightedness) and astigmatism. Like other types of refractive surgery, the LASIK procedure reshapes the cornea to enable light entering the eye to be properly focused onto the retina for clearer vision.

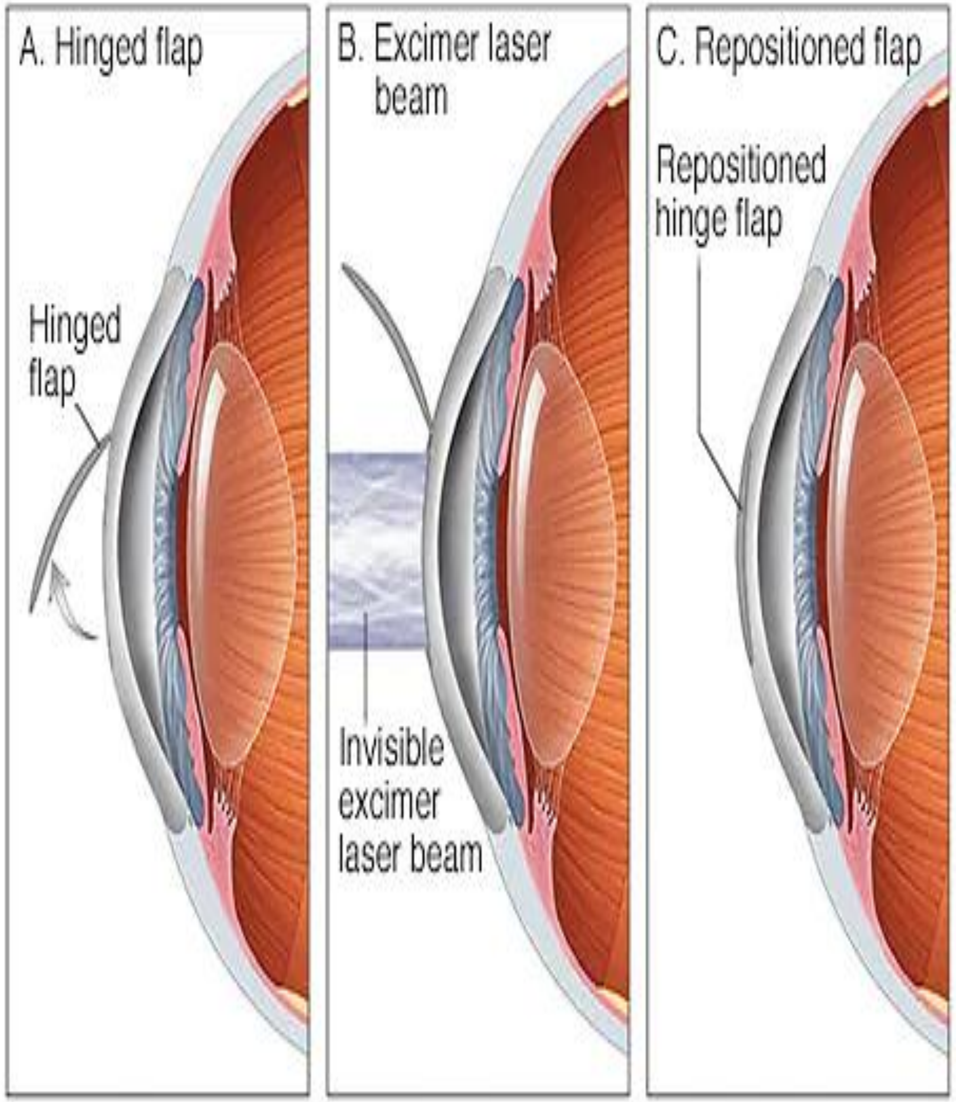
PURPOSES:

- to alter the shape of cornea.
- to correct the focal point of the eyes(to correct vision problems).
- When light does not focus on your retina the way it should, your vision is blurry. This is called as **refractive error**.
- improved vision without eyeglasses or contact lenses.

The general procedures

LASIK surgeon will create a very thin, superficial flap in your cornea with a small surgical tool called a **microkeratome** or with a **femtosecond laser.**

- Anesthetic eyedrops are applied to the eyes.
- The surgeon create a very thin, superficial flap in the cornea by using microkeratome.
- A programmed laser is used to reshape the inner corneal tissue.
- After reshaping the cornea, the surgeon lays the flap back into place.



Why LASER?

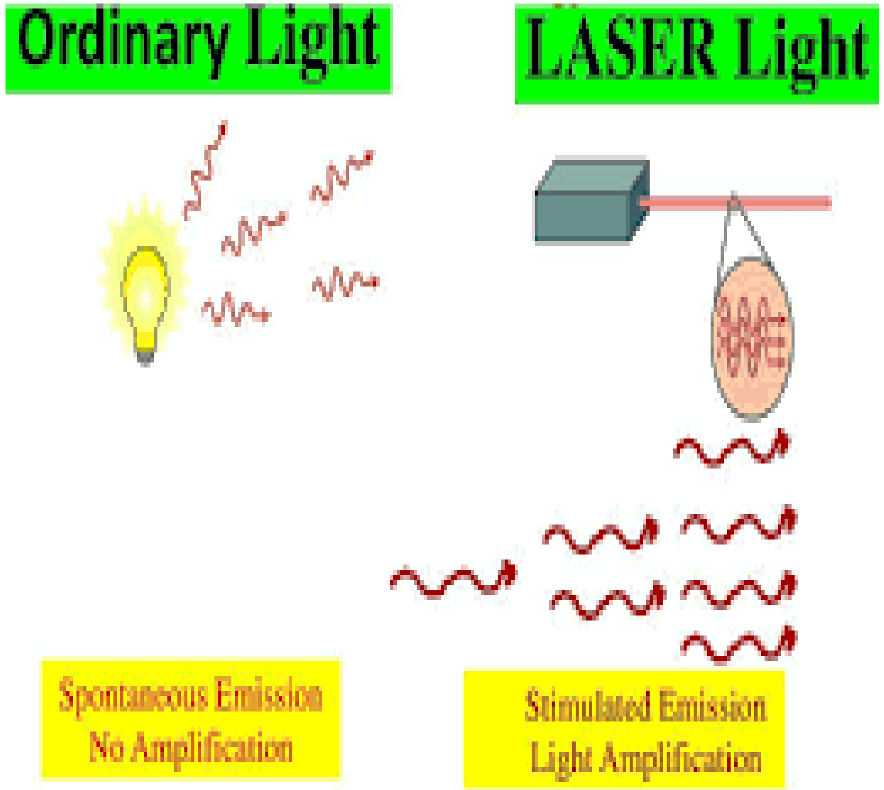
The term "LASER" stands for Light Amplified Stimulated Emission of Radiations.

Characteristics of laser

- Monochromatic(Single wavelength).
- Directional
- Great intensity of light
- Narrow beam.

From above characteristics of laser:

- Lasers are forms of light that can hold a huge amount of energy.
- The light can focus the energy on a target.
- That energy can be in the form of heat or can be used for cutting.



Microkeratome

The surgical instrument that helps with precision work during the LASIK. It is an instrument which was created with a blade that oscillates that was designed to use for creating the corneal flap in the procedure.

While a human’s cornea normally varies from about 500-600 micrometers in its thickness, it is an instrument that helps in creating a flap ranging from 83-200 micrometers in thickness during the procedure. This amazing instrument has been making its way throughout the world while being used to cut the cornea flap. The surgeon removes some corneal tissue using an **Excimer laser**.

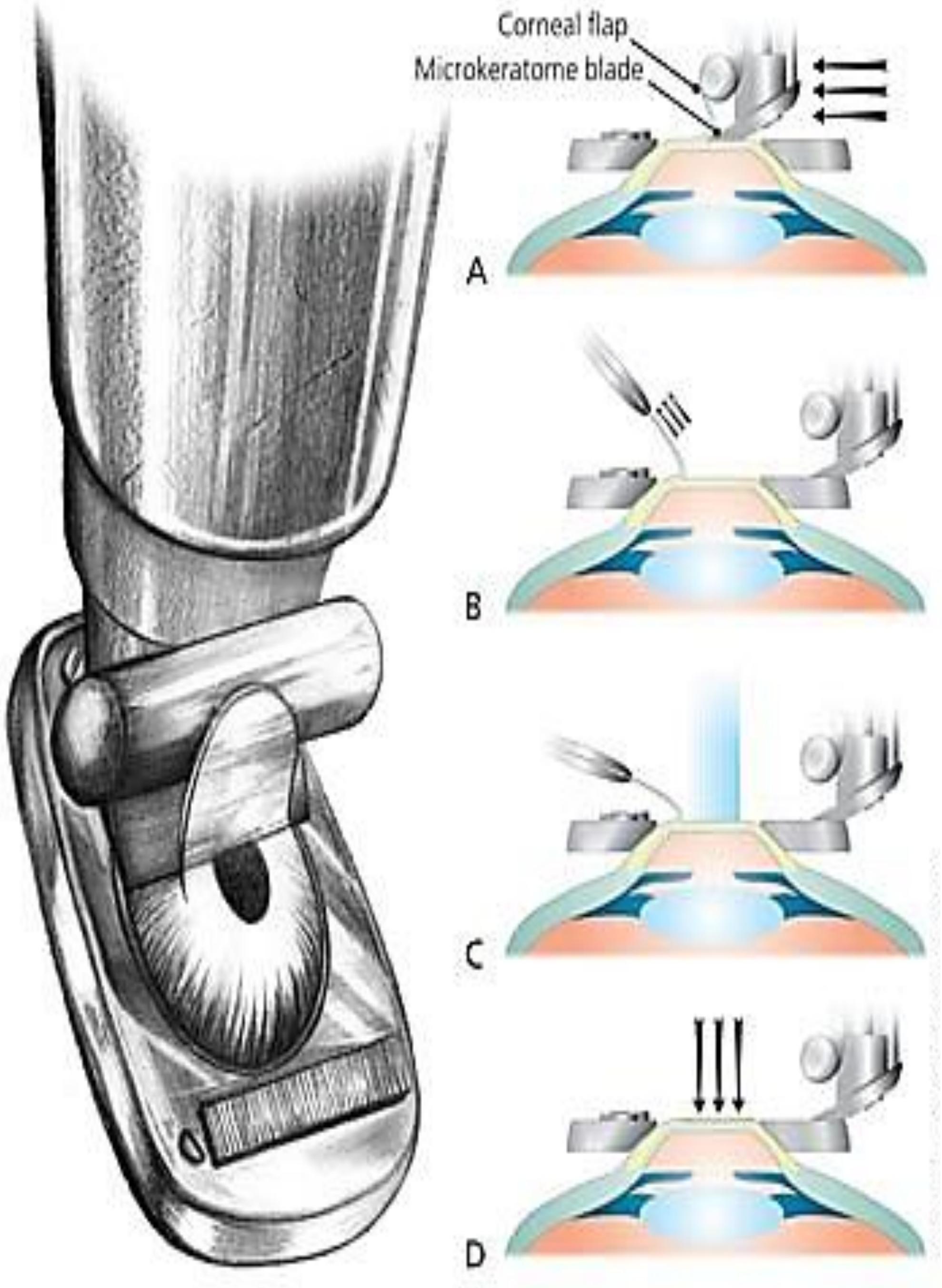
Excimer lasers create a cool ultraviolet light beam to remove ("ablate") microscopic amounts of tissue from the cornea to reshape it so light entering the eye focuses more accurately on the retina for improved vision. As a cold laser, the excimer laser can ablate the tissue accurately without thermal damage.

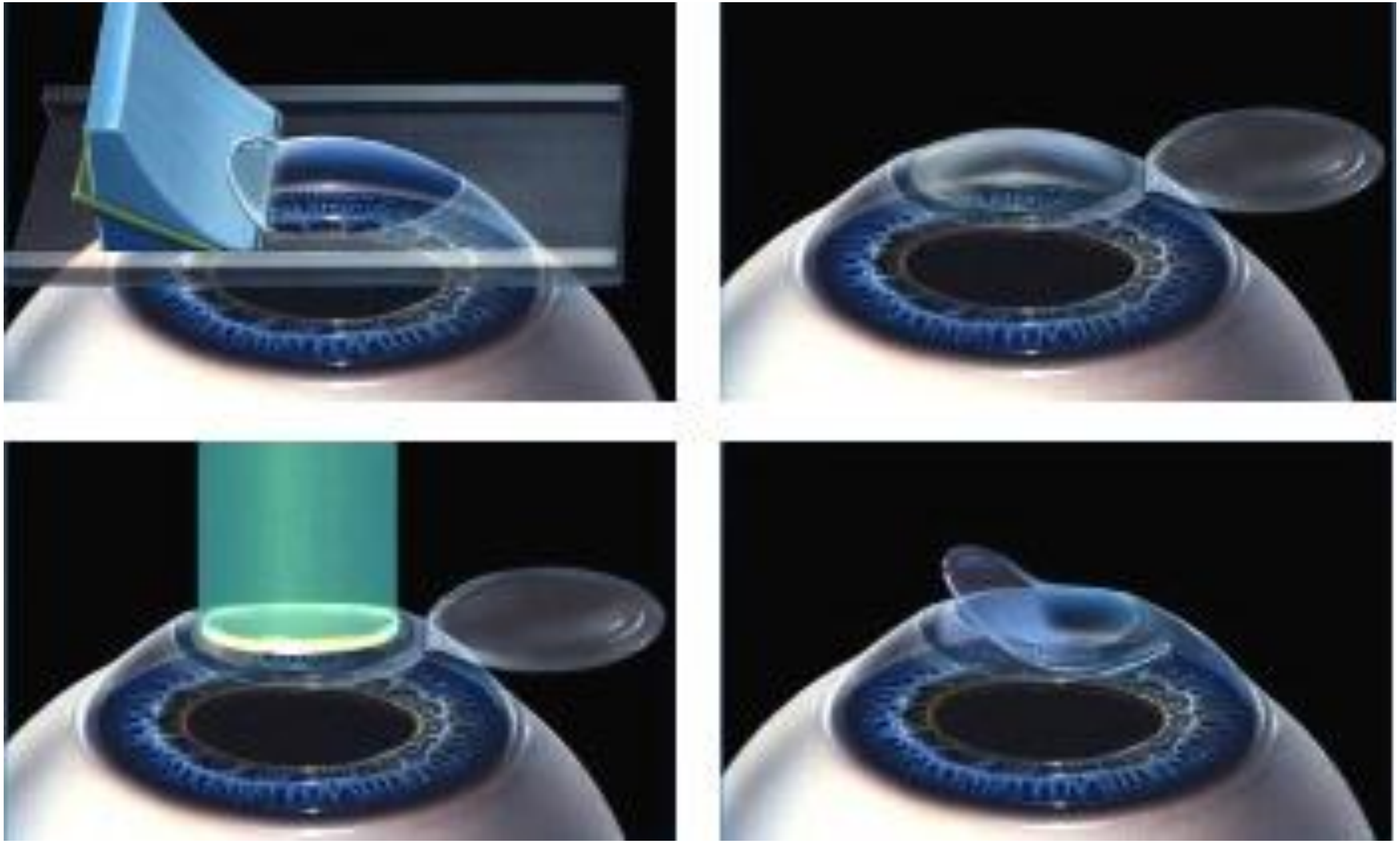
(A) The microkeratome is passed over the flattened cornea, lifting the corneal flap. A suction ring is applied to the front of your eye to prevent eye movements or loss of contact that could affect flap quality.

(B) The corneal flap is lifted to allow laser access to the stroma.

(C) Laser pulses remove a predetermined amount of corneal tissue to correct the refractive error.

(D) The corneal flap is repositioned and allowed to adhere.





Femtosecond Laser LASIK Technique

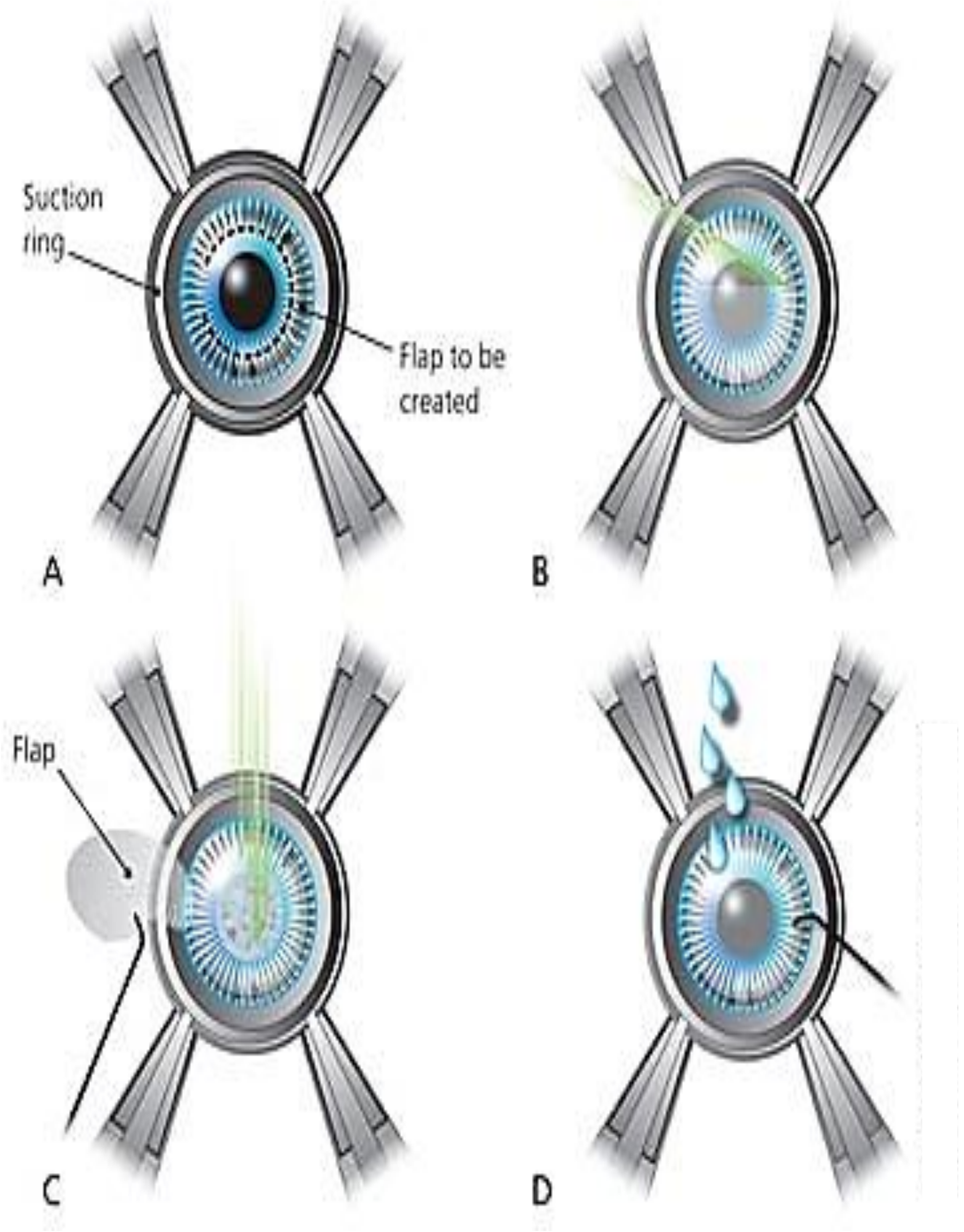
LASIK using the newer **femtosecond laser** technique.

(A)Suction ring is applied to stabalize and flatten cornea.

(B)Laser creates a space to form a flap.

(C)After flap is lifted, the laser removes tissue from predetermined areas.

(D)Flap is returned and eye is irrigated.



Before LASIK surgery

- Eye exam to ensure your eyes are healthy enough for the procedure. He or she will evaluate: the shape and thickness of your cornea; pupil size; refractive errors (myopia, hyperopia and astigmatism); as well as any other eye conditions.
- The tear film on the surface of eyes also will be evaluated, to reduce risk of developing dry eyes after LASIK.
- A corneal topographer is used to measure the curvature of the front surface of your eye and create a "map" of your cornea.
- Doctor also will ask you about your general health history and any medications you are taking to determine if you are a suitable candidate for LASIK.
- Stop wearing contact lenses for a period of time advised by your doctor (typically around two weeks) before your eye exam and before the LASIK procedure. This is because contact lens wear can temporarily alter the natural shape of your cornea.

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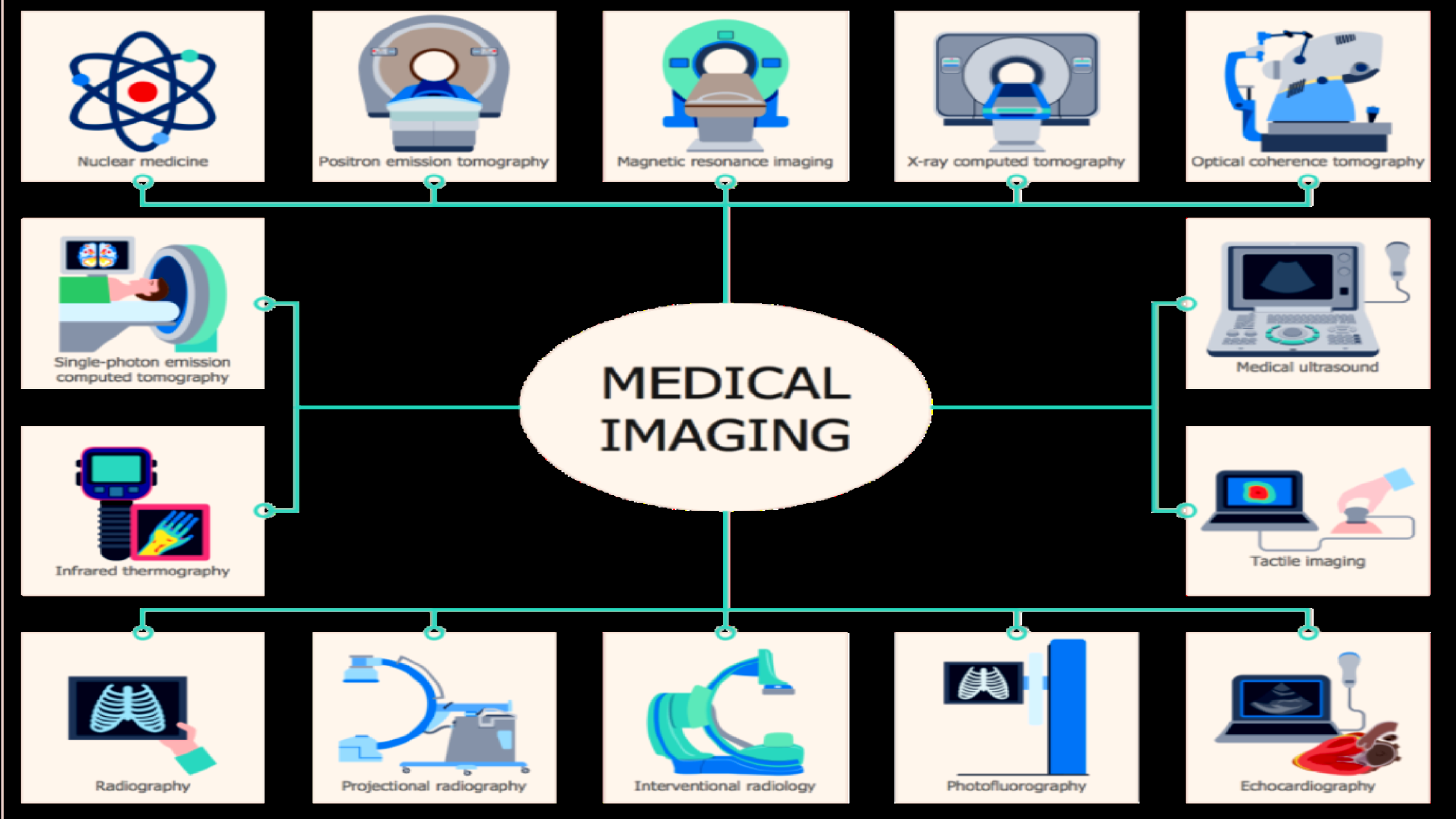
Fourth Stage- Lecture 2

Medical Imaging

Dr.Nasrin Nadher Jamil



MEDICAL IMAGING
Nuclear medicine
Positron emission tomography
Magnetic resonance imaging
X-ray computed tomography
Optical coherence tomography
Single-photon emission computed tomography
Medical ultrasound
Infrared thermography
Tactile imaging
Radiography
Projectional radiography
Interventional radiology
Photofluorography
Echocardiography

What is Medical Imaging?

Medical imaging is a non-invasive procedure that allows doctors to examine the internal structure of the body. Through imaging, doctors can diagnose and monitor diseases, injuries, and abnormalities of organs, bones, and structures. Some, but not all, imaging procedures use radiation, but the benefits typically outweigh the potential risks.

Medical imaging is the use of specific interactions between tissues and incident energy to reveal structural or functional information about the body. This information is used to reveal health- and medicine- related information .

The information is presented in the form of images that can be 2D or 3D. Medical imaging is a part of medical diagnosis field but not all the medical diagnosis is based upon medical imaging .

Although this definition applies across the broad field of medical imaging, medical imaging comes in different forms, each relying on specific interactions between tissues and incident energy to reveal structural or functional information about the body.

The basis of Medical Imaging

Medical imaging of the human body requires some form of energy. Visible light, which has limited ability to penetrate tissues at depth, is used mostly outside of the radiology department for medical imaging.

Visible light images are used in dermatology (skin photography), gastroenterology and obstetrics (endoscopy), and pathology (light microscopy).

All disciplines in medicine use direct visual observation, which also utilizes visible light. In the medical imaging techniques used in radiology, the energy used to produce the image must be capable of penetrating tissues.

In the medical imaging techniques used in radiology, the energy used to produce the image must be capable of penetrating tissues.

In diagnostic radiology, the electromagnetic spectrum outside the visible light region is used for medical imaging, including x-rays in mammography and computed tomography (CT); radiofrequency (RF) in magnetic resonance imaging (MRI), and gamma rays in nuclear medicine. Mechanical energy, in the form of high-frequency sound waves, is used in ultrasound imaging.

The tissue – energy interaction characteristics are related to:

-The actual structure (anatomy).

-Composition (biology and chemistry).

- Function (physiology and metabolism) of the body.

Types of imaging include:

- Computed Tomography.
- Ultrasound.
- Mammography.
- Cardiac-Interventional Radiography.
- Vascular-Interventional Radiography.
- Magnetic Resonance.
- Sonography.
- Angiograhpy.

The Role of a Medical Physicist

This translation of images to reality creates one of the core components of medical imaging expertise.

It is the foundation of the art of interpreting medical images to understand the connections between the image characteristics to those of tissue properties, anatomy, biology, chemistry, physiology, and metabolism, and using this knowledge to determine how these imaging attributes are affected by disease and disability.

We have to be careful in assigning each part of medical imaging expertise to.

-Manufacturing and maintaining medical imaging devices: engineers.

-Operating medical imaging equipment: medical physicists.

- Interpreting medical images to reveal information about the patient's health: a medical doctor.

Of course, patient safety and comfort must be considered when acquiring medical images; thus, excessive patient dose in the pursuit of a perfect image is not acceptable. Rather, the power and energy used to make medical images require a balance between patient safety and image quality. This is a medical physicist responsibility.

In most cases, the image quality that is obtained from medical imaging devices involves compromise.

Examples:

- Better x-ray images can be made when the radiation dose to the patient is high,
- Better magnetic resonance images can be made when the image acquisition time is long.
- Better ultrasound images result when the ultrasound power levels are large.

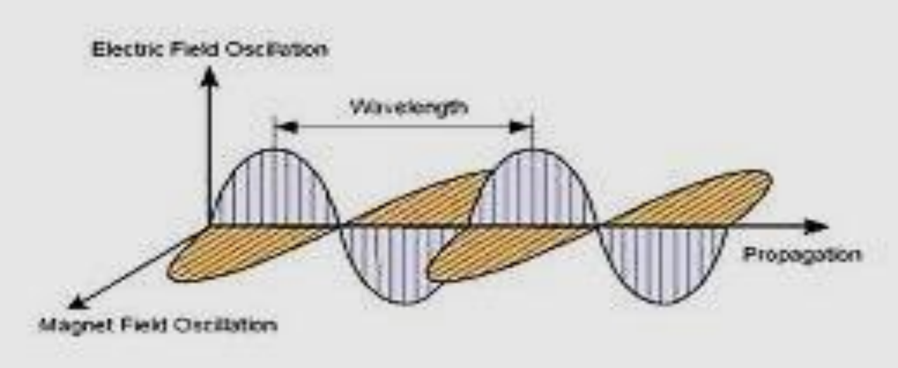
Of course, patient safety and comfort must be considered when acquiring medical images; thus, excessive patient dose in the pursuit of a perfect image is not acceptable.

Rather, the power and energy used to make medical images require a balance between patient safety and image quality. This is a medical physicist responsibility

Electromagnetic Radiation

Electromagnetic Radiation (EM) radiation has no mass, is unaffected by either electric or magnetic fields, and has a constant speed in a given medium. Although EM radiation propagates through matter, it does not require matter for its propagation.

EM radiation is commonly characterized by wavelength (λ), frequency (v), and energy per photon (E). The constant speed (c) of electromagnetic radiation in a vacuum is the product of the frequency and the wavelength of the electromagnetic wave: $c = v.\lambda$ …. (1)



Its maximal speed (3 X 10^8 m/s) occurs in a vacuum. In matter such as air, water, or glass, its speed is a function of the transport characteristics of the medium. Often it is convenient to assign wavelike properties to electromagnetic energy. The two interpretations of electromagnetic radiation are united by the equation: $E=hv$ …….(2)

The symbol (h) represents Planck's constant, 6.62×10^{-34} J s. From equation (1):

$v=c\lambda$ ....(3) .By combining equations (2) & (3):

$E=hc/\lambda$ ....(4)

Using this equation, the energy in units of kiloelectron volts (keV) of a photon of wavelength λ in nanometers (nm) may be computed by: $E=1.24/\lambda$ ....(4)

EM radiation travels in straight lines; however, its trajectory can be altered by interaction with matter. The interaction of EM radiation can occur by scattering (change in trajectory), absorption (removal of the radiation), or, at very higher energies, transformation into particulate radiation (energy to mass conversion).

EM radiation over a wide range of wavelengths, frequencies, and energy per photon comprises the EM spectrum. For convenient reference, the EM spectrum is divided into categories including the radio spectrum, infrared radiation, visible, ultraviolet (UV); and x-ray and gamma-ray regions. Several forms of EM radiation are used in diagnostic imaging:

- Gamma rays, emitted by the nuclei of radioactive atoms, are used to image the distributions of radiopharmaceuticals.
- X-rays, produced outside the nuclei of atoms, are used in radiography, fluoroscopy, and computed tomography.
- Visible light is produced when x-rays or gamma rays interact with various scintillators in the detectors used in several imaging modalities and is also used to display images.
- Radiofrequency EM radiation, near the FM frequency region, is used as the excitation and reception signals for magnetic resonance imaging(MRI).

Designation	Frequency (Hz)	Wavelength (m)	Energy (eV)
γ-rays	10^{18} to 10^{21}	3×10^{-10} to 3×10^{-13}	4×10^{3} to 4×10^{6}
X-rays	10^{15} to 10^{25}	3×10^{-7} to 3×10^{-17}	10 to 4×10^{10}
Ultraviolet	10^{15} to 10^{17}	3×10^{-7} to 3×10^{-9}	4–400
Visible	4×10^{14} to 7×10^{14}	7.5×10^{-7} to 4.3×10^{-7}	1.7–2.9
Infrared	10^{11} to 4×10^{14}	0.003 to 7.5×10^{-7}	4×10^{-4} to 1.7
Radar and microwave	10^{8} to 10^{11}	3 to 0.003	4×10^{-7} to 4×10^{-4}
Television	3×10^{7} to 3×10^{9}	30 to 0.3	4×10^{-8} to 4×10^{-6}
FM radio	8.8×10^{6} to 1.08×10^{8}	34 to 2.8	3.6×10^{-8} to 4.4×10^{-7}
AM radio	5.35×10^{5} to 1.605×10^{6}	5.61×10^{2} to 2.8×10^{2}	2.2×10^{-9} to 4.4×10^{-9}
Electric power	0 to 10^{3}	0 to 3×10^{5}	0 to 4×10^{-12}

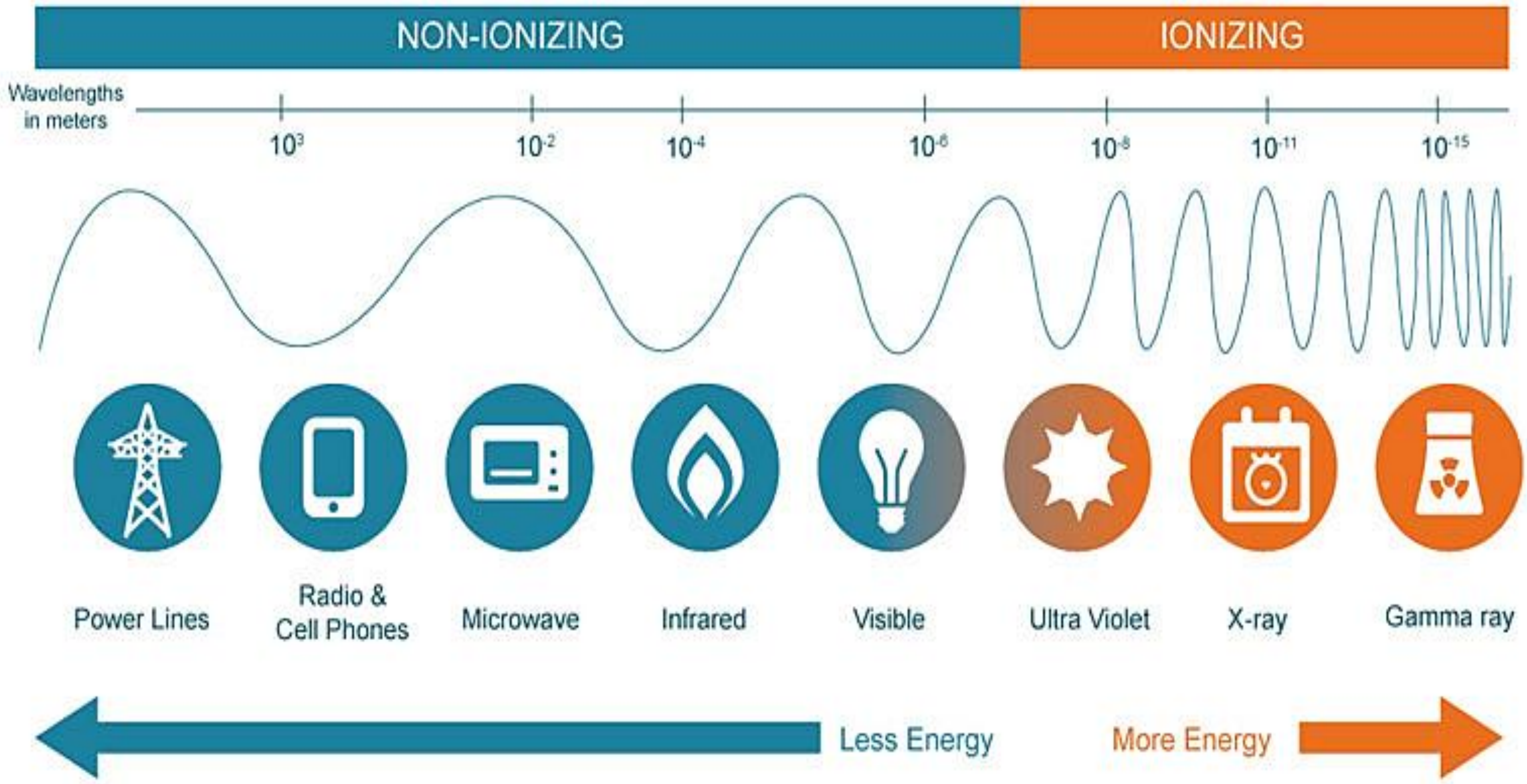
Radiation Interaction with Matter

Ionizing Radiation an atom or molecule that has lost or gained one or more electrons has a net electrical charge and is called an ion (e.g., sodium ion or Na+). Some but not all electromagnetic radiations can cause ionization.

The classification of radiation as "**ionizing**" is essentially a statement that it has enough quantum energy to eject an electron. This is a crucial distinction, since "ionizing radiation" can produce a number of physiological effects, such as those associated with risk of mutation or cancer.

In general, photons of higher frequency than the far UV region of the spectrum (i.e., wavelengths greater than 200 nm) have sufficient energy per photon to remove bound electrons from atomic shells, thereby producing ionized atoms and molecules. Radiation in this portion of the spectrum (e.g., x-rays and gamma rays) is called ionizing radiation.

EM radiation with photon energies in and below the UV region (e.g., visible, infrared, terahertz, microwave and radio waves) is called nonionizing radiation. Non-ionizing interaction is opposite to ionizing radiation. Meaning it does not lead to the production of radicals. The net result of the absorption of non-ionizing radiation is generally just to heat the sample.



NON-IONIZING
IONIZING
Wavelengths in meters
10^{3}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-11}
10^{-15}
Power Lines
Radio & Cell Phones
Microwave
Infrared
Visible
Ultra Violet
X-ray
Gamma ray
Less Energy
More Energy

When photons are applied to matter, it will either:

a) Penetrate it without interaction,

b) Elastic scattering.

c) Non-elastic scattering (lose some energy)

d) Be absorbed (lose all energy).

As a beam of ionizing radiation passes through a medium, the energy carried by the photons may be transformed into kinetic energy of charged particles (such as electrons). In the case of x-rays and gamma rays, the energy is transferred by photoelectric absorption, Compton scattering, and, for very high energy photons, pair production.

Kerma (K) is defined as the kinetic energy transferred to charged particles by ionizing radiation per unit mass. The SI unit of Kerma is the joule per kilogram with the special name of the gray (Gy) or milligray (mGy), Gy = 1J / kg.

Radiation Dose

1.Absorbed dose

The quantity absorbed dose (D) is defined as the energy (E) imparted by ionizing radiation per unit mass of irradiated material (M): **$E = \frac{D}{M}$**

The SI unit of absorbed dose and kerma, is the same (gray), where 1 Gy = 1 J/kg.

2. Equivalent Dose

Not all types of ionizing radiation cause the same biological damage per unit absorbed dose. To reflect the relative effectiveness of the type of radiation in producing biologic damage, a radiation weighting factor (W_R) was established by the International Commission on Radiological Protection (ICRP) as part of an overall system for radiation protection. The product of the absorbed dose (D) and the radiation weighing factor is the equivalent dose: **$H = D\ W_R$**

The SI unit for equivalent dose is joule per kilogram with the special name of the Sievert (Sv), where 1 Sv = 1 J/kg. Radiations used in diagnostic imaging (x-rays and gamma rays), have a WR of 1.

3.Effective Dose

Biological tissues vary in sensitivity to the effects of ionizing radiation. Tissue weighting factors (W_T) were also established by the ICRP as part of their radiation protection system.

The sum of the products of the equivalent dose to each organ or tissue irradiated (H_T) and the corresponding weighting factor (W_T) for that organ or tissue is called the effective dose (E), measured also in Sievert (Sv).

$$E = \Sigma T[W_T \times H_T]$$

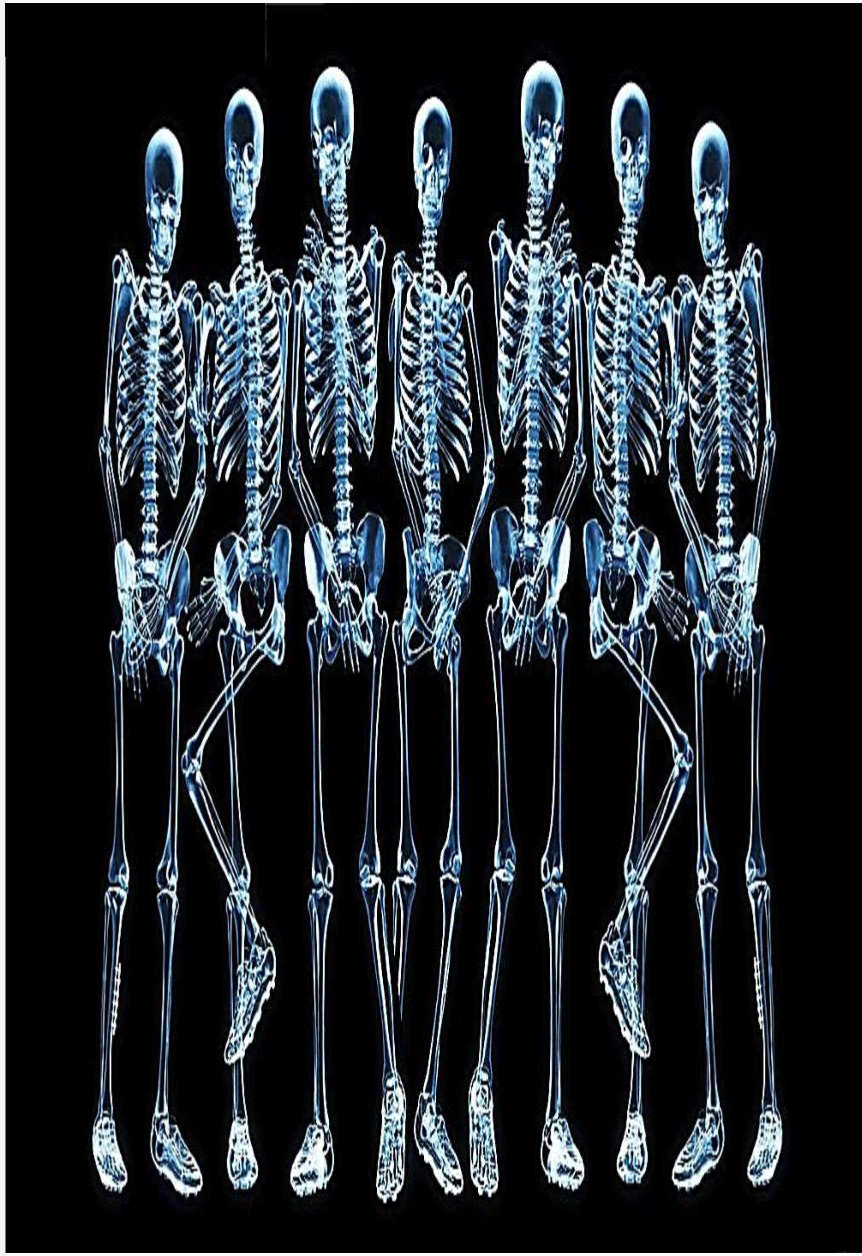
Electron Binding Energy

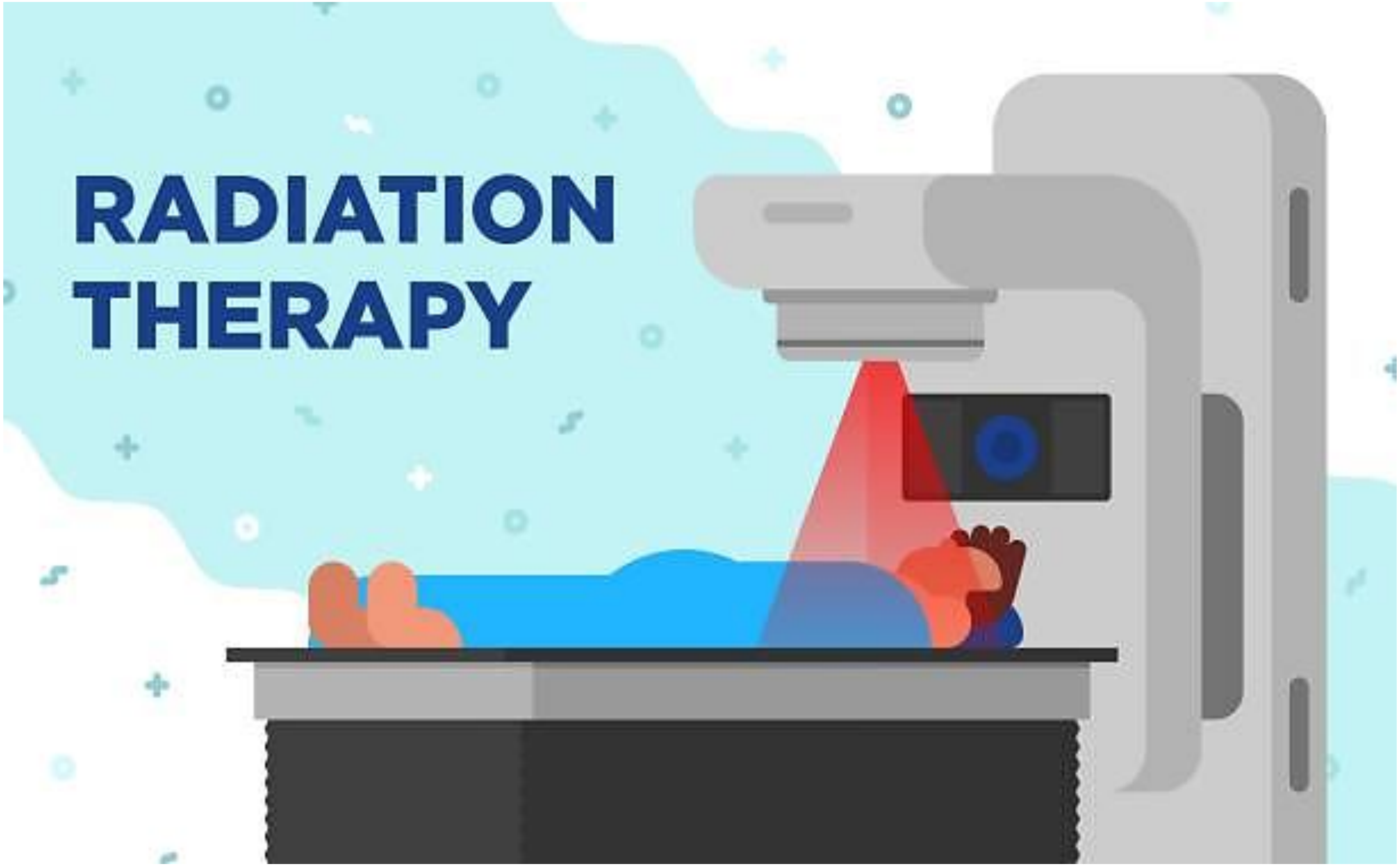
The energy required to remove an orbital electron completely from the atom is called its orbital binding energy. Thus, for radiation to be ionizing, the energy transferred to the electron must equal or exceed its binding energy. Due to the closer proximity of the electrons to the positively charged nucleus, the binding energy of the K-shell is greater than that of outer shells.

For a particular electron shell, binding energy also increases with the number of protons in the nucleus (i.e., atomic number).

Dates and events in the history of medical imaging

- **Wilhelm Conrad Röntgen discovered the x-ray on November 8th, 1895. This is a big milestone in medical history. Röntgen captured the first ever x-ray picture using his wife's hand, but the first clinical use of x-rays by physicians took place the following year. Röntgen later earned a Nobel Prize in Physics for this discovery. Today, there are nearly 150 million x-ray procedures performed in the U.S. each year!**
- **During World War I, Marie Curie established the "petites Curies", mobile radiography units to assist battlefield surgeons on the front lines.**
- **In 1927, 37% of radiologic technologists were nuns. Today, there are over 330,000 registered radiologic technologists.**
- **Ultrasound was first used for clinical purposes in 1956. Ultrasound is a type of imaging that uses high frequency sounds waves rather than radiation.**
- **Radiation therapy became a specialized field in 1964.**
- **The first patient brain-scan done through CT (Computed Tomography) scanning was performed in 1971. Today, there are over 78 million CT procedures performed each year.**
- **The first MR scan of the human body was performed in 1977. Today, there are over 37 million MR procedures performed each year.**
- **The first ever 3D mammography exam was performed in the U.S. in 2011**




RADIATION
THERAPY

Nuclear Physics: the detailed study of the nuclei of an atom along with its structure, interaction, and reaction with other nuclei is termed Nuclear Physics.

In Nuclear Physics, we study the varying properties of the nuclei using the principle of quantum mechanics.

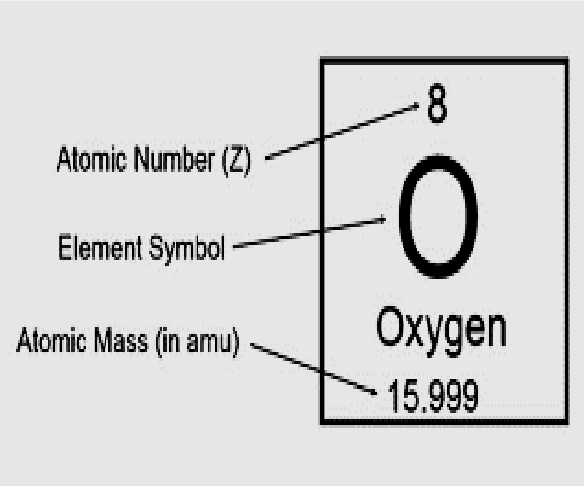
Atomic Physics: is the study of the atomic structure, whereas nuclear physics is a sub-branch of atomic science where a part of the atom we know as the nucleus, we study it in depth.

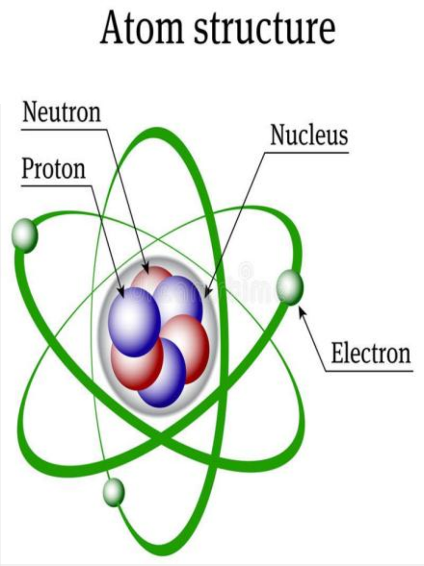
Atomic number(Z): Number of protons in an atom.

Atomic mass number(A): Number of nucleons in an atom.

A= Z + N , Z = number of protons, N = number of neutrons.

Protons and neutrons commonly called Nucleons.



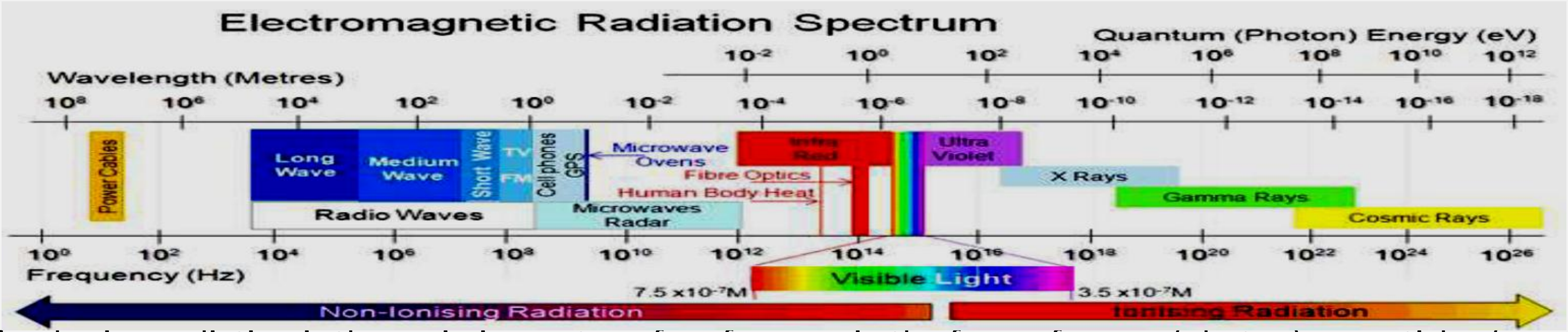


If the atom is supplied with extra energy-by strong heating or by bombardment with some fast moving particle-one or more electrons may jump from one energy level to a higher one.

The atom is then said to be in an **excited** state.

Isotopes	Isobars	Isotones
Same Atomic Number	Same Atomic mass number	Same number of Neutrons
Number of protons & electrons are same. Neutrons only differ	All neutrons, protons, and electrons differ	Number of neutrons are same . Number of electrons & Proton differ
Iso means Same, P stands for Protons	Iso means same, Baros means weight	Iso means same, N means Neutrons

Radiation is a form of energy which travels from a source as waves or as energized particles. At the lower end of the radiation spectrum we find radio waves and microwaves, which are generally considered harmless .Sunlight consists of radiation from long wavelength infrared to short wavelength ultraviolet. Beyond the ultraviolet range, the types of radiation we find have so much energy that they can knock electrons out of atoms, in a process known as **ionization**.

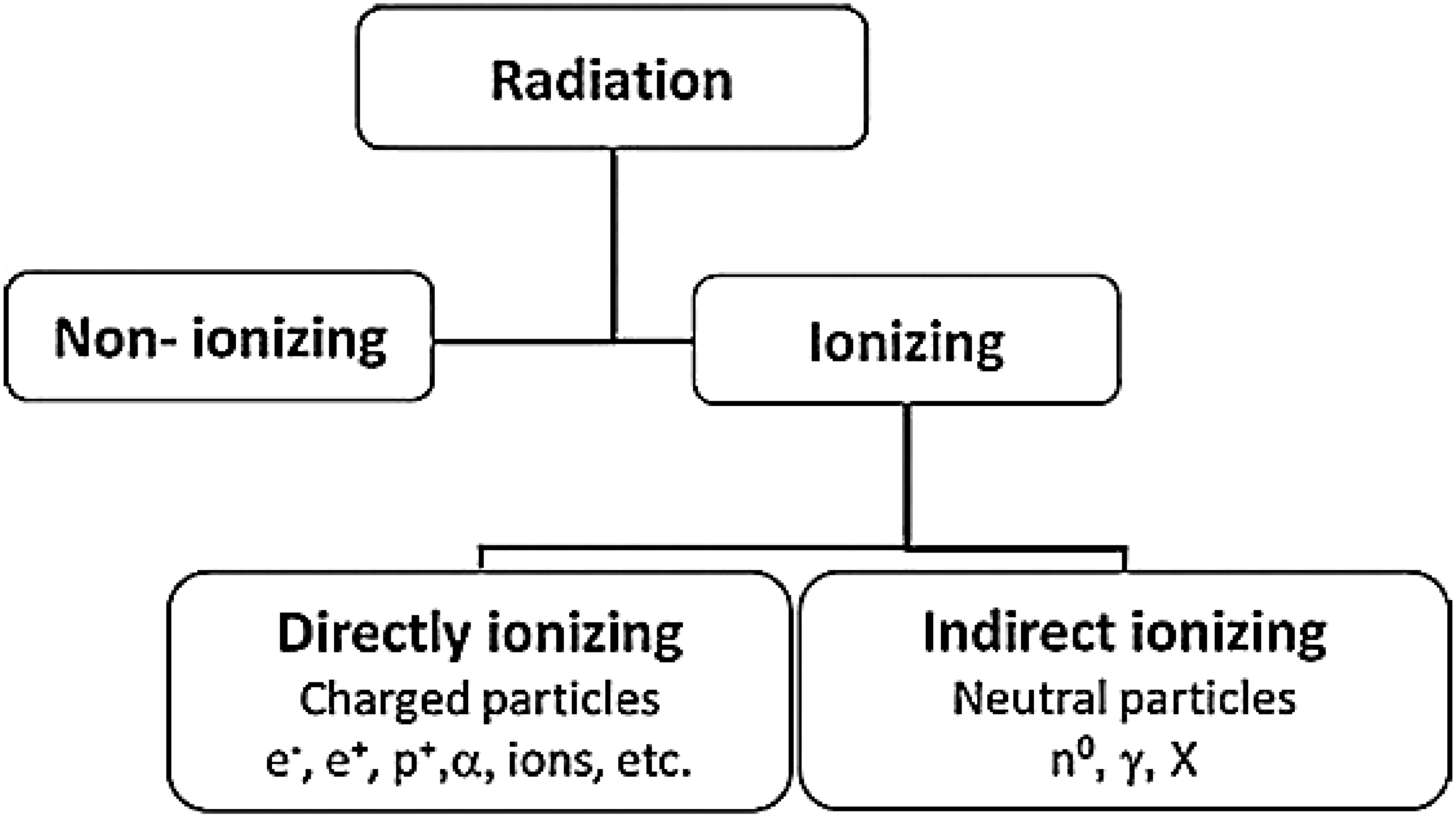


In physics, radiation is the emission or transfer of energy in the form of waves (photon) or particles (mass) through space or material medium.

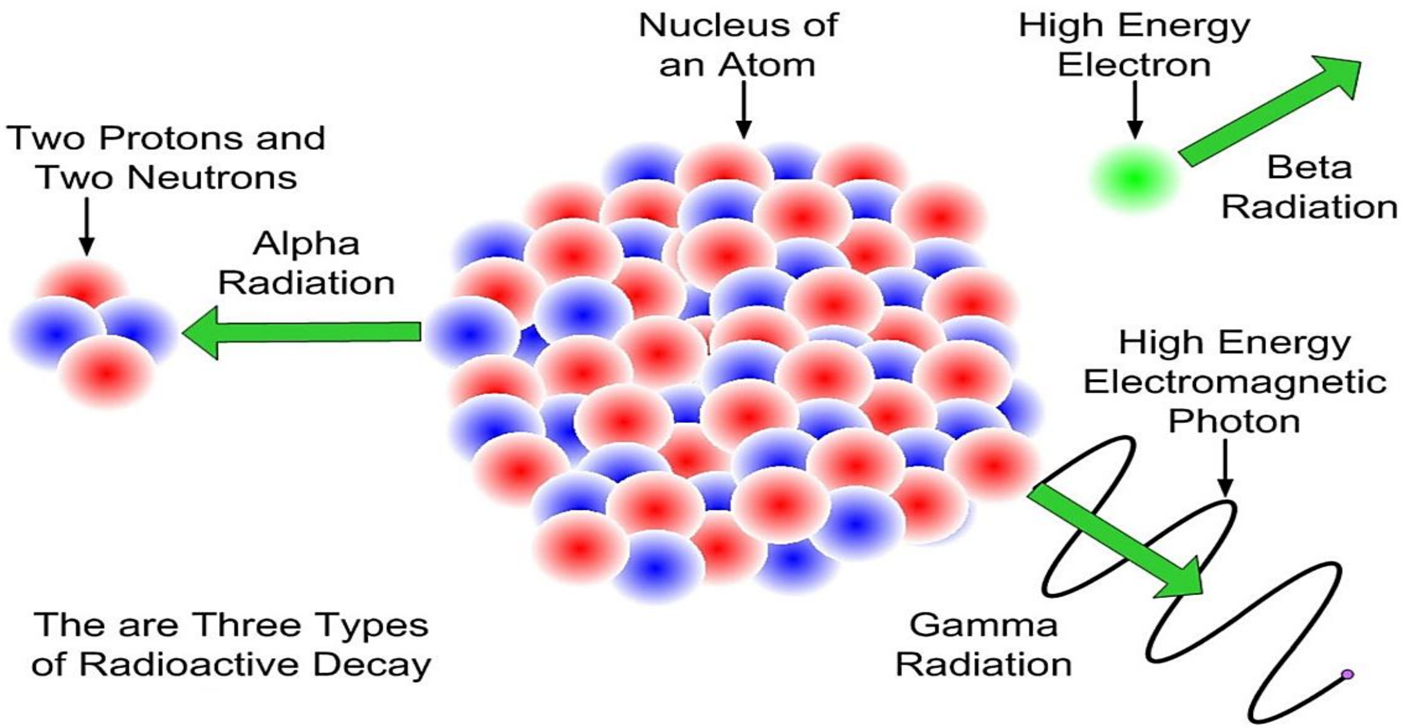
- Waves are including an electromagnetic radiation, such as radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma radiation.
- Particles are including the alpha, beta.

Nuclear Radiation

It is an energy which released via elementary particles of the atomic nucleus which is caused by the procedure of nuclear decay.


Radiation
Non- ionizing
Ionizing
Directly ionizing
Charged particles
e-, e+, p+,α, ions, etc.
Indirect ionizing
Neutral particles
n0, γ, X

Radioactive decay: is the process by which the unstable nucleus tries to change into a more stable form. As, it is the process in which the transformation will take place depending on the composition of the nucleus. It is spontaneous emission of radiation.



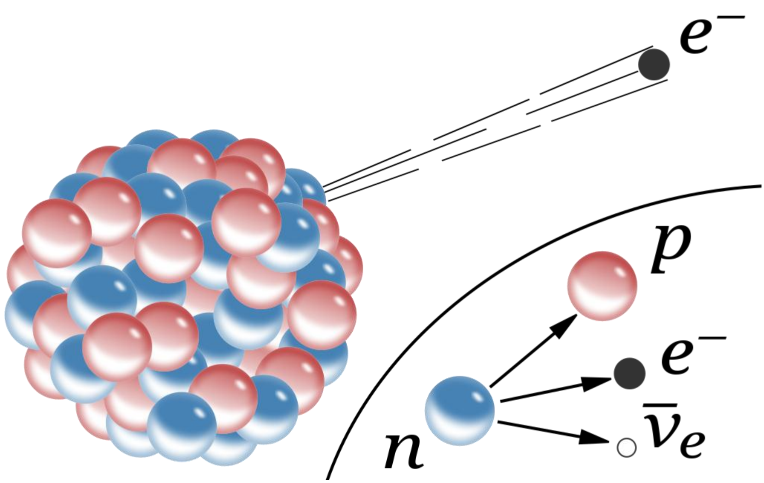
Alpha decay: happens when the unstable atom emits two protons and two neutrons, basically a helium nucleus. The original atom, with fewer protons and neutrons, becomes a different element.

Beta decay

Beta decay or (β⁻ decay) is a process in which the neutron in the nucleus is essentially transformed into a proton and electron:

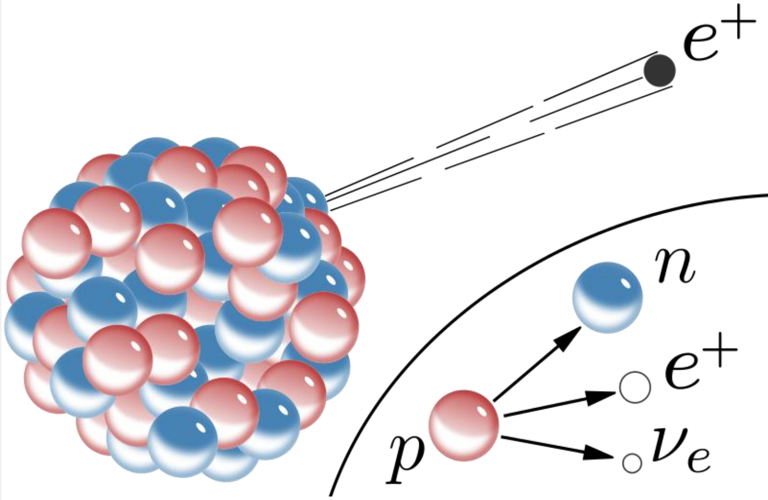
$$n \rightarrow p + \beta^- + \upsilon + \text{energy}$$

In nuclear physics, beta decay is a type of radioactive decay in which a beta particle is emitted from an atomic nucleus, transforming the original nuclide to an isobar.



Positron emission

Positron emission is a type of radioactive decay where a proton inside a radioactive nucleus is converted into a neutron while releasing a positron and an electron neutrino. This is also known as beta plus decay. A positron is a subatomic particle with the same mass as an electron and a numerically equal but positive charge. It is also called beta particle (β+ or e+). An electron neutrino (Ve) is a subatomic particle that has no net electrical charge. The positron emission takes place in proton-rich radioactive nuclei. It is used in medicine for functional imaging with the special imaging technique PET.



Gamma decay: **type of radioactivity in which some unstable atomic nuclei dissipate excess energy by a spontaneous electromagnetic process.**

Gamma rays are electromagnetic radiation with high frequency. They have10.000 times more energy than visible light. When atoms decay by emitting α or β particles to form a new atom, the nuclei of the new atom formed may still have too much energy to be completely stable. This excess energy is emitted as gamma rays. Radioactive materials that emit gamma radiation constitute both an external and internal hazard to humans. Gamma radiation frequently accompany the emission of alpha and beta radiation.

Radiation units

Quantity	SI unit	Older unit	Conversion factor (traditional/SI)	Conversion factor (SI/traditional)
Activity	becquerel (Bq); 1 Bq = 1 nuclear transformation s^{-1}	curie (Ci)	1 Ci = 3.7 10^{10} Bq	1 Bq = 2.7 10^{-11} Ci
Absorbed dose	gray (Gy) 1 Gy = 1 J kg^{-1}	rad	1 rad = 0.01 Gy	1 Gy = 100 rad
Equivalent dose or effective dose	sievert (Sv) 1 Sv = 1 J kg^{-1}	rem	1 rem = 0.01 Sv	1 Sv = 100 rem
Exposure	coulomb per kilogram of air (C kg^{-1})	roentgen (R)	1 R = 2.58 10^{-4} C kg^{-1}	1 C kg^{-1} = 3876 R

Alpha particles

The particles are helium nuclei.

- Can penetrate a piece of paper.
- Energy: a few MeV.
- Radiological hazard only if inhaled, ingested or absorbed through a wound

Beta particles

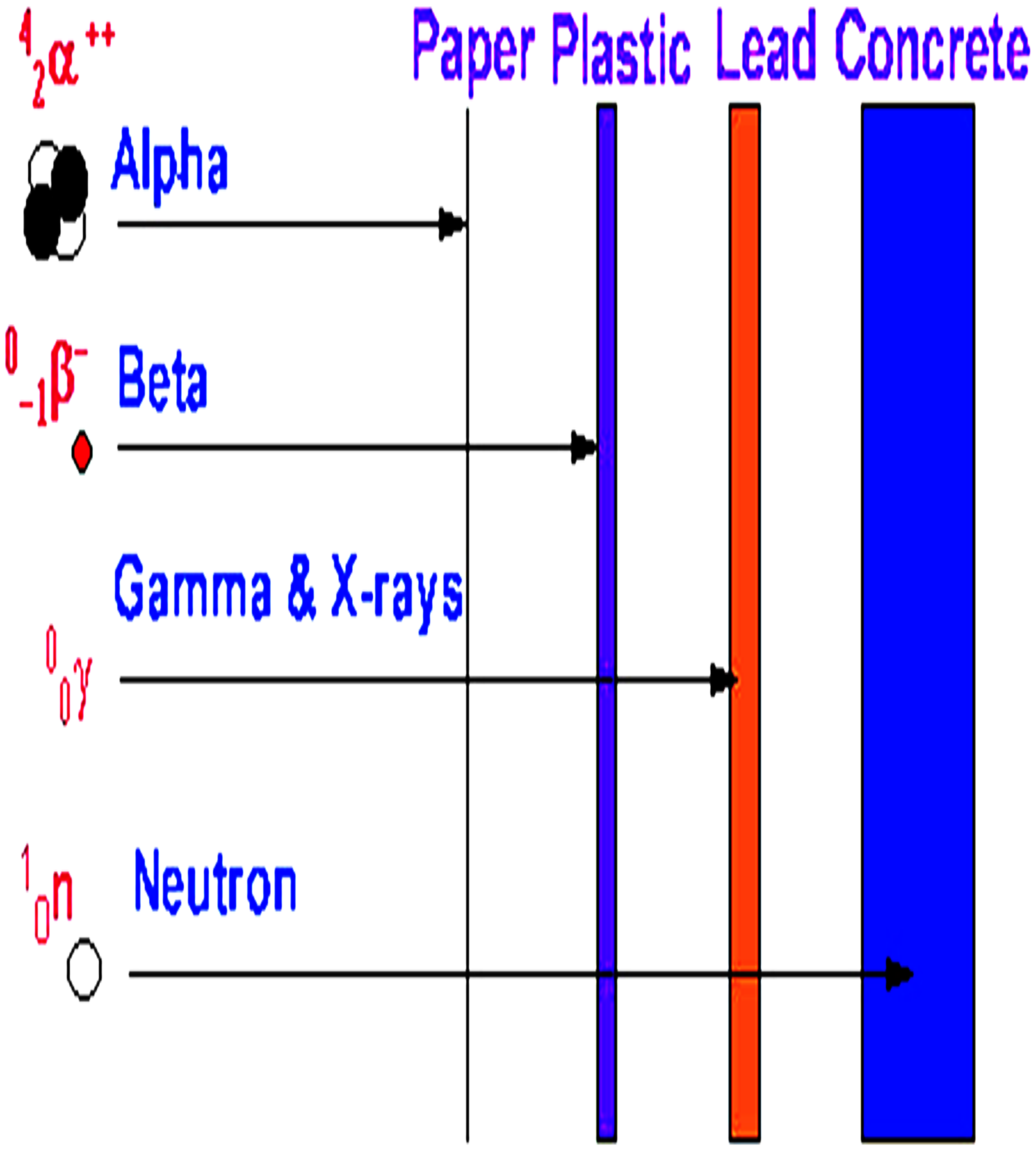
The particles are either electrons or positrons.

- positron is the antiparticle(+e) of the electron(-e)
- Energy: a few keV to a few MeV.
- Can penetrate a few mm of aluminum.
- Dangerous for skin and eyes in case of external irradiation

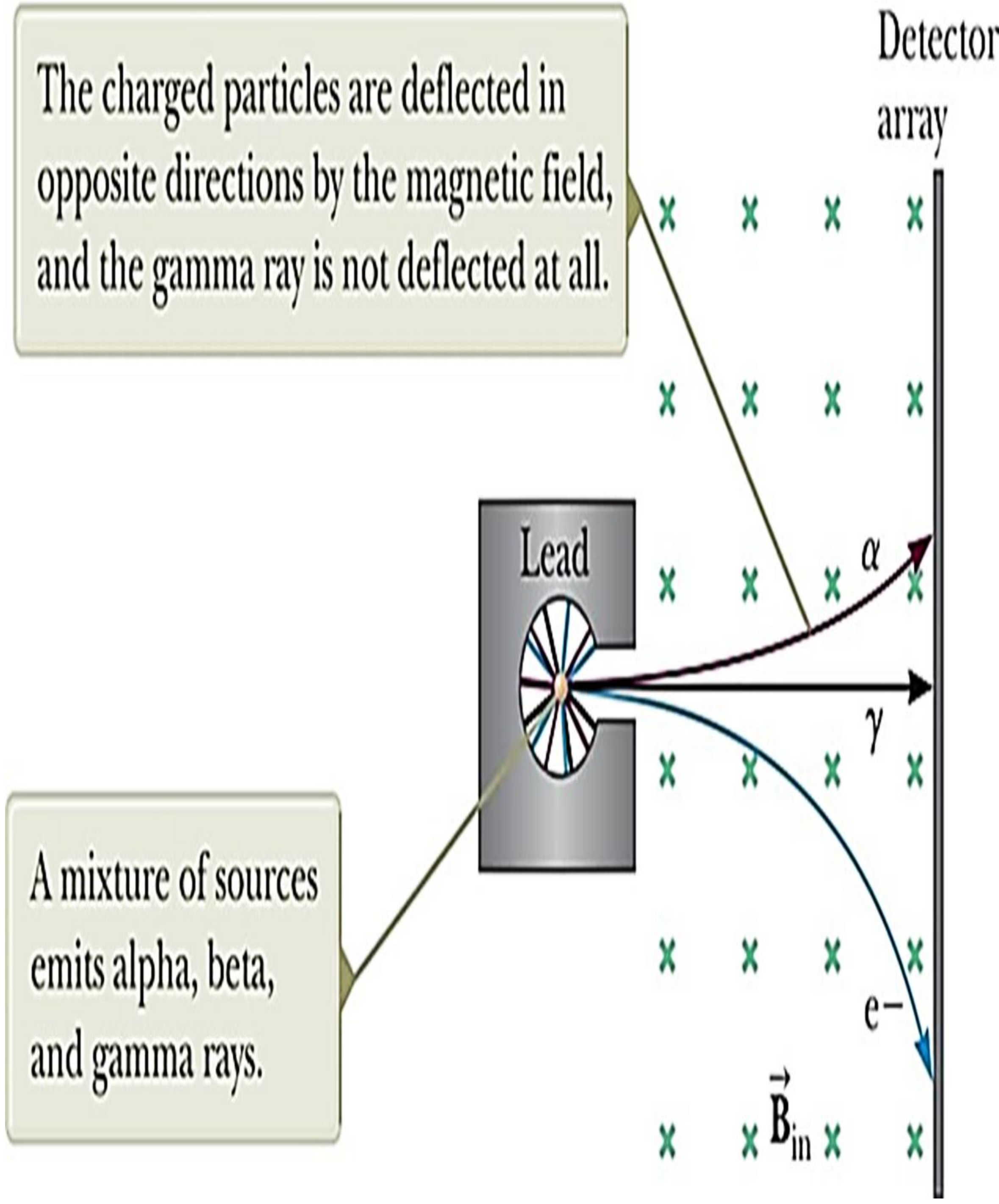
Gamma rays

The “rays” are high energy photons.

- Very penetrating.
- Neutral particles.



4 2 α ++
Paper Plastic Lead Concrete
Alpha
0 -1 β-
Beta
Gamma & X-rays
0 0 γ
1 0 n
Neutron



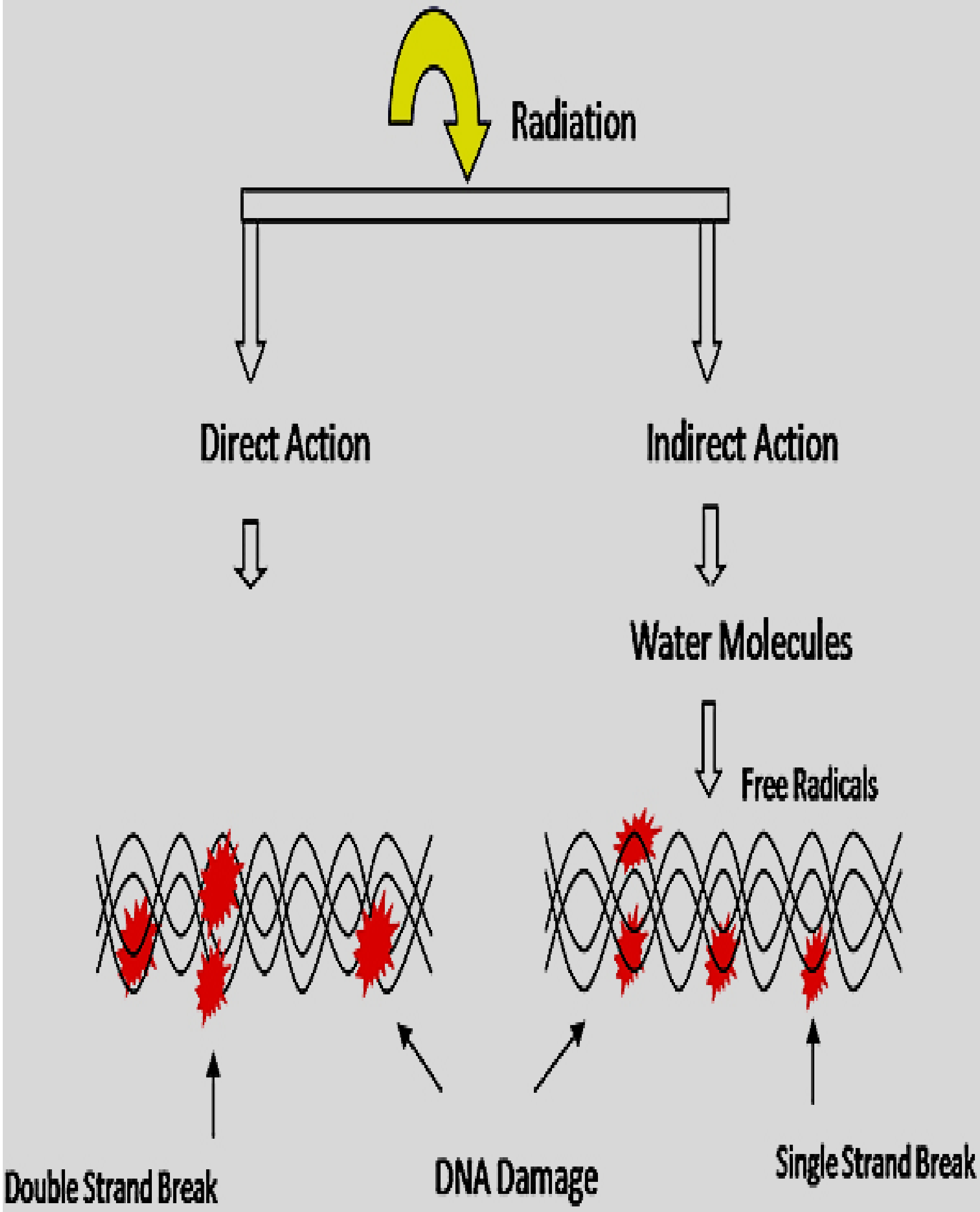
The charged particles are deflected in opposite directions by the magnetic field, and the gamma ray is not deflected at all.
Detector array
Lead
α
γ
e−
A mixture of sources emits alpha, beta, and gamma rays.
B in

Interaction of radiation with cell

Direct action: direct interaction with critical target in cell lead to destroy DNA.

Indirect action: react with H_2O in cell to form **free radical** (ionization), free radicals highly reactive, working on breakage of DNA strands , produce damage to DNA, biological effects results causing cell death.

A **free radical** is an atom or molecule that has no electrical charge, but is highly reactive because it has an odd number of electrons in its outer shell. Free radicals tend to quickly recombine to form stable electron configurations. However, in high enough concentration in the cell, they can create organic free radicals (R°) and H_2O_2 (hydrogen peroxide), a toxic molecule. OH° + RH become R°+ H_2O, and two OH° become H_2O_2. Organic free radicals in DNA lead to breakage of strands and crosslinking. OH°, since it oxidizes (removes electrons), is more damaging than H°, which is a reducing agent (gives up its electrons).



Human response to radiation

- A high level of radiation exposure delivered over a short period of time can cause biological effects within hours, days or weeks and can sometimes result in death. This is known as **acute radiation syndrome**, "**radiation sickness**" or **early effects of radiation**.
- If the biological effects of radiation can be appear after years or decays after exposure, its known as "**late effects of radiation**".
- If the biological effects of radiation appear on a new generation, its called "**genetic effects of radiation**".

Radiation Damage

Radiation absorbed by matter can cause damage. The degree and type of damage depend on many factors:

1. Type and energy of the radiation.
2. Properties of the matter.
3. Radiation’s penetrating power.

Radiation damage in biological organisms is primarily due to ionization effects in cells. Ionization disrupts the normal functioning of the cell.

Types of Damage in Cells

1. Can lead to cancer at high radiation levels.
2. Can seriously alter the characteristics of specific organisms
3. Can lead to defective offspring.

Biological effects of radiation arise when ionizing radiation interacts with an organism/tissue and leaves some energy behind.

Photons passing through matter transfer their energy through the following three main processes: Photoelectric absorption, Compton scattering, and Pair production.

Nuclear Medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease.

Radiotherapy: is the branch of medicine that deals with the treatment of some medical conditions especially cancer disease by delivering high-energy radiation beams directly to a tumor, or intended target to destroy or weaken particular cells. It is aim to deliver a precise dose of radiation to a defined tumor volume with as minimal damage as possible to surrounding normal tissues.

In radiotherapy, high-energy rays are used to damage cancer cells and stop them from growing and dividing. Cells may become cancerous due to the accumulation of defects, or mutations, in their DNA.

The interaction of radiation with a cell is a matter of chance [probability]. If an interaction occurs, the damage may not be expressed, in fact damage is more frequently repaired. The initial deposition of energy occurs very quickly. The radiation is deposited in the cell randomly and expression of damage occurs after a latent period, ranging from hours to years or even generations. The DNA is the sensitive target in the cell.

When is the radiotherapy used?

The use of radiation therapy is determined by the decision of a team of doctors, this team including a radiation oncologist, a medical oncologist and surgeon. Sometimes radiation therapy is the only treatment a patient needs. Other times, it is combined with other treatments, such as surgery and chemotherapy.

Why is the radiotherapy used?

- To cure cancer:

– Destroy tumors that have not spread to other body parts.

– Reduce the risk that cancer will return after surgery or chemotherapy.

– Shrink the cancer before surgery.

- For palliation (to reduce symptoms):

– Shrink tumors affecting quality of life, like a lung tumor that is causing shortness of breath.

– Reducing pain or neurologic symptoms by reducing the size of a tumor.

How does Radiation Therapy Work?

Radiation therapy works by damaging the DNA within cancer cells, destroying their ability to reproduce and causing the cells to die. When the damaged cancer cells are destroyed by radiation, the body naturally eliminates them. Normal cells can be affected by radiation, but they can repair themselves in a way cancer cells cannot.

How is Radiation Therapy Delivered?

Radiation therapy can be delivered either externally or internally. The type of treatment used will depend on the location, size and type of cancer.

– **External beam radiation:** therapy typically delivers radiation using a **linear accelerator**.

– **Internal radiation therapy:** called brachytherapy, involves placing radioactive sources into or near the tumor.

Difference between External Radiation Therapy and Nuclear Medicine Treatment

External radiation (Local therapy)

（Irradiate strong beam using an accelerator）

Nuclear medicine treatment (Systemic therapy)

（Internal radiation therapy by injection）

The success of radiation therapy depends on:

1. The type and extent (range) of the cancer.
2. The skill of the radiotherapist, the physician who specializes in the treatment of cancer with radiation .
3. The kind of radiation used in the treatment.
4. The accuracy with which the radiation is administered (direction) to the tumor.

The units are used to measure the amount of radiation to the patient:-

1-Erythematic dose: the quantity of x-rays that caused redding of the skin.

2-Exposure (Roentgens (R)) .

$$1R=2.58x10^{-4} \ c/kg \text{ of air.}$$

3-Absorbed dose (rad):The (rad) is defined as 100 ergs/g. that is a radiation beam that gives 100ergs of energy to 1g of tissue an absorbed dose of 1(rad) or gray =100(rad).

The (rad) can be used for any type of radiation in any material; the roentgen (R) is defined only for x-rays and γ-rays in air.

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Medical Devices

Fourth Stage

Medical Linear Accelerator (Linac)

Dr.Nasrin Nadher Jamil

Radiotherapy

Radiation therapy, also called radiation oncology, radiotherapy, or therapeutic radiology, the use of ionizing radiation (high-energy radiation that displaces electrons from atoms and molecules) to destroy cancer cells.

It is the branch of medicine that deals with the treatment of some medical conditions especially cancer disease by delivering high-energy radiation beams directly to a tumor, or intended target to destroy or weaken particular cells. It is aim to deliver a precise dose of radiation to a defined tumor volume with as minimal damage as possible to surrounding normal tissues.

It is the use of various forms of radiation to safely and effectively treat cancer and other diseases.

Difference between External Radiation Therapy and Nuclear Medicine Treatment

External radiation
(Local therapy)

（Irradiate strong beam using an accelerator）

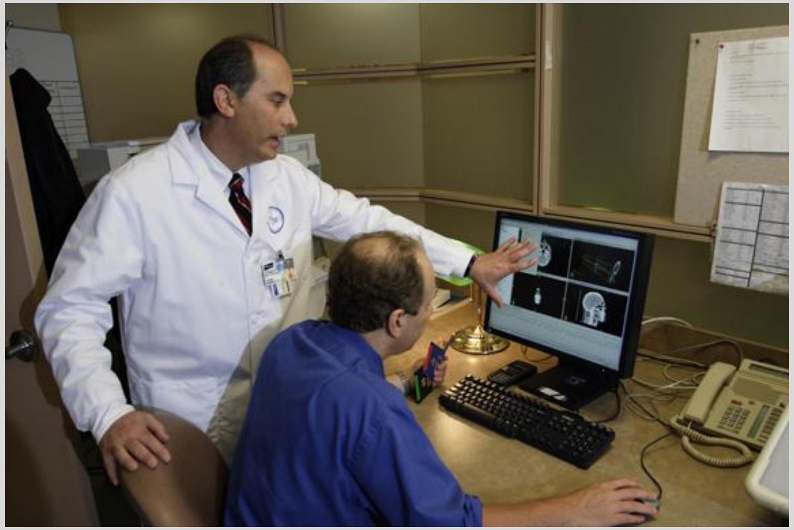
Nuclear medicine treatment
(Systemic therapy)

（Internal radiation therapy by injection）

Treatment Planning

- The radiation oncologist works with the medical physicist and dosimetrist to create an individualized treatment plan for the patient.

- The treatment is mapped out in detail including the type of machine to be used, the amount of radiation that is needed and the number of treatments that will be given.



Radiation oncologist and dosimeters creating a treatment plan

External beam machine(EBRT)

The majority of modern radiation therapy treatments are external beam teletherapy, or long-distance therapy (sometimes also called External Beam RadioTherapy ((EBRT)). External beam machines produce ionizing radiation either by radioactive decay of a nuclide, most commonly cobalt^{-60}, or through the acceleration of electrons or other charged particles, such as protons. Most radiation therapy treatments use irradiation generated by linear accelerators, which impart a series of relatively small increases in energy to particles such as protons, carbon ions. The accelerated particles bombard a target, which then produces the therapeutic beam of radiation. The energy of the beam is determined by the energy of the accelerated particles.

What is LINAC

A linear particle accelerators have many applications: they generate X-rays and high energy electrons for medicinal purposes in radiation therapy, serve as particle injectors for higher-energy accelerators, and are used directly to achieve the highest kinetic energy for light particles (electrons and positrons) for particle physics.

Linear particle accelerator (shortened to Linac) is a type of particle accelerator that greatly increases the kinetic energy of charged subatomic particles or ions by subjecting the charged particles to a series of oscillating electric potentials along a linear beam line. It is a therepatic device.

Ionizing radiation in medicine works by damaging the DNA of cells including cancer cells. Today, LINACs are used all over the world and they are one of the primary methods for healing patients from cancer diseases. They are getting more precise and focused only on contaminated tissue so the patients are getting more radiation on contaminated tissue and less on healthy tissue but with bigger power.

What is this equipment used for?

A medical linear accelerator (LINAC) is the device most commonly used for external beam radiation treatments for patients with cancer. It delivers high-energy x-rays or electrons to the region of the patient's tumor. These treatments can be designed in such a way that they destroy the cancer cells while sparing the surrounding normal tissue. The LINAC is used to treat all body sites, using conventional techniques:

Intensity-Modulated Radiation Therapy (IMRT)

Volumetric Modulated Arc Therapy (VMAT)

Image Guided Radiation Therapy (IGRT)

Stereotactic Radiosurgery (SRS)

Stereotactic Body Radio Therapy (SBRT).

Components of Linac

1. **The source:** the design of the source depends on the particle that is being moved. Electrons are generated by a cold cathode, the hot cathode and photocathode, or radio frequency ion sources. Protons are generated in an ion source, which can have many different designs.
2. A high voltage source for the initial injection of particles.
3. A hollow pipe vacuum chamber. For therapy the pipe may be only 0.5 to 1.5 meters long.
4. Within the chamber, electrically isolated cylindrical electrodes are placed. The length of each electrode is determined by the frequency and power of the driving power source and the nature of the particle to be accelerated with shorter segments near the source and longer segments near the target. The mass of the particle has a large effect on the length of the cylindrical electrodes.
5. One or more sources of radio frequency energy used to energize the cylindrical electrodes. The very high power accelerator will use one source for each electrode. The sources must operate at precise power, frequency and phase appropriate to the particle type to be accelerated to obtain maximum device power.

Components of Linac(cont.)

6. An appropriate target the electrons are accelerated to produce X-rays then water cooled tungsten target is used. Various target materials are used when protons or other nuclei are accelerated, depending upon the specific investigation.

7. The additional magnetic or electrostatic lens elements may be included to ensure that the beam remains in the center of the pipe and its electrodes.

Who operates Linac?

The patient's radiation oncologist prescribes the appropriate treatment volume and dosage. The medical physicist and the dosimetrist determine how to deliver the prescribed dose and calculate the amount of time it will take the accelerator to deliver that dose. Radiation therapists operate the linear accelerator and give patients their daily radiation treatments.

How does the equipment work?

The linear accelerator uses microwave technology (similar to that used for radar) to accelerate electrons in a part of the accelerator called the "**wave guide**," then allows these electrons to collide with a heavy metal target to produce high-energy x-rays. These high energy x-rays are shaped as they exit the machine to conform to the shape of the patient's tumor and the customized beam is directed to the patient's tumor. The beam is usually shaped by a multileaf collimator that is incorporated into the head of the machine.

The patient lies on a moveable treatment couch and lasers are used to make sure the patient is in the proper position. The treatment couch can move in many directions including up, down, right, left, in and out. The beam comes out of a part of the accelerator called a gantry, which can be rotated around the patient. Radiation can be delivered to the tumor from many angles by rotating the gantry and moving the treatment couch.

How is safety ensured?

Patient safety is very important and is assured in several ways. Before treatment is delivered to the patient, a treatment plan is developed and approved by the radiation oncologist in collaboration with the radiation dosimetrist and medical physicist. The plan is double-checked before treatment is given and quality-assurance procedures are performed to ensure that the treatment will be delivered as planned.

Quality assurance of the linear accelerator is very important. There are several systems built into the accelerator so that it will not deliver a higher dose than the radiation oncologist has prescribed. Each morning before any patient is treated, the radiation therapist performs checks on the machine to make sure that the radiation intensity is uniform across the beam and that it is working properly. In addition, the medical physicist conducts more detailed monthly and annual checks of the linear accelerator.

Modern linear accelerators also have internal checking systems that do not allow the machine to be turned on unless all the prescribed treatment requirements are met.

During treatment, the radiation therapist continuously observes the patient using a closed-circuit television monitor. There is also a microphone in the treatment room so that the patient can speak to the therapist if needed. Port films (x-rays taken with the treatment beam) or other imaging tools such as cone beam CT are checked regularly to make sure that the beam position doesn't vary from the original plan.

Safety of the **staff** operating the linear accelerator is also important. The linear accelerator sits in a room with lead and concrete walls so that the high-energy x-rays are shielded and no one outside of the room is exposed to the x-rays. The radiation therapist must turn on the accelerator from outside the treatment room. Because the accelerator only emits radiation when it is actually turned on, the risk of accidental exposure is extremely low.

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Medical Devices

Fourth Stage

Positron Emission Tomography (PET)

Dr.Nasrin Nadher Jamil

What is a PET scan?

Positron emission tomography (PET) also known as PET imaging or scan, is a type of nuclear medicine imaging, which identifies changes at the cellular level, thus helping to diagnose a disease even in the early stages. It uses the unique decay characteristics of radionuclides that decay by positron emission.

PET is a nuclear medical imaging technique which produces a 3D image of functional processes in the body by detecting the radiation emitted by photons.

PET scan is usually non-invasive and painless, except when you receive injections. It uses small amounts of radioactive materials called **radiotracers** or **radiopharmaceuticals**, which accumulate in the regions of tumour or inflammation or bind to specific proteins. Based on the type of exam, the radiotracer is either injected, swallowed or inhaled as a gas. The radiotracers emit radioactive emissions, which are detected by a special camera or device, which is connected to a computer that produces images of the organ or tissue.

What is a PET scan used for?

A PET scan can show how well certain parts of your body are working, rather than simply showing what they look like.

PET scans are particularly helpful for investigating confirmed cases of cancer to determine how far the cancer has spread and how well it's responding to treatment.

Uses of PET scan:

- **Cancer:**

1.detection, staging, response to treatment.

2.differentiation between radiation necrosis and recurrence.

- **Neurology:**

1.early diagnosis of Alzheimer's disease

2.localization of seizure focus in interictal phase

3.localizing eloquent areas (e.g. speech, motor function)

- **Heart:**

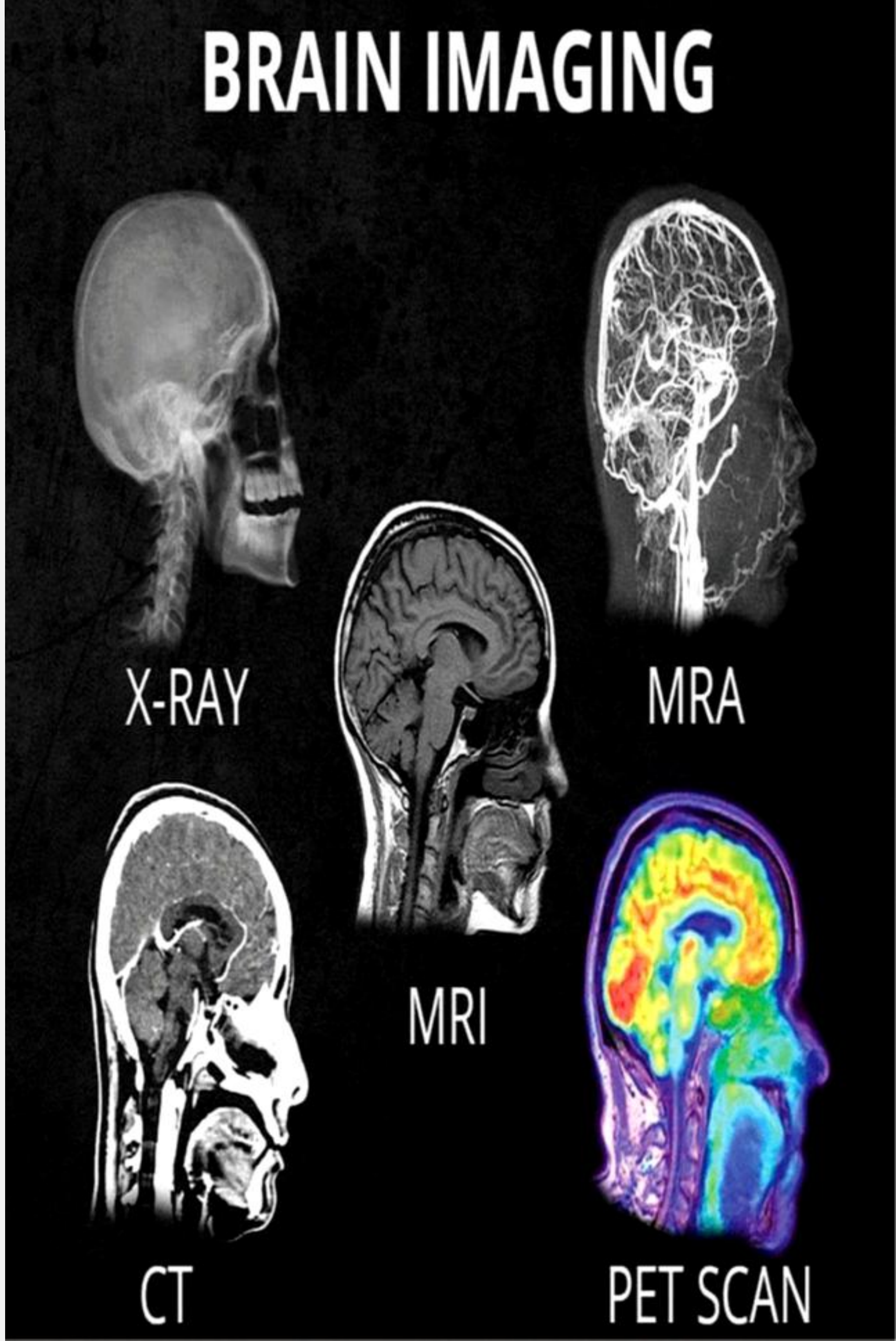
identification of hibernating myocardium

PET vs. CT and MRI

PET is a unique type of medical imaging that reveals information about the physiology of organs and tissues, unlike CT or MRI machines which only yield images of anatomy. By doing this, PET scans can often detect irregularities such as cancer significantly earlier than other diagnostic tests.

MRI and many other procedures where we can see normal or diseased tissues in the body. They tell us 'the location' (position) in the body the image corresponds to. If we wanted to see what were happening in these locations, we would then need to perform functional imaging techniques like PET scan.

PET works by injecting a radioactive tracer into the patient which is taken up in different parts of the body by varying amounts; the positron decay of the tracer is detected and an image of the body is reconstructed from this data.



PET scans use a radioactive tracer to show how an organ is functioning in real time. PET scan images can detect cellular changes in organs and tissues earlier than CT and MRI scans. Your healthcare provider may perform a PET scan and CT scan at the same time (PET-CT). This combination test produces 3D images that allow for a more accurate diagnosis.

Some hospitals now use a hybrid PET/MRI scan. This new technology creates extremely high-contrast images. Providers mainly use this type of scan for diagnosing and monitoring cancers of the soft tissues (brain, head and neck, liver and pelvis).

Unlike other imaging techniques, PET scans focus on processes and molecular activity within your body. This gives them the potential to find disease in its earliest stages.

Diseased cells in your body absorb more of the radiotracer than healthy ones do. These are called "**hot spots**." The PET scanner detects this radiation and produces images of the affected tissue. A PET/CT scan combines X-ray images from a CT scan with PET scan images.

Anatomic vs. Functional Imaging

- Anatomic Imaging
  - Physical Structures, Bulk Properties of Patient
  - Generally Very High Resolution Images (~1mm or less)
  - X-Ray/CT, MRI, Ultrasound
- Functional Imaging
  - Biochemical Processes Ongoing in Patient
  - Generally Poorer Resolution (~4-5mm or more)
  - Radioisotope Techniques: NM /SPECT, PET
  - Other Techniques: MR (MRS, fMRI), MEG (MSI), ...

PET/CT Scan

PET/CT is a nuclear medicine test that uses special imaging cameras and a radioactive solution called FDG (Flurodeoxyglucose) to create very clear pictures of a cell's metabolism and if it is abnormal. CT uses X-rays to provide detailed anatomical information, including the location, size and shape of lesions or tumors in the body. When both applications are combined together, the two techniques provide accurate and specific information about where abnormalities are located and whether they are cancerous.

Positron Emission Tomography (PET) imaging is most useful in combination with anatomical imaging, such as CT, modern PET scanners are now available with an integrated CT scanner.

Because the two scans can be performed in immediate sequence during the same session, with the patient not changing position between the two types of scans, the two sets of images are more precisely registered, so that areas of abnormality on the PET imaging can be more perfectly correlated with anatomy on the CT images.

These images will allow the radiologist to determine if your organs are functioning appropriately.

- Functional imaging obtained by PET, which depicts the spatial distribution of metabolic or biochemical activity in the body can be more precisely aligned or correlated with anatomic imaging obtained by CT scanning. Two- and three-dimensional image reconstruction may be rendered as a function of a common software and control system.
- PET scans show metabolic changes occurring at the cellular level in an organ or tissue. This is important because diseases often begin at the cellular level. CT scans and MRIs cannot reveal problems at the cellular level.
- PET scans can detect very early changes in your cells. CT scans and MRIs can only detect changes later, as a disease alters the structure of your organs or tissues. Detection of illness at the cellular level gives your doctor the best view of complex systemic diseases.

How is it performed?

- Before the scan takes place a small amount of radioactive material is injected into the body, this is carried round by the bloodstream, collecting in certain areas. This is called a ‘tracer’. This fluid usually takes about an hour to travel round the body, allowing cells to absorb it. After that time, scanning begins. This may take 30 to 45 minutes.

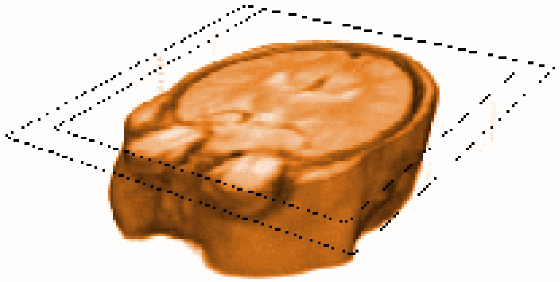
These substances are injected into the body, and are usually tagged with a radioactive atom (C^{-11}, F^{-18}, O^{-15} or N^{-13}) that has short decay time. A typical dose would be 14 mSv.

- Some patients, specifically those with heart disease, may undergo a stress test in which PET scans are obtained while they are at rest and again after undergoing the administration of a pharmaceutical to alter the blood flow to the heart.

- Usually, there are no restrictions on daily routine after the test, although you should drink plenty of fluids to flush the radioactive substance from the body.

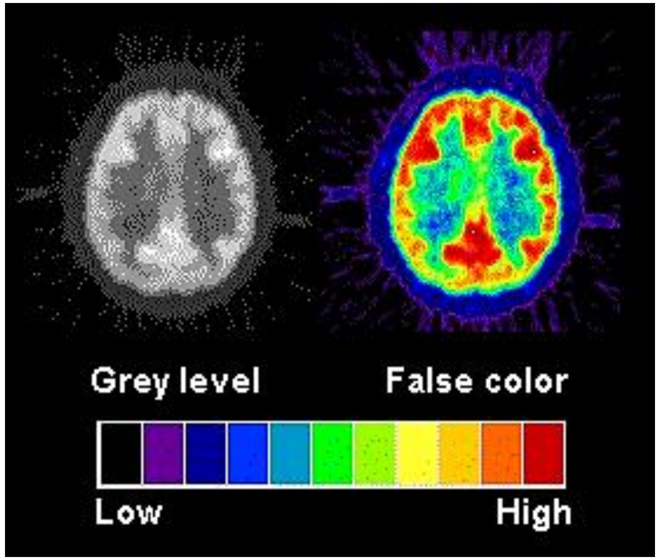
After injecting the radiopharmaceutical, the patient is placed on a special moveable bed which slides by remote control into the circular opening of the scanner (called gantry). Placed around this opening, and inside the gantry, there are several rings of radiation detectors. Each crystal detector emits a brief pulse of light every time it is struck with a gamma ray coming from the radioisotope within the patient's body. The pulse of light is amplified (increased in intensity), by a photomultiplier, and the information is sent to the computer which controls the apparatus. The whole process is called **scintigraphy** (from scintillation, which is the pulse of light).

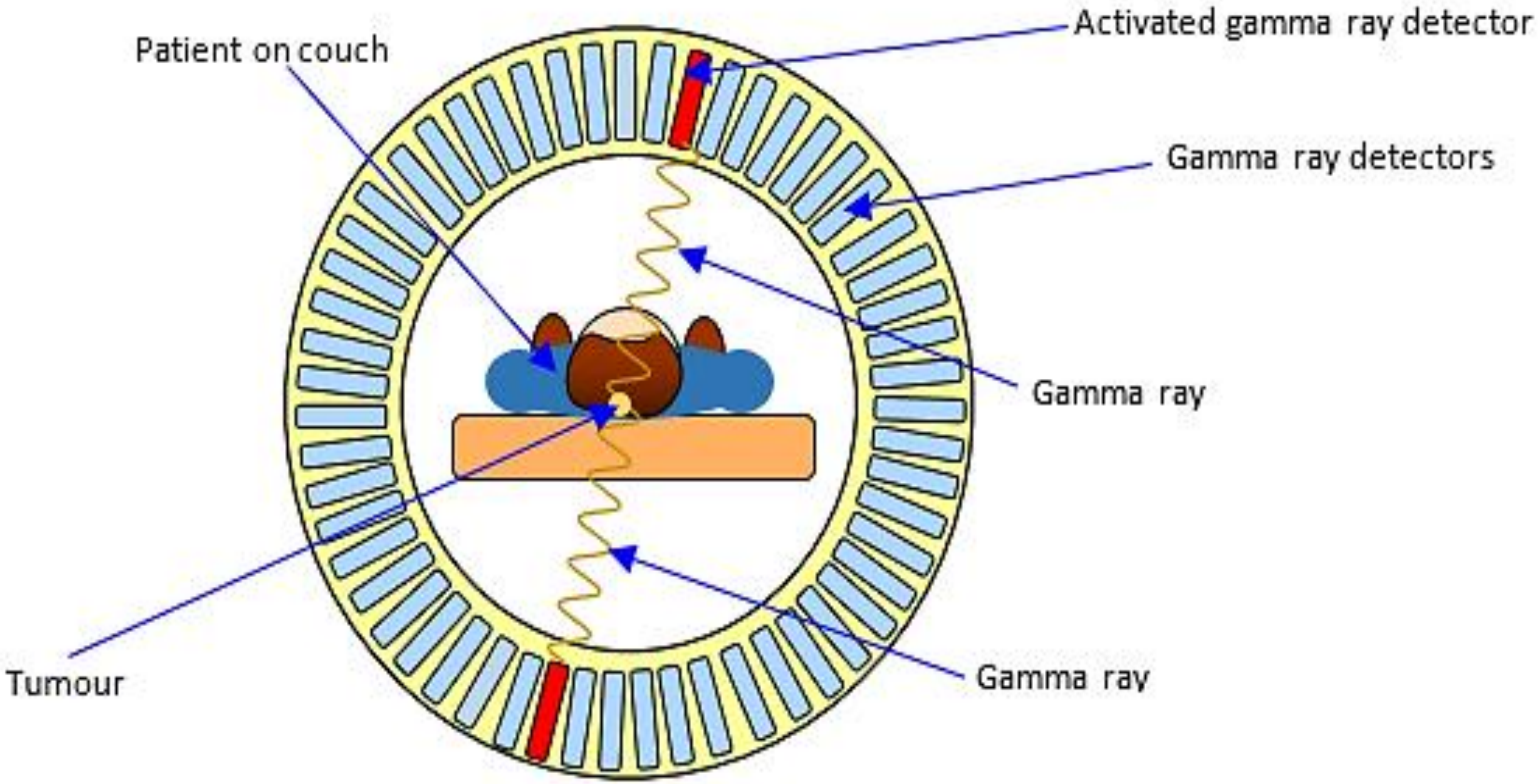
Since the gamma radiation emitted inside the brain is symmetrical, a pair of detectors positioned at 180 degrees of each other will sense simultaneously both rays.



The computer working with the scintigraphy data, reconstructs the exact places inside the brain where each pulse of radiation came from. It also counts the number of pulses per second coming from each point of the image. That's because the brain structures which have higher concentrations of the injected radiopharmaceutical emit a higher amount of radiation, meaning that they are more active in terms of cell metabolism or blood circulation.

The number of radiation pulses counted by the computer during a fixed interval of time is displayed in its video screen as a dot, with its intensity shown in shades of gray (gray levels). Black means no activity (zero counts), and pure white the highest count level. The same image can be displayed in false color, which is able to show in a better contrast the "hot" regions. The false color scale converts each level of gray into a shade of color, like in a rainbow, being red the highest activity count, then coming yellow, then green, and so forth. Blue, violet and black represent the lowest levels of activity.



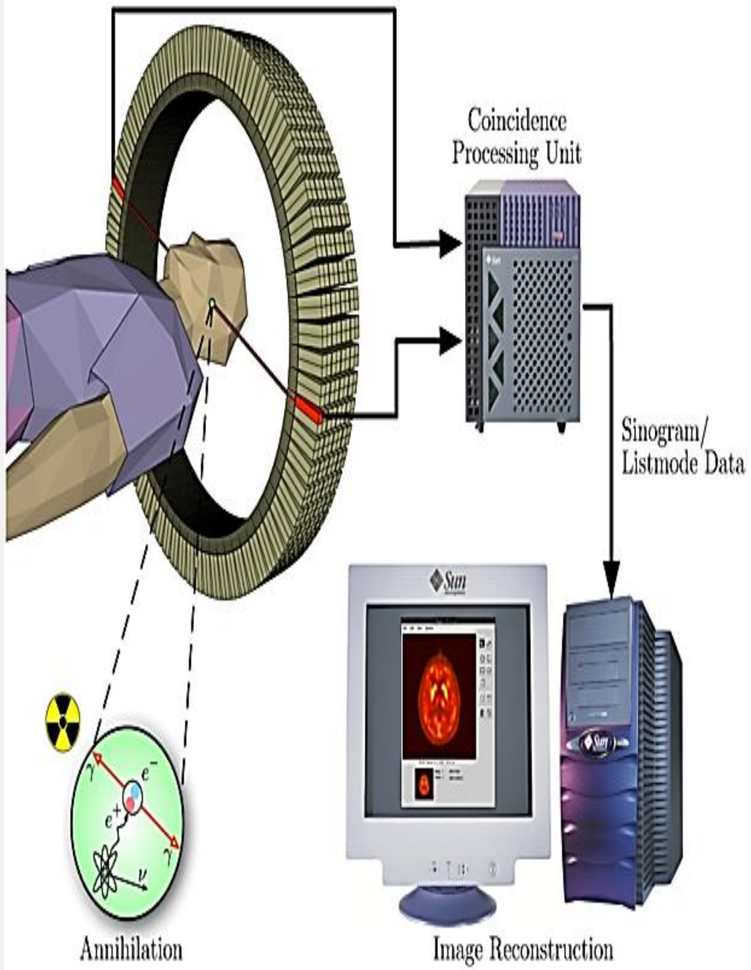


Positron emission tomography (PET) scanner

The Physics of PET

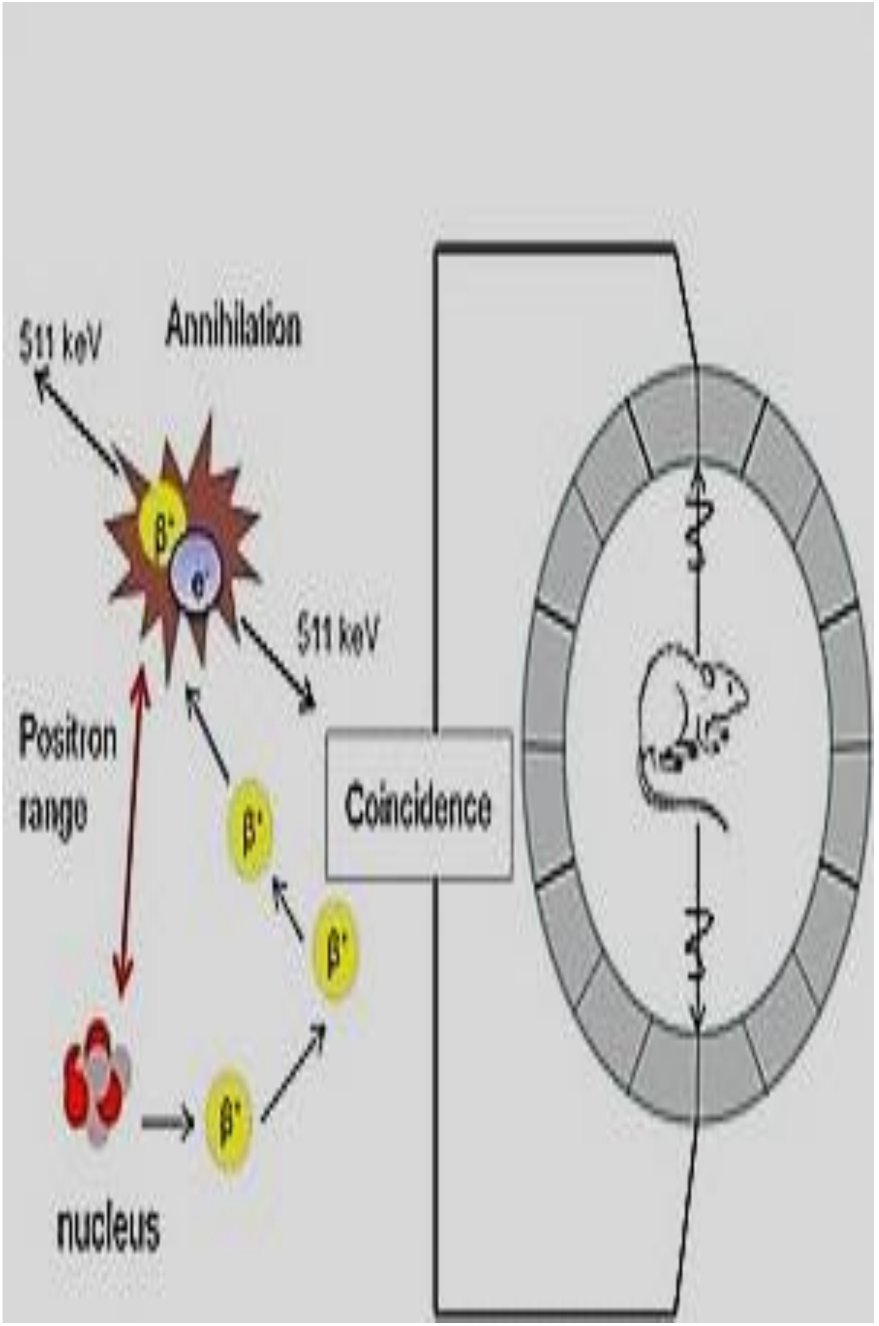
The radioactive decay mechanism for positron emitters used in PET is **positron emission**, whereby a proton in the nucleus is transformed into a neutron and a positron. Certain radioisotopes decay by positron emission, and such radioisotopes can be used as tracers. A tracer is essentially a biological compound of interest labelled with a positron emitting isotope, such as ^{11}C, ^{18}F, and ^{15}O. These isotopes are used because they have relatively short half-lives (minutes to less than two hours), allowing the tracers to reach equilibrium in the body, but without exposing the subjects to prolonged periods of radiation.

If injected into the body, they can be readily followed because the emission of the annihilation pairs of coincident gamma rays at 180° allows their source to be located along a line. Data collection for emissions at several angles permits precise location of any concentration of the radioisotope. An image of a slice of the body (called a tomograph) can be constructed by using a ring of detectors.



When a positron is emitted by a nucleus, it almost instantly finds an electron and the pair annihilates, converting all the mass energy of the two particles into two gamma rays. The two gamma ray photons possess momentum, and the conservation of momentum requires that they travel in opposite directions. A simultaneous detection of gamma ray photons in two detectors places the source on a line between those detectors.

These two photons are detected by the PET camera and simultaneously localized within a fixed period of time by a series of opposing detectors, which correspond to multiple rings of scintillation crystals. By collecting a statistically significant number of radioactive events, mathematical algorithms reconstruct a three-dimensional image that shows the distribution of the positron-emitting molecules in the brain.

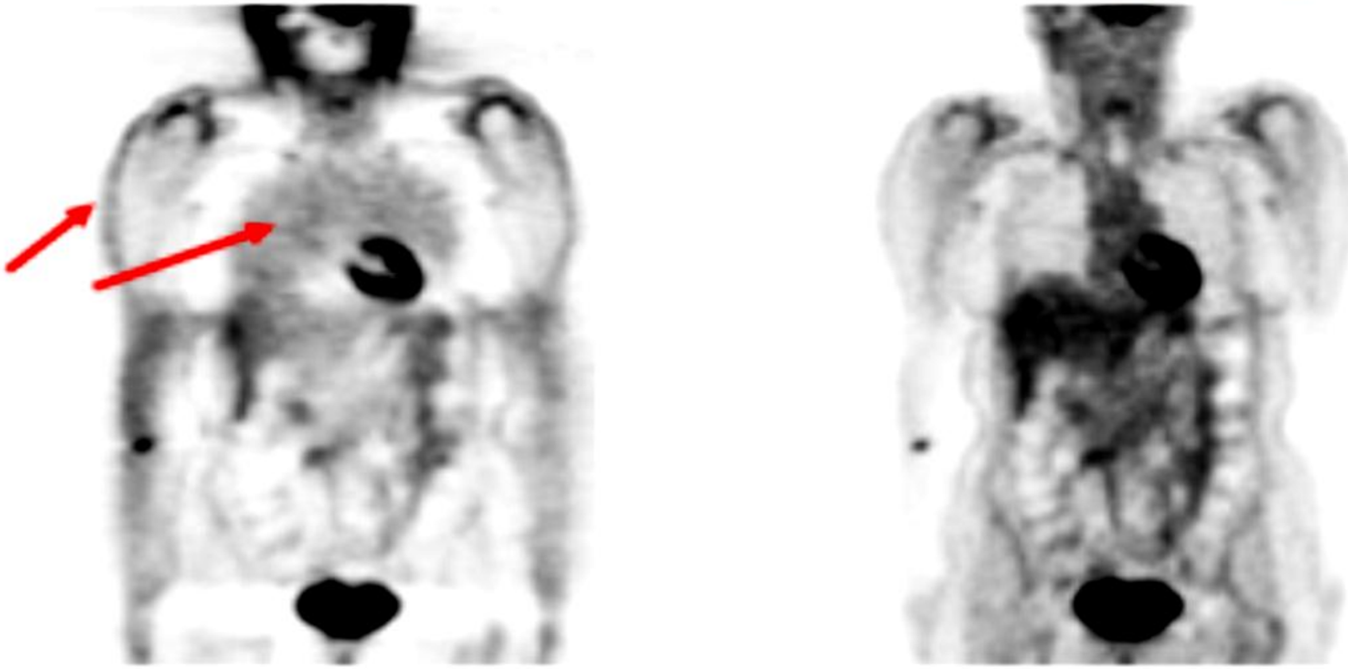


The Physics of PET(cont.)

For a given location, you can sum the signal from all detector pairs that correspond to a line going through that location. All directions are equally probable for a given location, so you can normalize the signal as a measure of the concentration of the radioisotope at that location.

A positron emitter that can be inserted into a glucose molecule is the fluorine isotope 18F. Not only does the glucose pass the blood-brain barrier and enter the brain easily, the concentration of the radioactively tagged glucose is a measure of the level of metabolic activity at that location in the brain.

Imaging using radioactive materials: Positron emission tomography



- Regions of high metabolic activity appear dark through radioactive labeling
- In raw images lungs and skin show higher tracer uptake than muscle
- Images require attenuation correction based on patient anatomy (use CT image acquired with PET)

Synthesis of radiotracers

(FDG). The radiotracers used in a PET scan are synthesised in a cyclotron. The synthesis of radiotracers can be summarised into two stages: firstly a radioactive isotope with a short half-life is created by proton bombardment, and then this radioisotope is chemically incorporated into a biological molecule. The radioactively labelled biological molecule is taken up by the body, and higher concentrations of it show up as hot spots on the scan. The most commonly used radiotracer in PET is fluorodeoxyglucose

For FDG synthesis, the target used is enriched water (H**2**18O). Protons accelerated by the cyclotron knock and replace neutrons from the isotope of oxygen, forming radioactive F-18:

$$^{18}_{8}O + ^{1}_{1}p \rightarrow ^{18}_{9}F + ^{1}_{0}n + \gamma$$

Since the half-life of F-18 is only 110 minutes, it has to be incorporated into glucose to form FDG very quickly. This is done via a complicated chemical process that is usually automated. The end product, FDG is identical to glucose, except that the second OH group has been replaced by the radioactive F-18 made in the cyclotron:

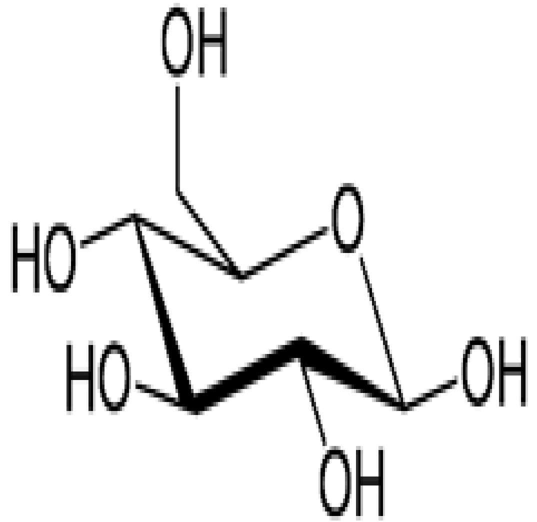
Decay and distribution of FDG

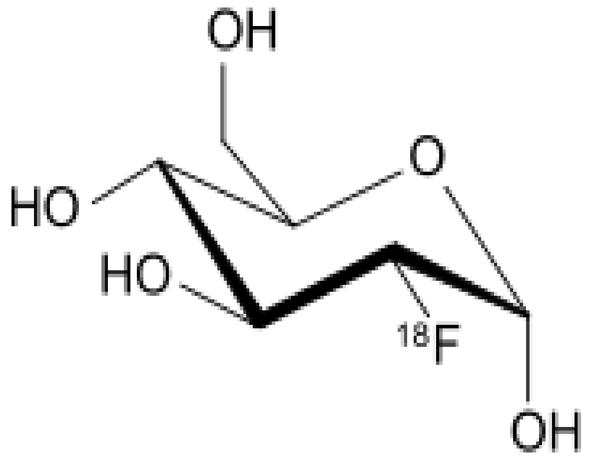
When FDG taken up into a cell, it is phosphorylated into FDG-phosphate, and this molecule cannot be broken down further, so is therefore trapped in the cell. Cancerous cells divide much faster than normal body cells, so their energy needs are much higher. This means that more FDG would be taken up by a cancer cell as compared to a normal cell; resulting in a hot spot on the scan.

Atoms decay when the ratio of protons to neutrons in the nucleus is skewed, a proton enriched nucleus like in F-18 would try to lose its extra proton to become O-18. It does this by positron emission:

$$^{18}_{9}F \rightarrow \, ^{18}_{8}O + \, ^{0}_{1}\beta^{+} + v_e$$

Essentially, a proton in the nucleus of F-18 turns into a neutron, releasing a high-speed positron (β+) and a neutrino. When this decay is complete, the FDG becomes glucose-phosphate, which can be metabolised normally





Skeletal formula of FDG (bottom) and glucose (top). The second OH group is replaced by radioactive F-18.

Positron Emission

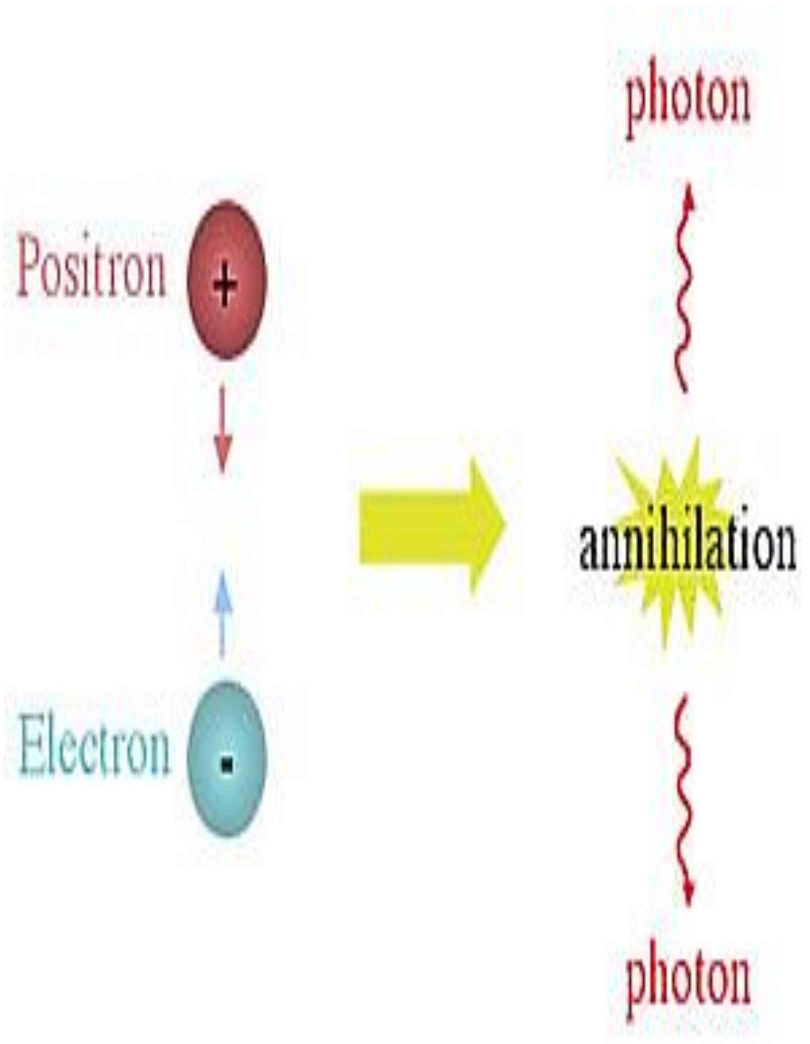
The positron (β+) has exactly the same mass and same magnitude of charge as the electron except that the charge being carried is positive.

For positron emission to be energetically feasible, the total energy difference between the parent and the daughter states should be at least 1.022 MeV. Positron emitters are of special interest in medicine because the main elements (e.g. carbon, oxygen and nitrogen) that constitute living organisms have isotopes that emit positrons.

The positron will have some initial energy after emission from the parent nucleus.

It travels a short distance from the nucleus, scatters and collides with loosely bound electrons nearby before fusing with one of them to form positronium and then annihilates.

Their mass converts into energy in the form of two 511 keV emitted 180° to each other of these two 511 keV photons forms the basis of PET imaging. The probability that both 511 keV photons will escape from the body without scattering is very high and both photons can be detected with two detectors at opposite ends of the line.



Limitations

- PET can give false results if a patient's chemical balances are not normal. Specifically, test results of diabetic patients or patients who have eaten within a few hours prior to the examination can be adversely affected because of blood sugar or blood insulin levels.
- Also, because the radioactive substance decays quickly and is effective for a short period of time, it must be produced in a laboratory near the PET scanner.
- It is important to be on time for the appointment and to receive the radioactive substance at the scheduled time. PET must be done by a radiologist who has specialized in nuclear medicine and has substantial experience with PET. Most large medical centers now have PET services available to their patients.
- The value of a PET scan is enhanced when it is part of a larger diagnostic work-up. This often entails comparison of the PET scan with other imaging studies, such as CT or MRI.

For Medical Devices Lab.

How do I prepare for a PET scan?

PET scans are an outpatient procedure, which means you go home the same day. Your healthcare provider will give you detailed instructions on how to prepare for the scan. In general, you should:

- Make sure your provider has a current list of all medications, vitamins and supplements you take, as well as any allergies you have.
- Alert your provider if you think you could be pregnant or if you're breastfeeding (chest feeding).
- Not eat anything for six hours before the test. Your healthcare provider may change this direction if you have diabetes.
- Drink only water.
- Avoid caffeine for 24 hours before the test if you're being tested for a heart problem.
- Wear comfortable clothes and leave metal accessories, such as jewelry, eyeglasses, dentures and hairpins at home.
- Tell your healthcare provider if being in an enclosed space makes you anxious. You may be able to take a mild sedative to help you relax during the procedure.

What should I expect during a PET scan?

- You’ll receive an IV injection of a radiotracer that contains a safe amount of a radioactive drug. The most commonly used radiotracer is fluorodeoxyglucose (FDG).
- You’ll sit in a chair for about an hour while the radiotracer moves through your bloodstream and gets absorbed by your organs and tissues. Too much activity can send the radiotracer to areas of your body that your healthcare provider isn’t testing. You won’t be able to feel the radiotracer.
- If you’re getting a PET/CT scan, you may also get an IV injection of a contrast dye. This dye helps produce sharper CT images.
- You’ll lie on an exam table that slides in and out of the PET/CT scanner. This scanner is shaped like a doughnut. The doughnut or tunnel opening is about 30 inches in diameter.
- During the scan, which usually takes about 30 minutes, you must remain still. Movement can blur the images.
- You’ll hear buzzing and clicking sounds as the scanner takes images.
- A technologist will review the scans before you leave to ensure the images are in focus.

Ministry of Higher Education
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UNIVERSITY OF ANBAR
Applied Science College – Heet
Dept. of Biophysics

Medical Devices

Fourth Stage

Computed Tomography (CT)

Dr.Nasrin Nadher Jamil


SOMATOM
Definition AS

What is CT SCAN?

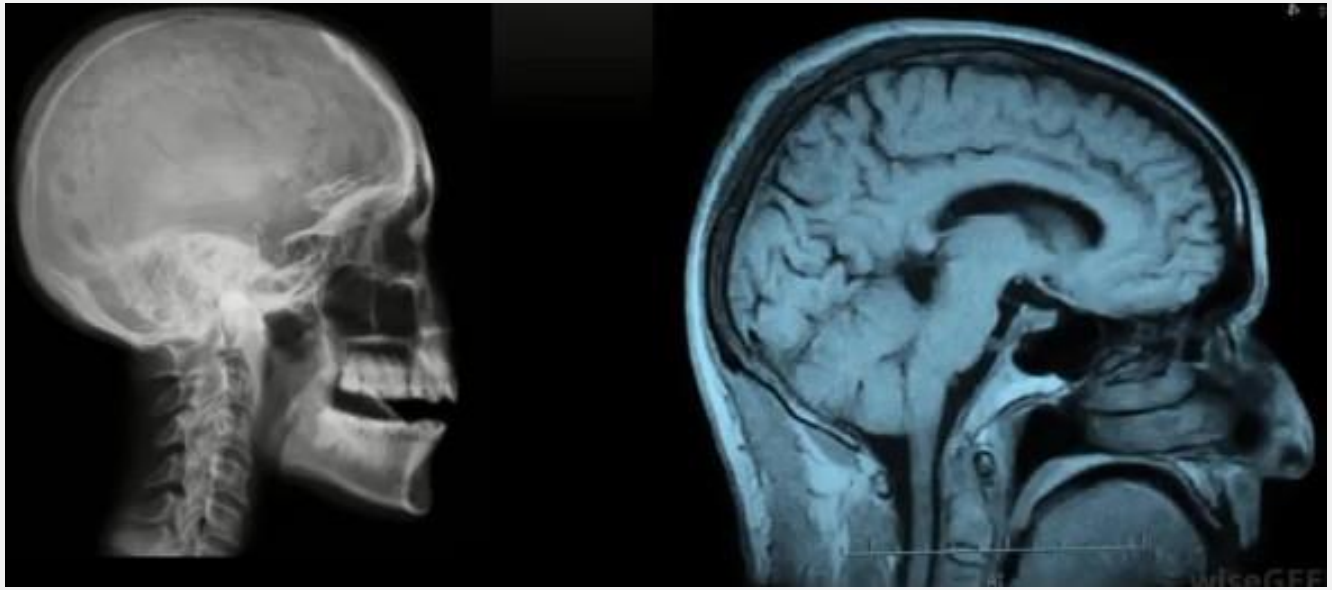
- **A CT scan or computed tomography scan (formerly known as Computed Axial Tomography or CAT scan) is a medical imaging technique used in radiology to get detailed images of the body noninvasively for diagnostic purposes.**
- **CT scan, uses X-rays and a computer to take detailed pictures of the organs. These pictures look like cross-sections or "slices" of the body that are then put together by the computer.**
- **Tomography comes from the Greek word tomo meaning "section" or "cut" and graph meaning write. A conventional tomogram is an image of a section of a patient parallel to the film. With the development of technologies, parallel sections were overcome by cross-sections and conventional tomography was replaced with computerised tomography.**
- **It is one of the diagnostic tools and a medical imaging procedure that uses a special kind of X-ray machine. Instead of sending out a single X-ray through the body as with ordinary x-ray, several beams are sent at the same time from different angles. This allows more detailed images from within the body to be constructed, allowing the user to see inside the object without cutting and these images are then interpreted by a doctor.**

How is CT different from a regular x-ray?

During a regular x-ray procedure, a stationary machine sends x-rays through the body to make a single "shadow" picture. A conventional X-ray image is basically a shadow. You shine a "light" on one side of the body, and a piece of film on the other side registers the silhouette of the bones.

In CT, the x-ray machine rotates around the body, taking multiple pictures at different angles that allow a computer to make a detailed image of the patient's anatomy. This 3D imaging system provides much more information than a regular x-ray.

X-ray



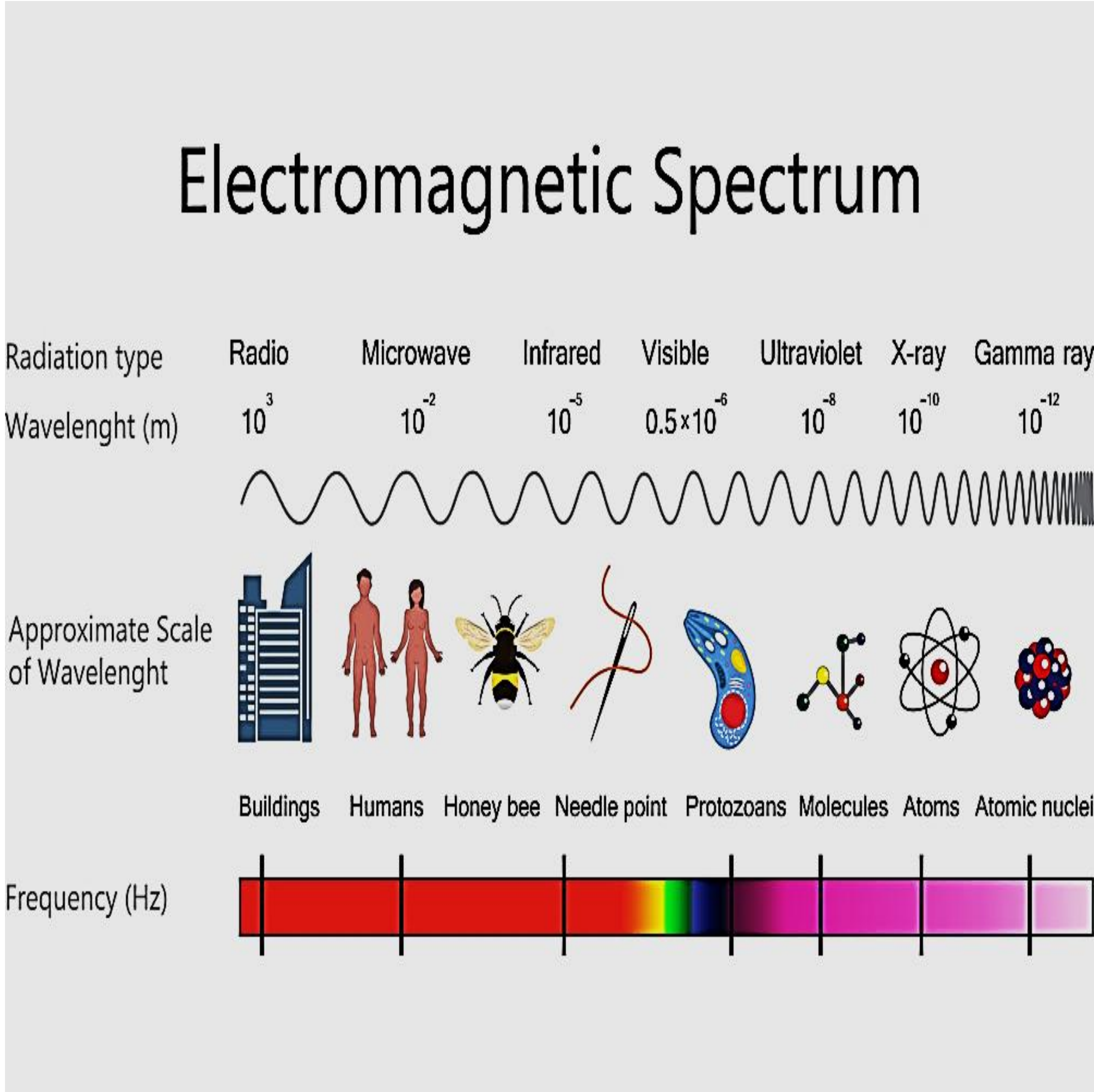
CT

Why X-ray?

X-rays are on the electromagnetic spectrum and have a wavelength(10^{-10}) and a frequency between 3×10^{16} Hz to 10^{19} Hz.

x-ray images have the ability to use electro magnetic waves at such a high frequency that the ray penetrates and passes through soft and less dense materials.

X-ray photons are basically the same thing as visible light photons, but they have much more energy. This higher energy level allows X-ray beams to pass straight through most of the soft material in the human body.



Types of CT machines

Spiral CT

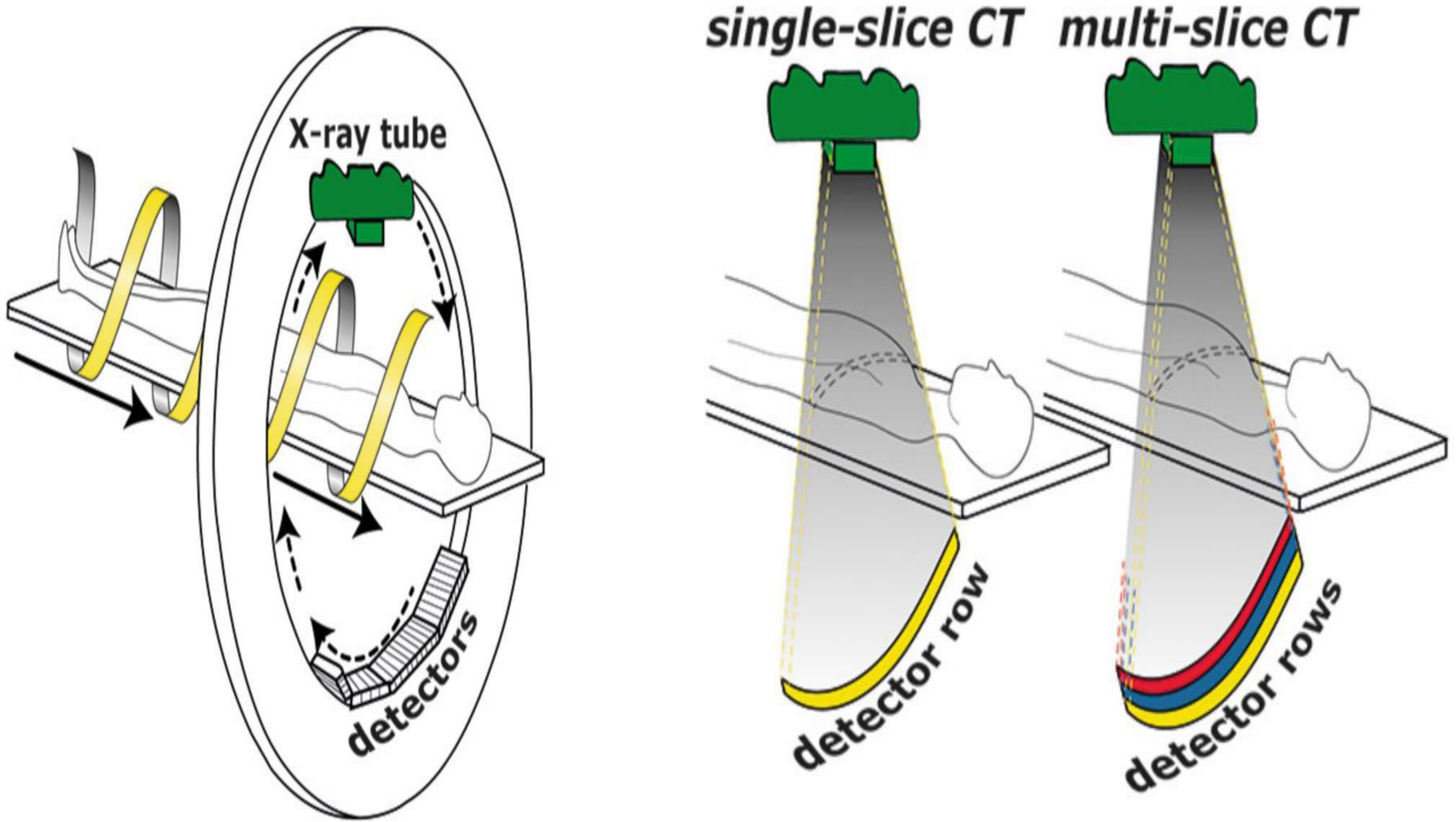
Spinning tube, commonly called spiral CT, or helical CT is an imaging technique in which an entire X-ray tube is spun around the central axis of the area being scanned. These are the dominant type of scanners on the market because they have been manufactured longer and offer a lower cost of production and purchase.

In conventional CT technique, first a slice is made of the desired area, after which the table moves up a little. In this way the patient is imaged slice by slice (step-by-step). Around 1990, the 'slip ring' technique was developed where the x-ray tube and detector ring rotate and continue scanning without interruption. This led to the so-called spiral CT where the scanner table moves with constant speed through the ring with the rotating x-ray tube and detectors. This generates a helix/spiral-shaped pattern.

Multi slice CTB

In multislice computed tomography or (MSCT) or multidetector computed tomography (MDCT), a higher number of tomographic slices allow for higher-resolution imaging. Modern CT machines typically generate 64-640 slice per scan.

The development of the multislice CT scanner (also known as multidetector CT or volume CT) significantly reduced scan time. As opposed to standard systems, multislice CT uses multiple detector rows. In this setting, not just one slice is scanned per rotation, but multiple slices simultaneously.



X-ray tube
detectors
single-slice CT
multi-slice CT
detector row
detector rows

Why get a CT Scan

- **CT scan images help doctors diagnose and pinpoint infections, muscle disorders, bone fractures, cancer, tumors and other abnormalities.**
- **In emergency situations, CT scans are life-saving tools that allow doctors to quickly determine the extent of internal injuries or internal bleeding.**
- **CT scans are also vital in cancer diagnosis, treatment and research.**

Risks of CT

- **A CT scan involves a small targeted dose of radiation. The chance of developing cancer as the result of a CT scan is thought to be less than 1 in 2,000. Problems that could possibly arise from radiation exposure include cancer and thyroid issues. The risk from a single scan is small, but it increases if you have many X-rays or CT scans over time.**

NOTE:

- **You will be asked to remove any metallic items and ALL jewelry that might interfere with the scan.**
- **For certain exams a contrast dye will be used(it can highlight and emphasize blood vessels, intestines, and other areas.**

Dose versus image quality

In general, higher radiation doses result in higher-resolution images while lower doses lead to increased image noise and unsharp images. However, increased dosage raises the adverse side effects, including the risk of radiation.

Several methods that can reduce the exposure to ionizing radiation during a CT scan exist:

1.New software technology can significantly reduce the required radiation dose.

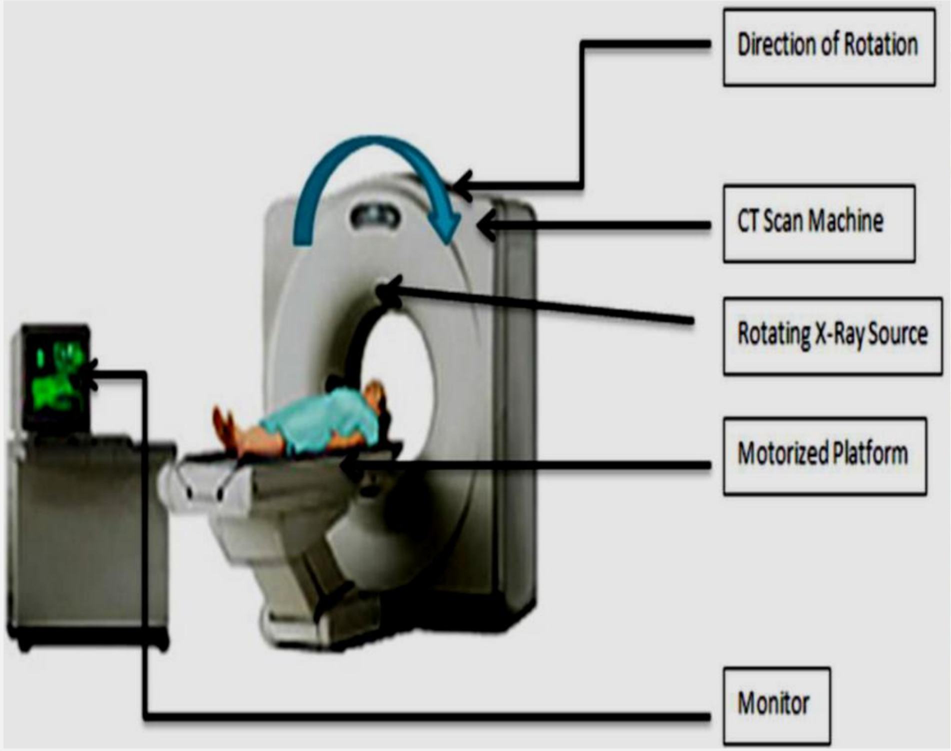
2.Individualize the examination and adjust the radiation dose to the body type and body organ examined. Different body types and organs require different amounts of radiation.

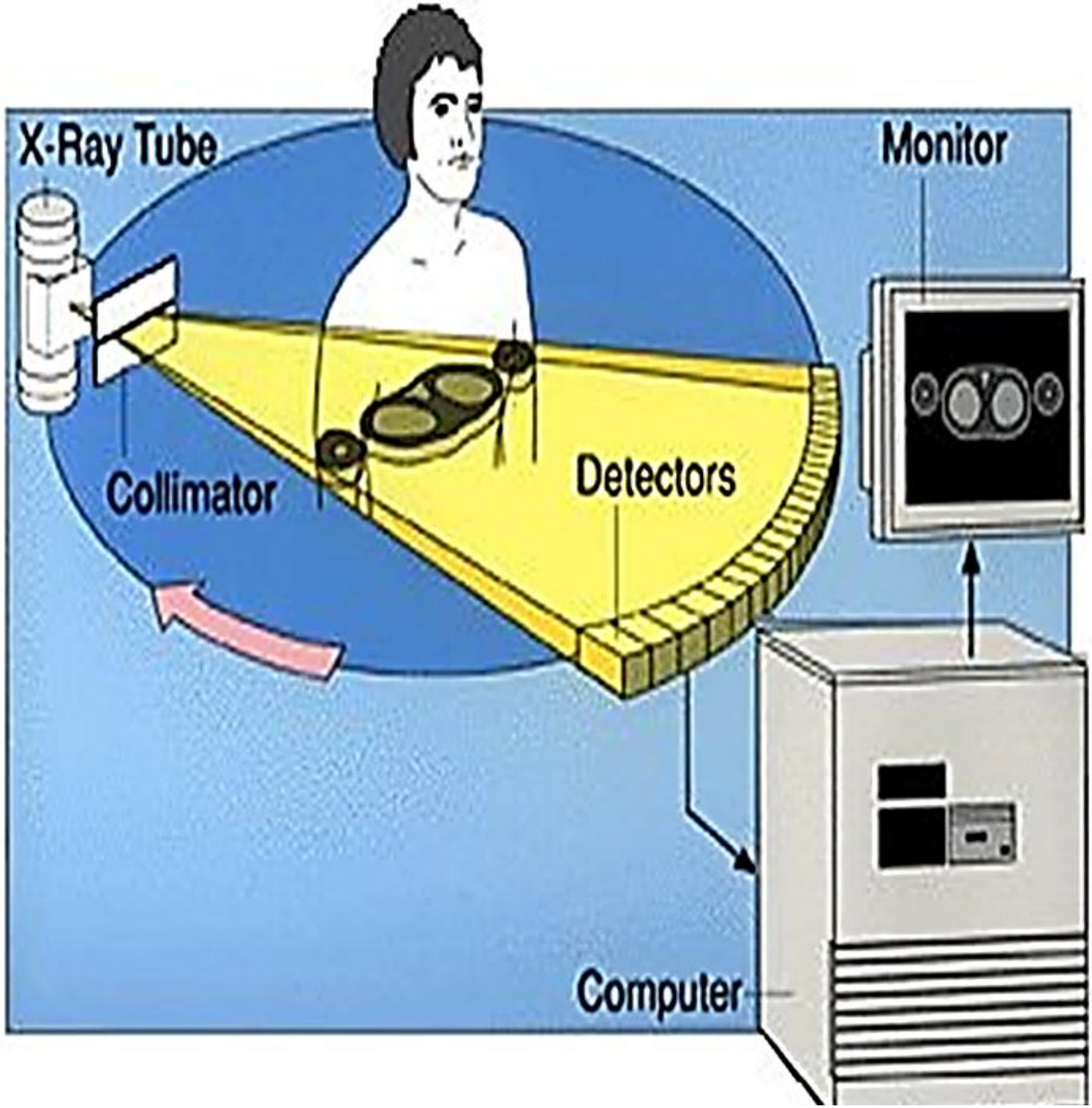
The Contrast Material (Dye

Contrast media used for X-ray CT, as well as for plain film X-ray, are called radiocontrasts. Radiocontrasts for X-ray CT are, in general, iodine-based. Iodine has a high atomic number (53), and interactivity with the X-ray. It is the excellent element for being able to differentiate between different tissues of the body and how blood is transmitted through those tissues. This is useful to highlight structures such as blood vessels that otherwise would be difficult to delineate from their surroundings. Using contrast material can also help to obtain functional information about tissues. A small catheter may be used so that the contrast material (dye) can be given to the person during the exam, while oral contrast makes it easier to see the bowel loops. Often, images are taken both with and without radiocontrast.

Components of CT

1. X-Ray Tube.
2. Collimator.
3. Detectors.
4. Monitor
5. Computer.





The CT scanner is typically a large box like machine with a hole, or short tunnel in the center. In the CT scanner there is one X ray source but a large number of detectors. This machine is also provided with a narrow examination table (motorized platform) that slides into and out of this tunnel, the patients lies on it during the examination.

Physics of CT

The X-ray flows from the rotating X-ray beams, then they pass through the body they detected on rotating X-ray detector. When X-ray passes through the body, the intensity of the X-ray changed according to the nature of the body.

The image construction in CT scan follows on the law of radiation attenuation, as the X-ray photons pass through a medium (Tissue), it will be absorbed and attenuated (energy lost), the intensity of the incident X-ray photons reduces with increasing the distance that the photon traverse (tissue thickness).

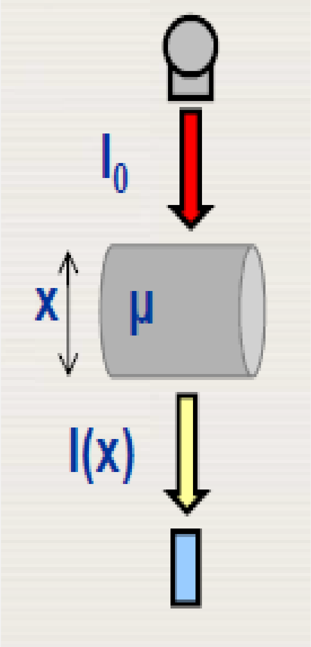
X rays diminish exponentially in intensity as they pass through a material of thickness Δx

according to the relationship: Beer's law

$$I(x) = I_0 e^{-\mu x}$$

where $I(x)$ is the intensity of the attenuated X ray beam,

I_0 the unattenuated X ray beam, x the thickness of the material.



The values that are assigned to the pixels in a CT image are associated with the

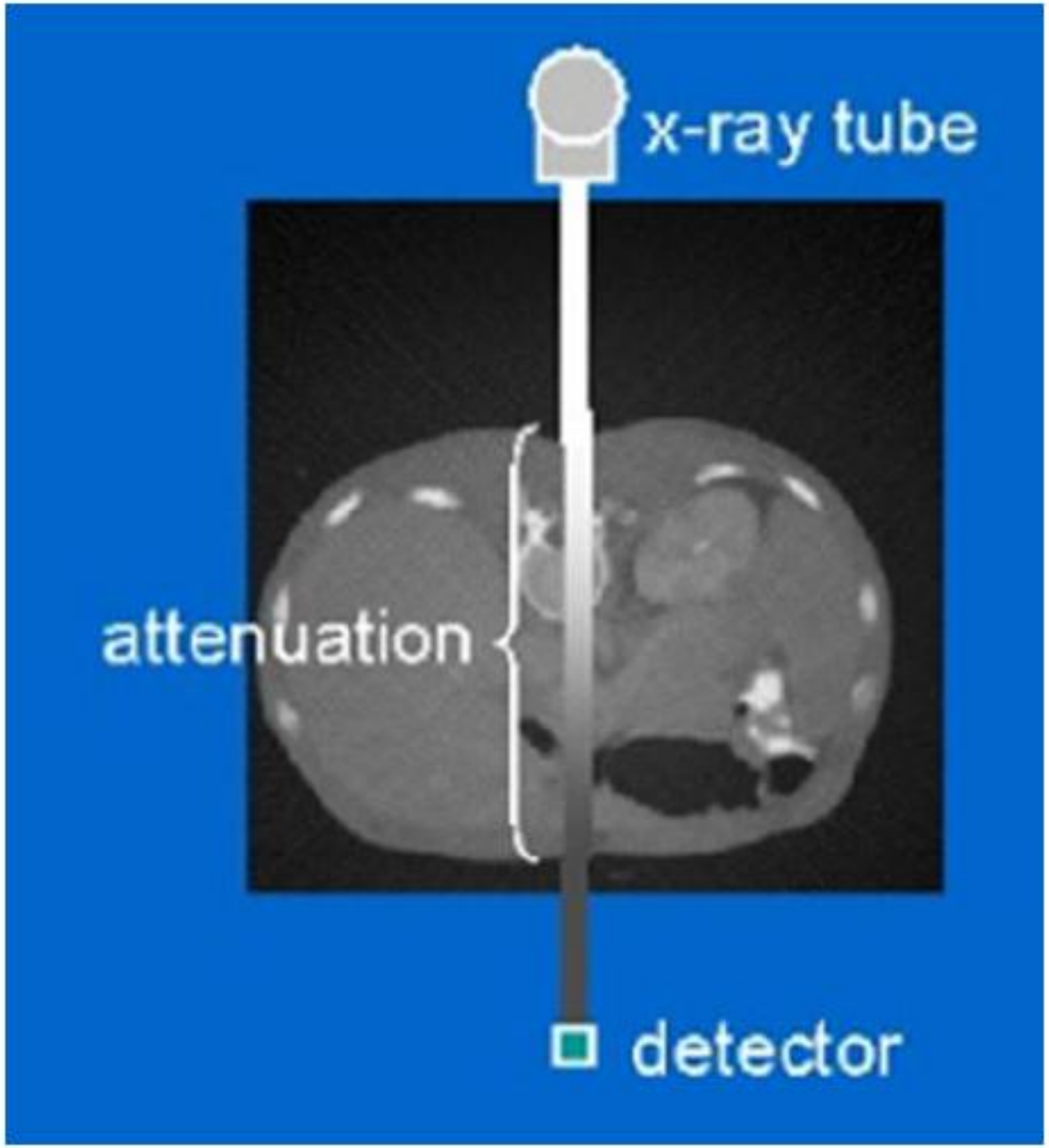
average linear attenuation coefficient μ (m^{-1}) of the tissue represented within that pixel.

As an X ray beam is transmitted through the patient, different tissues are uncounted with different linear attenuation coefficients.

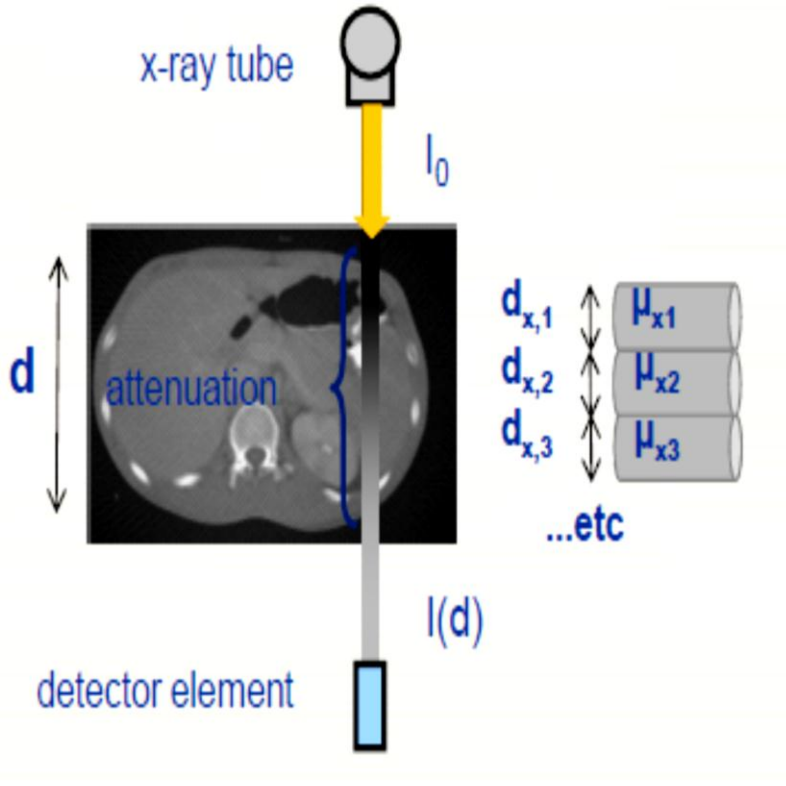
Physics of CT(cont.)

CT measures the average attenuation coefficient (μ) between tube and detectors as the X-ray beams pass through sections of an object from hundreds of different angles. From the captured measurements a computer with custom software is able to reconstruct an accurate slices images

Attenuation coefficient reflects the degree to which the X-ray intensity reduced by a material.

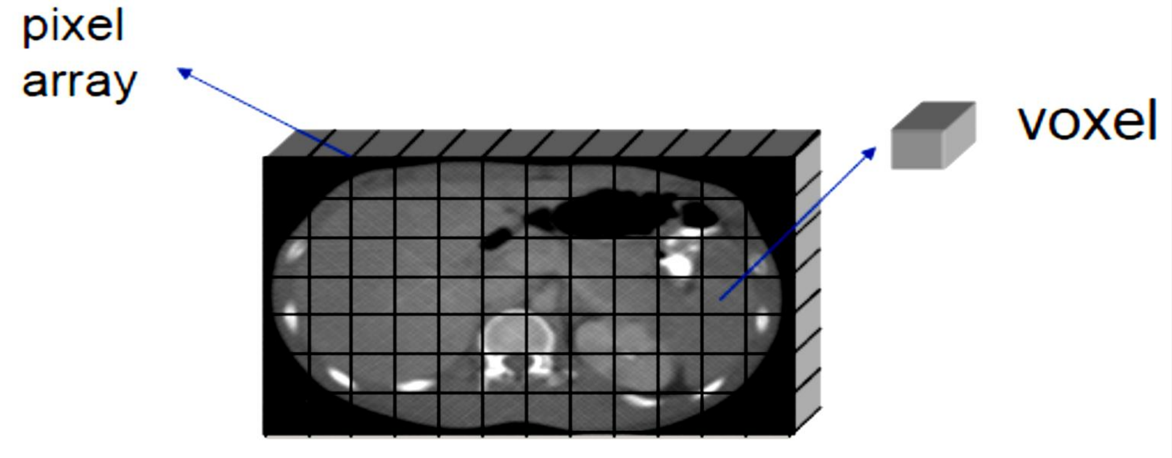


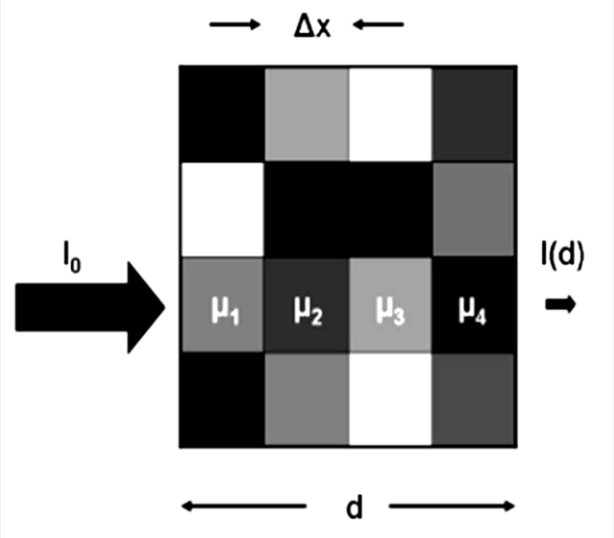
Physics of CT(cont.)



A CT image is composed of a matrix of pixels representing the average linear attenuation co-efficient in the associated volume elements (voxels).

- **Illustration: a simplified 4 x 4 matrix representing the measurement of transmission along one line.**
- **Each element in the matrix can in principle have a different value of the associated linear attenuation coefficient.**

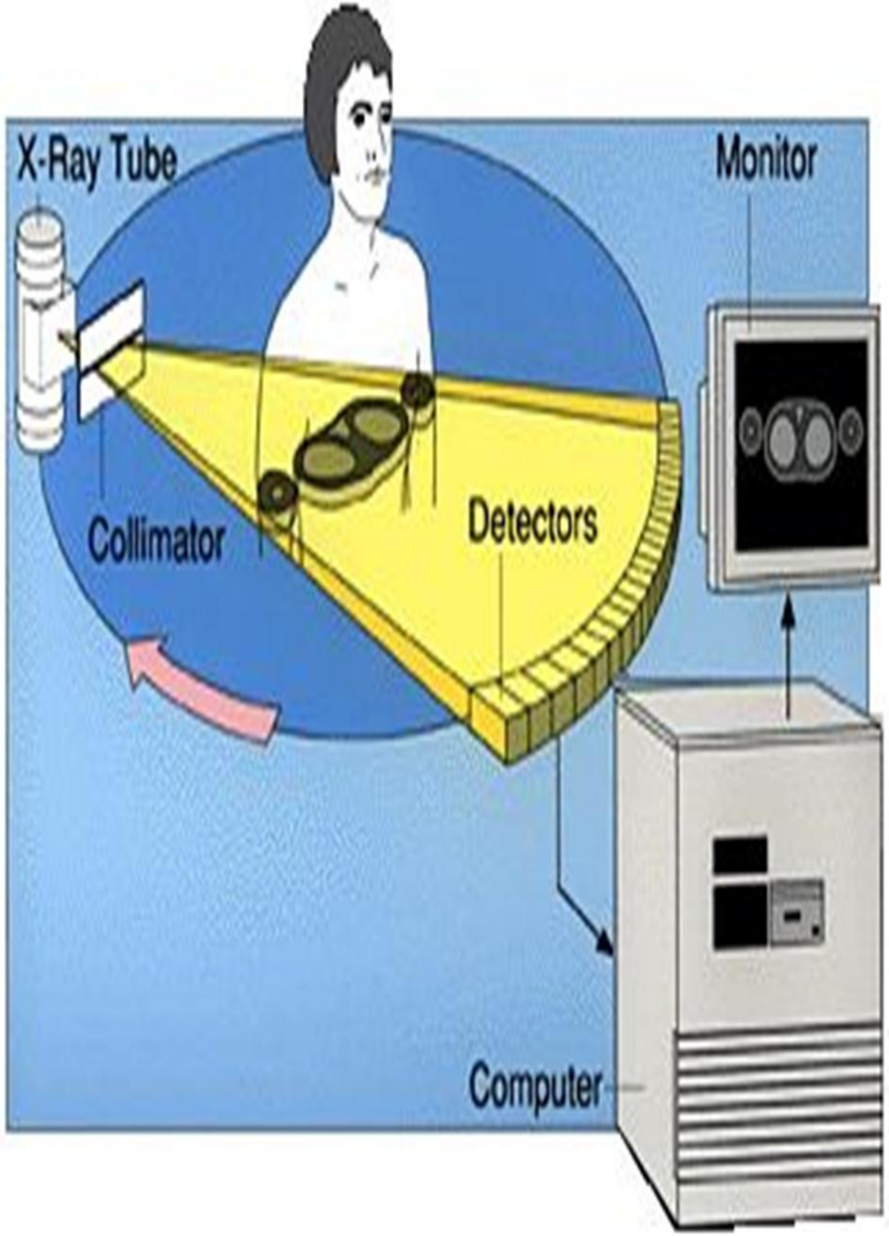




How does CT work?

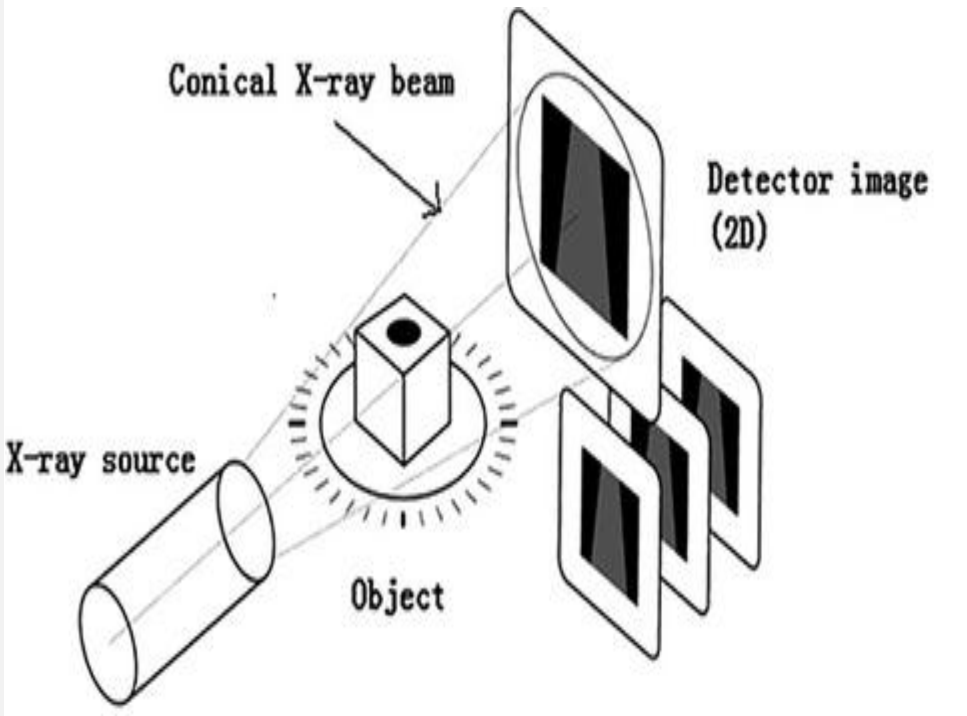
CT is based on the x-ray principal: as x-rays pass through the body, they are absorbed or attenuated (weakened) at differing levels creating a matrix or profile of x-ray beams of different strength. This x-ray profile is registered on film, thus creating an image. In the case of CT, the film is replaced by a banana shaped detector which measures the x-ray profile.

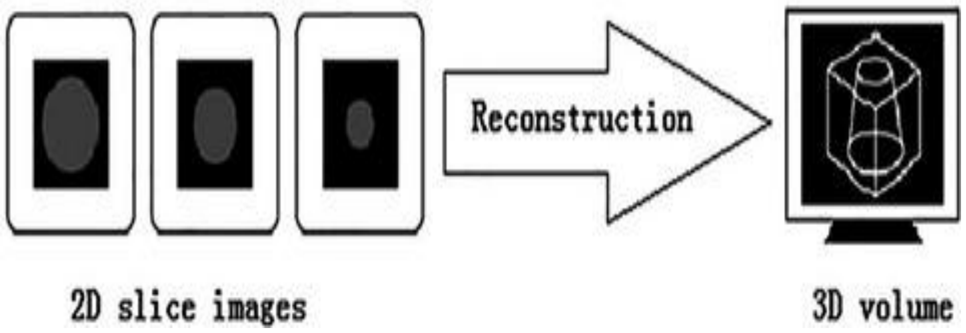
- **A CT scanner looks like a big, square doughnut. The patient aperture (opening) is 60 cm to 70 cm in diameter.**
- **Inside the covers of the CT scanner is a rotating frame which has an x-ray tube mounted on one side and the banana shaped detector mounted on the opposite side.**
- **A fan beam of x-ray is created as the rotating frame spins the x-ray tube and detector around the patient (see figure).**
- **Each time the x-ray tube and detector make a 360° rotation, an image or "slice" has been acquired. This "slice" is collimated (focused) to a thickness between 1 mm and 10 mm using lead shutters in front of the x-ray tube and x-ray detector.**



How does CT work?(cont.)

- As the x-ray tube and detector make this 360Â° rotation, the detector takes numerous snapshots (called profiles) of the attenuated x-ray beam. Typically, in one 360° lap, about 1,000 profiles are sampled.
- Each profile is subdivided spatially (divided into partitions) by the detectors and fed into about 700 individual channels. Each profile is then backwards reconstructed (or "back projected") by a dedicated computer into a two-dimensional image of the "slice" that was scanned.
- Multiple computers are used to control the entire CT system. There is also a dedicated computer that reconstructs the "raw CT data" into an image.
- The CT gantry and table have multiple microprocessors that control the rotation of the gantry, movement of the table (up/down and in/out), tilting of the gantry for angled images, and other functions such as turning the x-ray beam on an off.

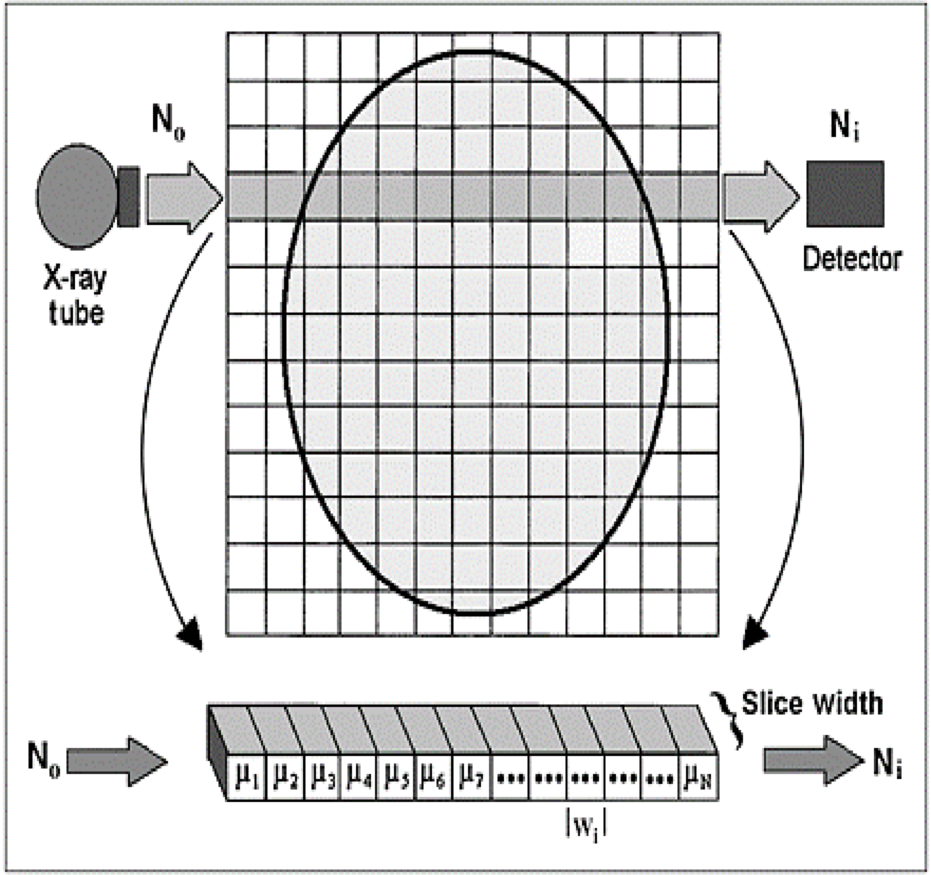




• From the above it can be seen that the basic data needed for CT is the intensity of the attenuated and unattenuated X ray beam, respectively I(d) and I0, and that this can be measured.

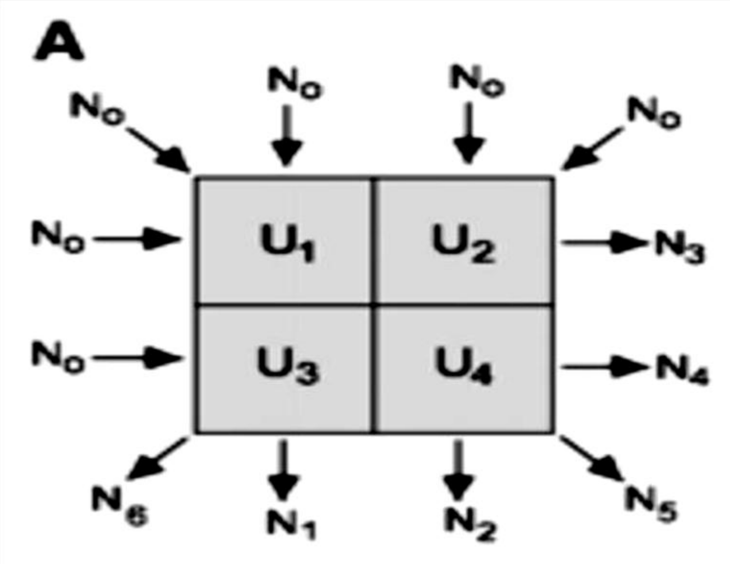
• Image **reconstruction techniques** can then be applied to derive the matrix of **linear attenuation coefficients**, which is the **basis of the CT image**.

In CT the matrix of reconstructed linear attenuation coefficients ($\mu_{material}$) is transformed into a corresponding matrix of **Hounsfield units ($HU_{material}$)**, where the **HU scale** is expressed relative to the linear attenuation coefficient of **water** at **room temperature** (μ_{water}):



Reconstruction matrix. Hounsfield envisioned scanned slice as being composed of matrix of small boxes of tissue called voxels, each with attenuation coefficient μ. X-Ray transmission measurements (Ni) can be expressed as sum of attenuation values occurring in voxels along path of ray for Ni

To carry out reconstruction, consider the row of voxels through which a particular ray passes during data collection. Ni is the transmitted x-ray intensity for this ray measured by the detector. No is the x-ray intensity entering the subject (patient) for this ray. It can be shown that a derived measurement Xi can be related to a simple sum of the attenuation values in the voxels along the path of the ray; for the row of voxels in the following figure:



Hounsfield envisioned dividing a slice into a matrix of 3-dimensional rectangular boxes (voxels) of material (tissue). Conventionally, the X and Y directions are within the plane of the slice, whereas the Z direction is along the axis of the subject (slice thickness direction). The Z dimension of the voxels corresponds to the slice thickness. The X and Y voxel dimension depend on the size of the area over which the x-ray measurements are obtained (the scan circle) as well as on the size of the matrix (the number of rows and columns) into which the slice is imagined to be divided. For example, suppose that each translation covers 250 mm. After collection of all of the views, the measurements cover a scan circle with a diameter of 250 mm. If this scan circle is divided into a matrix of 250 rows × 250 columns, each voxel is 1 × 1 mm. If a 512 × 512 matrix is used (as is common today), each voxel is approximately 0.5 × 0.5 mm. This matrix is referred to as the reconstruction matrix.

PITCH

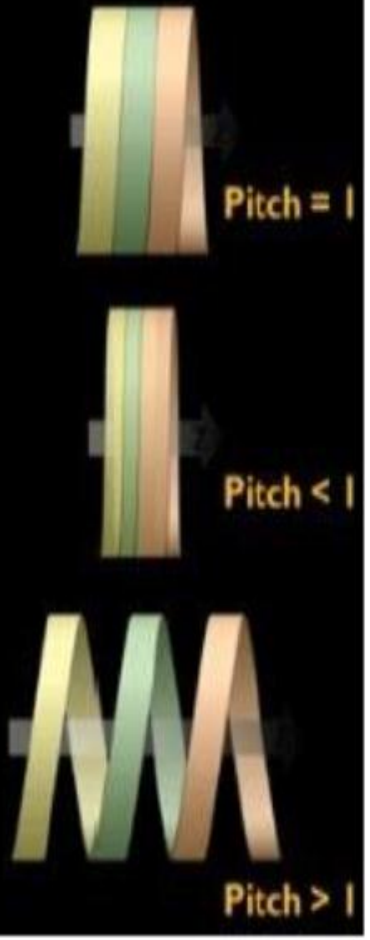
- The relationship between patient and tube motion is called Pitch.
- ***It is defined as table movement during each revolution of x-ray tube divided by collimation width.***
- For example: For a 5mm section, if patient moves 10mm during the time it takes for the x-ray tube to rotate through 360°, the pitch is 2.
- Increasing pitch reduces the scan time and patient dose.

$$\text{Slice Pitch} = \frac{\text{table motion during one rotation}}{\text{slice thickness}}$$

PITCH & DOSE

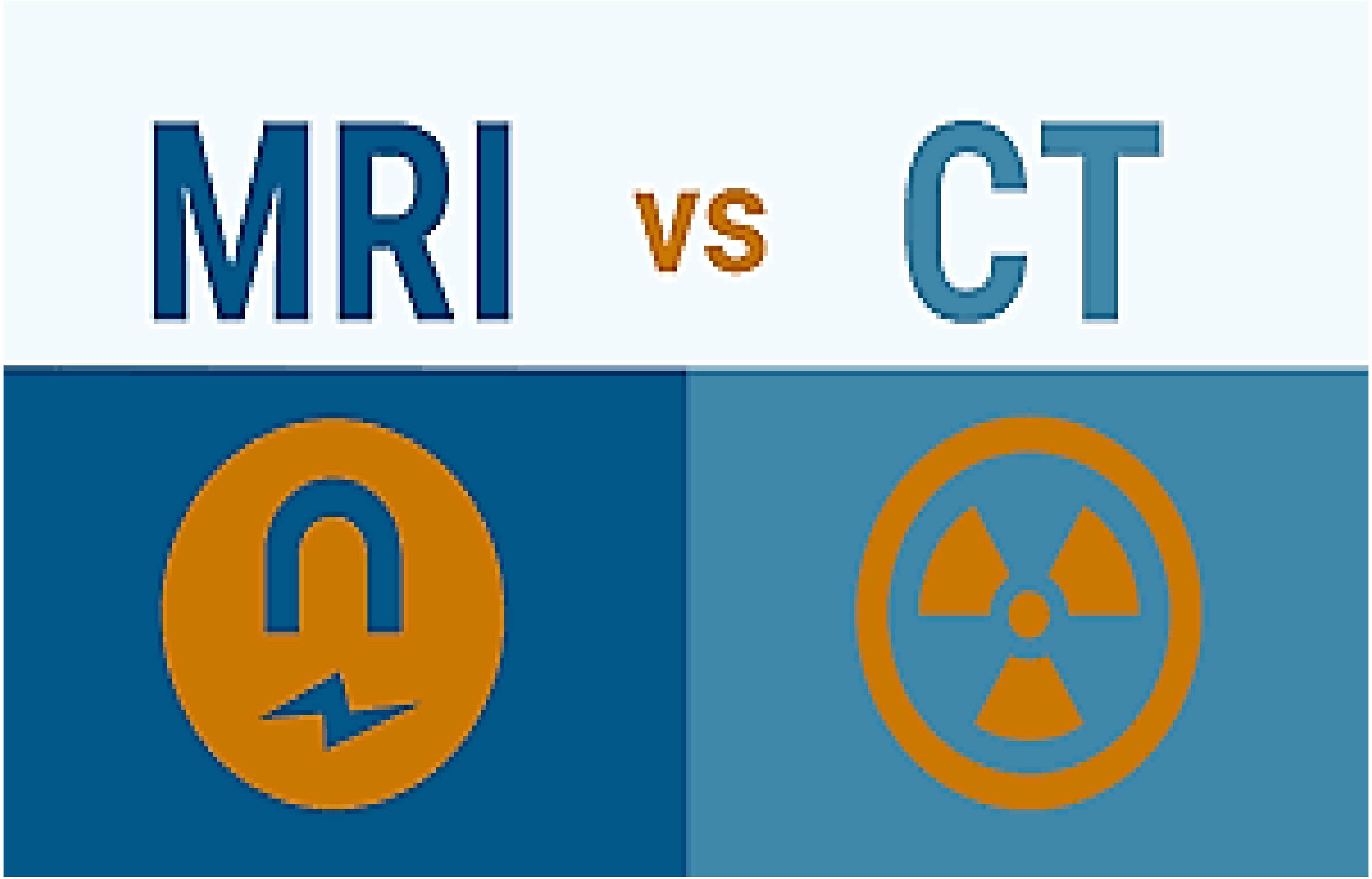
- Pitch >1 implies extended imaging and reduced patient dose with lower axial resolution
- Pitch <1 implies overlapping and higher patient dose with higher axial resolution

$$\text{Dose} \propto \frac{1}{\text{Pitch}}$$



Pitch

- Affects
  - Total scan time
  - Dose
  - Noise / Resolution


MRI
vs
CT

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Medical Devices

Fourth Stage- Lecture 2

Magnetic Resonance Imaging (MRI)

Dr.Nasrin Nadher Jamil

Medical imaging

Medical imaging refers to the different imaging technologies that are used to view the human body in order to diagnose and monitor.

Each type of technologies provides different information about the area of the body being studied or treated.

Medical imaging such as:

1- Ultrasound Imaging (US Imaging)

2- Magnetic Resonance Imaging (MRI)

3-Computerized tomography CT-scan and X-ray Imaging

4-Gamma-ray Imaging .

5- Positron emission tomography (PET scans)

Magnetic Resonance Imaging (MRI)

What is MRI?

A medical imaging technique that records changing magnetic fields. Can give different kinds of images based on the pulse sequence. Capable of complete body scans, but commonly used for brain.

It is also called NMRI (Nuclear Magnetic Resonance Imaging), (Magnetic Resonance Tomography (MRT).

MRI scanning is painless and does not involve x-ray radiation.

Physical principle

MRI is based on the principles of nuclear magnetic resonance (NMR), which is a spectroscopic technique used to obtain microscopic chemical and physical data about molecules.

MRI Uses

- Anomalies of the brain and spinal cord
- Tumors, cysts, and other anomalies in various parts of the body
- Breast cancer screening for women who face a high risk of breast cancer
- Injuries or abnormalities of the joints, such as the back and knee
- Certain types of heart problems
- Diseases of the liver and other abdominal organs
- The evaluation of pelvic pain in women, with causes including fibroids and endometriosis
- Suspected uterine anomalies in women undergoing evaluation for infertility
- Find unhealthy tissue in the body.
- Surgery planning.

Why MRI ?

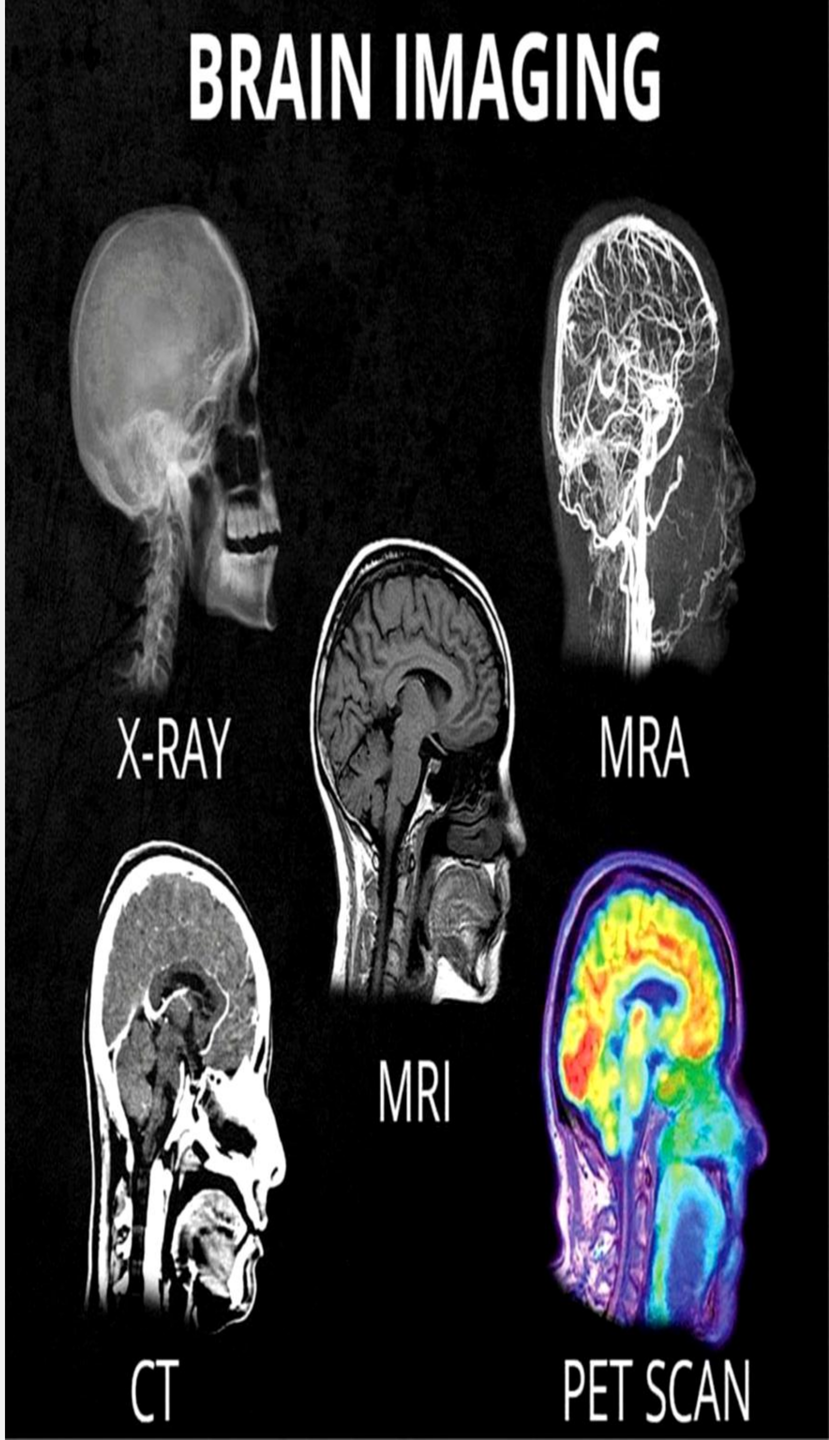
1.Utilizes non ionizing radiation, (unlike x-rays).

2. Ability to image in any plane, (unlike CT scans).

3. Very low incidents of side effects.

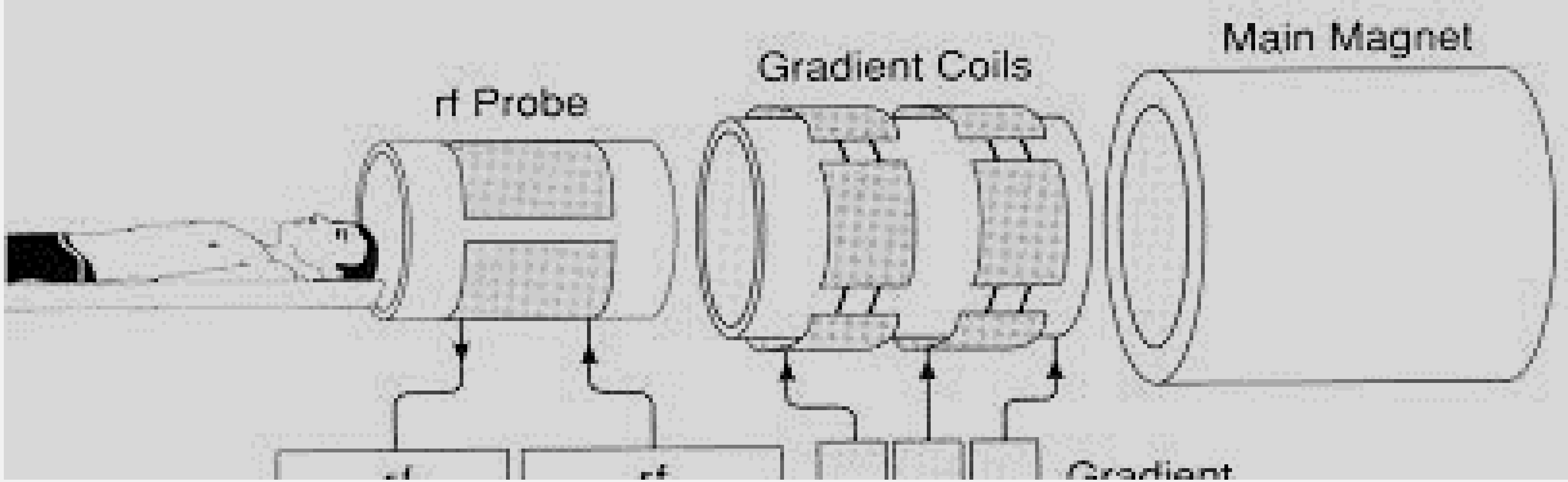
4. Ability to diagnose, visualize, and evaluate various illnesses.

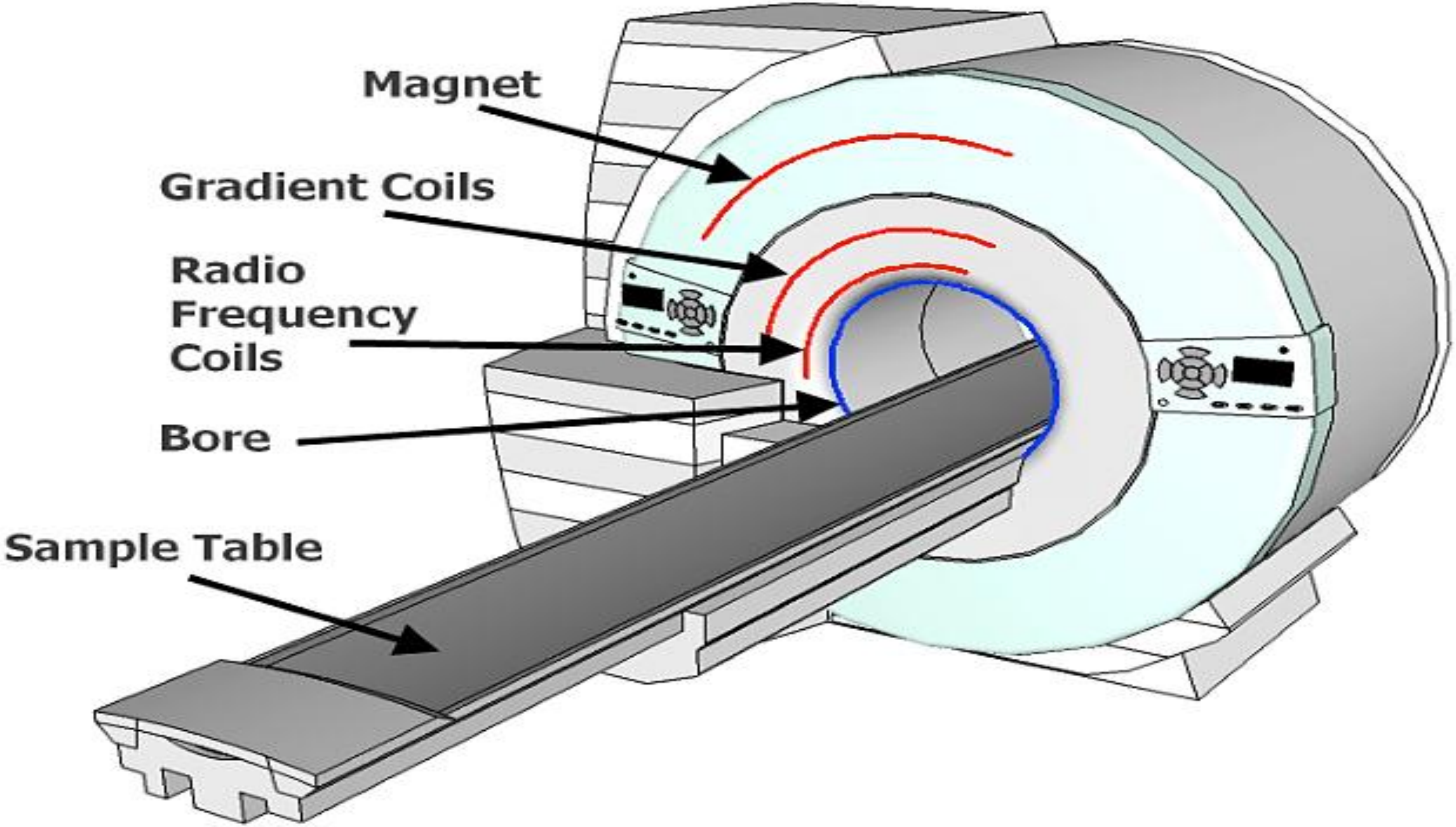
MRI uses magnetic fields not ionizing radiation and hence is just as safe to use as ultrasound, however the necessary equipment is certainly more complicated and expensive.



MRI Components

1. A magnet which produces a very powerful uniform magnetic field.
2. Gradient Magnets which are much lower in strength.
3. Equipment to transmit radio frequency (RF).
4. A very powerful computer system, which translates the signals transmitted by the coils.




Magnet
Gradient Coils
Radio
Frequency
Coils
Bore
Sample Table

MRI Components(cont.)

- The function of magnet is producing a stable and very intense magnetic field(The magnets currently used in scanners today are in the 0.5-tesla to 2.0-tesla range (5,000 to 20,000-gauss).
- There are three types of magnets used in MRI systems:

1. Resistive magnets.
2. Permanent magnets.
3. Super conducting magnets (the most commonly used type in MRI scanners).

- The function of gradient coils are used to produce deliberate variations in the main magnetic field.
- Magnetic field is orderly or alike over the region of the patient's body when the MRI system is in resting state.
- During the imaging processing the field must be distorted with gradient. A gradient is a change in field strength from one point to another in the patient's body.
- During an imaging procedure the gradients, the sound or noise are produced that are come from the turning on and off the magnet for many times.

Radio frequency (RF)

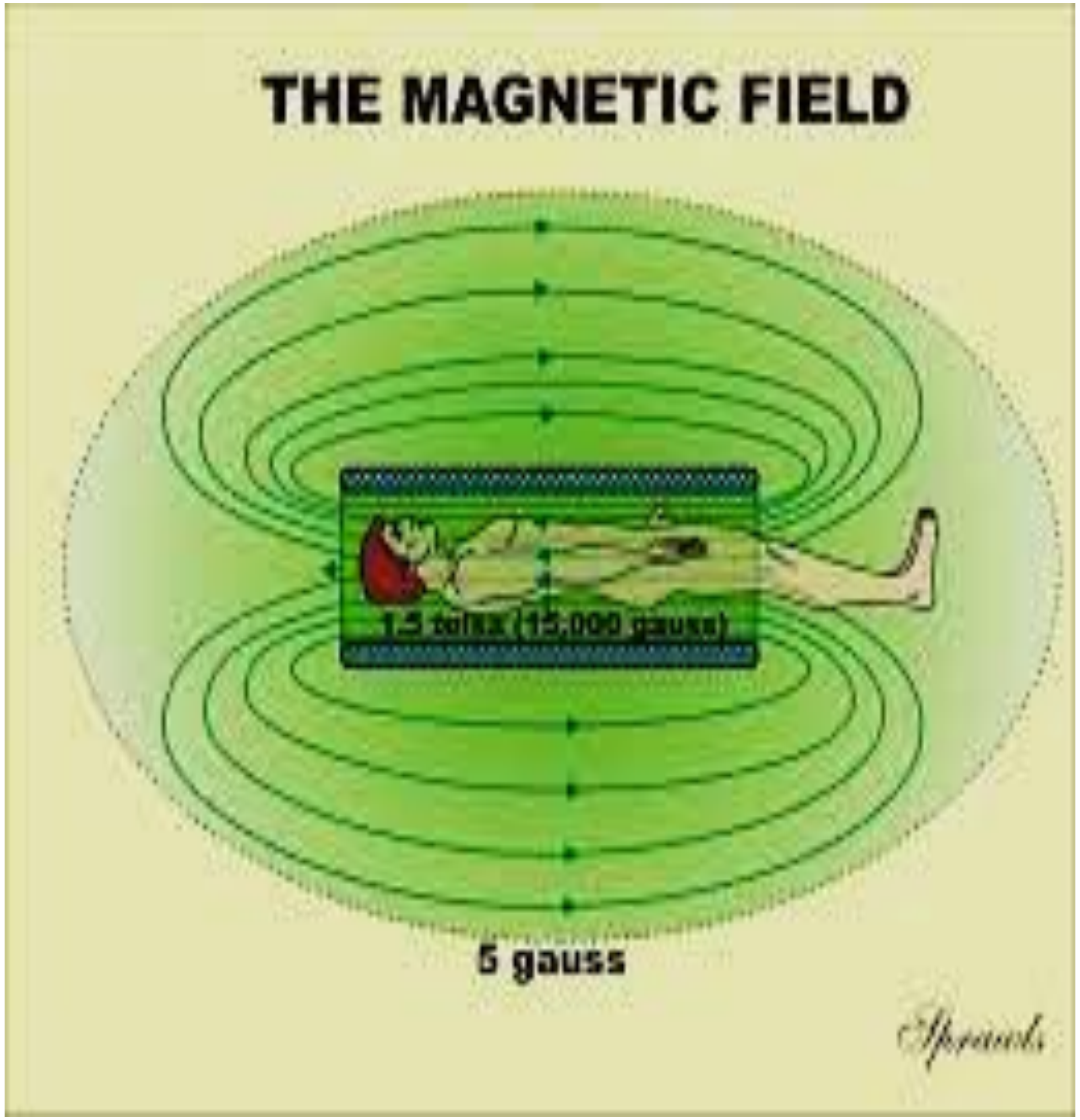
- **The radio frequency (RF) is used as the communication link; as for both transmitting and receiving signals with the patient's body in producing an image.**
- **The RF coils are located within the magnet assembly and closed to the patient's body.**
- **There are different coil designs for different parts of human bodies. But the three basic types are body, head and surface coils.**
- **The RF transmitter generated RF energy, which is used to the coils and then transmitted to the patient's body. The energy is generated as a series of discrete RF pulses. The transmitter should be able in producing approximately high power outputs on the order of several thousand watt.**
- **the transmitter consists of certain components such as RF modulators and power amplifiers but it is considered as a unit that produces pulses of RF energy.**
- **When a short period after a sequence of RF pulses is transmitted to the patient's body, the resonating tissue will respond by returning an RF signal. This RF signals are then picked up by the coils and the receiver will process it. After that, the signal will be converted into a digital form and send to the computer.**

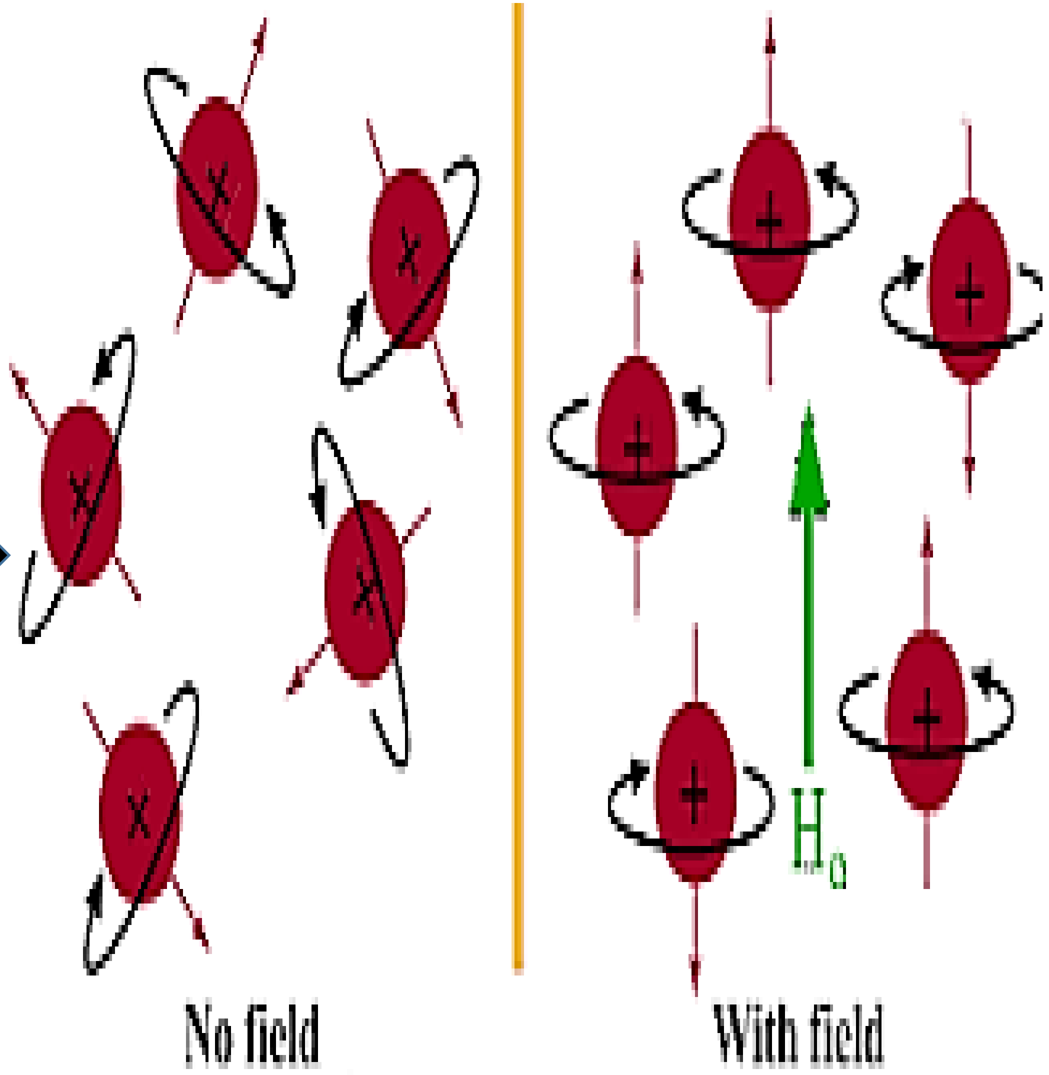
Computer system

- **A digital computer is a fundamental element in MRI system. The production and display of an MRI image is a series of several specific steps that have to be managed and controlled by the computer.**
- **There are some steps or process before a computer can display the images which is acquisition control, image reconstruction, image storage and retrieval, and lastly is viewing control and post processing.**

How does MRI WORK?

- Our bodies are made up of 60% water and water is magnetic. Each of the billions of water molecules inside us consists of an oxygen atom bonded to two hydrogen atoms. We know it as H_2O.Small parts of the hydrogen atoms act as tiny magnets and are very sensitive to magnetic fields.
- MRI stands for magnetic resonance imaging and an MRI scanner is one of the main diagnostic tools that doctors use to examine inside our bodies.
- The first step in taking MRI scan is to use a big magnet to produce a unified magnetic field around the patient.
- The gradient adjusts the magnetic field into smaller sections of different magnetic strengths to isolate specific body parts. For example, the brain.
- molecules inside us are arranged randomly, but when we lie inside the magnetic field most of our water molecules move at the same rhythm or frequency as the magnetic field.


THE MAGNETIC FIELD
1.5 tesla (15,000 gauss)
5 gauss


H_0
No field
With field

How does MRI WORK?

The ones that don't move along the magnetic field are called low energy water molecules.

To create an image of a body part, for example the brain:

the machine focuses on the low energy water molecules. Radio waves move at the same rhythm or frequency as the magnetic fields in a MRI machine. By sending radio waves that match or resonate with the magnetic field, the low energy water molecules absorb the energy they need to move alongside the magnetic field.

When the machine stops emitting radio waves the water molecules that had just moved along the magnetic field release the energy they had absorbed and go back to their position. This movement is detected by the MRI machine .

How does MRI WORK?

The signal is sent to a powerful computer which uses imaging software to translate the information into an image of the body. By taking images of the body in each section of the magnetic field the machine produces a final three dimensional image of the organ which doctors can analyze to make a diagnosis. These images are formed from a series of slices which can be viewed from:

the front to the back (coronal).

from the top to the bottom (axial), and from one side of the body to the other (sagittal).

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Dept. of Biophysics

Medical Physics

Second Stage - Lecture 6

Laser in Medicine

Dr.Nasrin Nadher Jamil

What is Laser?

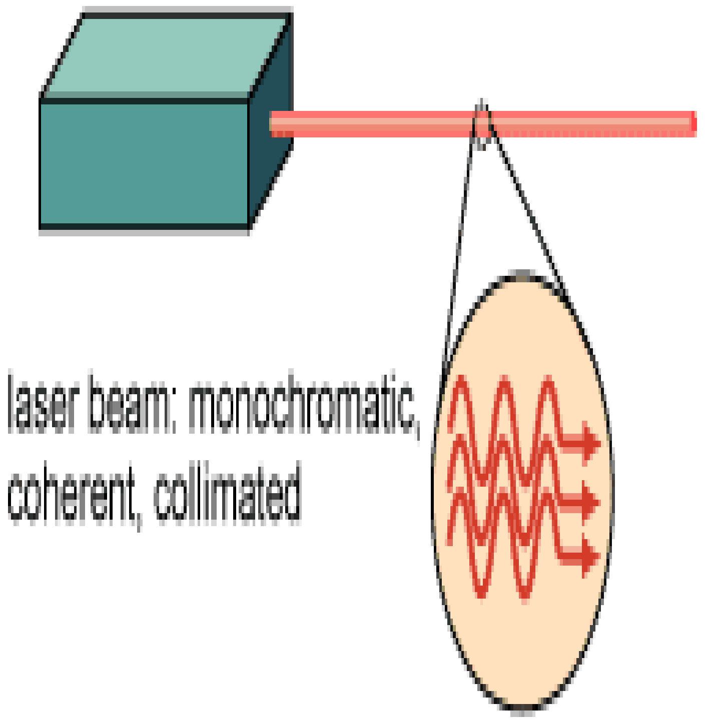
The word "laser" is an acronym for "Light Amplification by Stimulated Emission of Radiation". Laser light is a form of Electromagnetic Radiation.

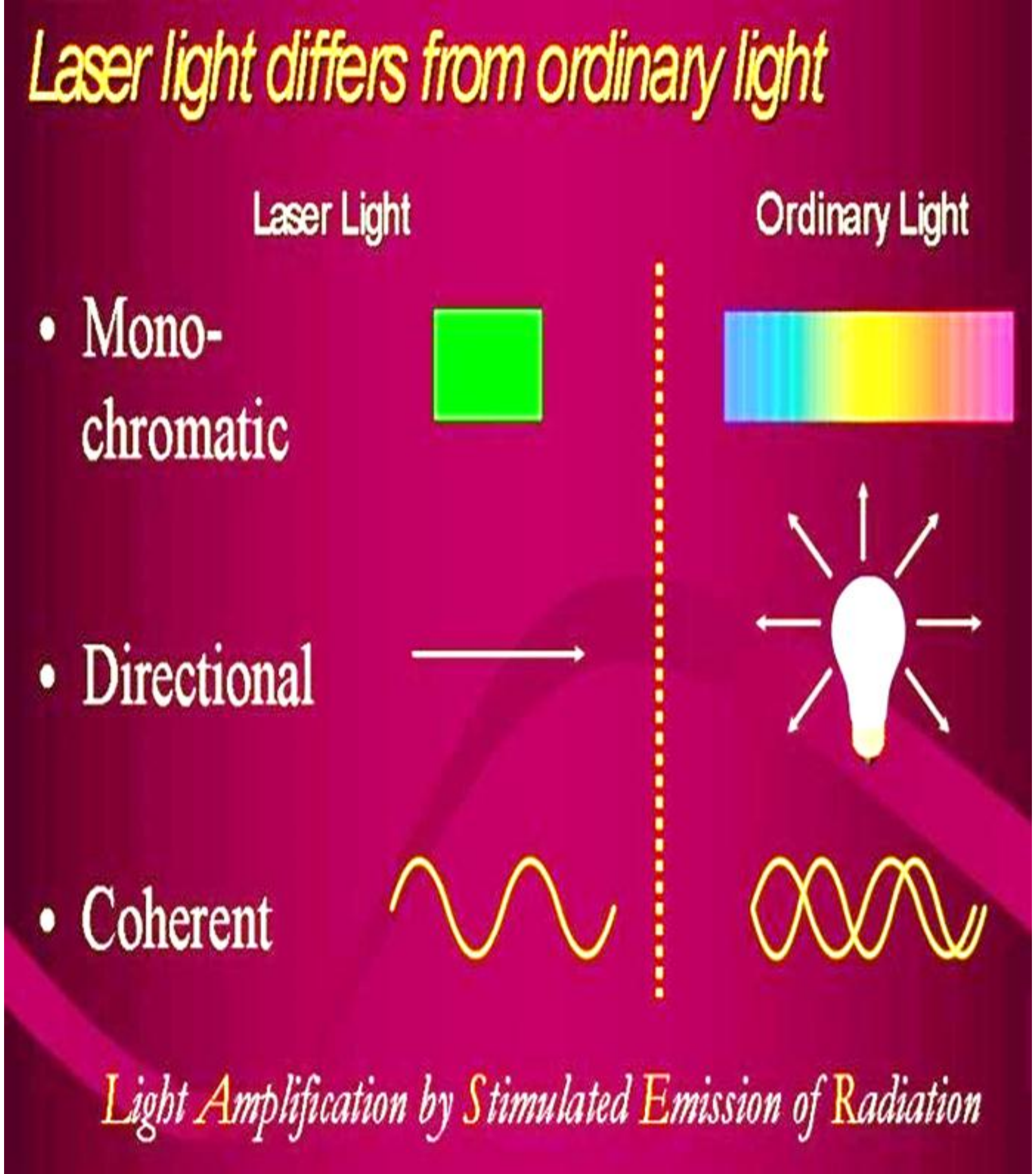
All devices operating at frequencies higher than microwaves are called lasers (including infrared laser, ultraviolet laser, X-ray laser and gamma-ray laser). All devices operating at microwave or lower radio frequencies are called masers.

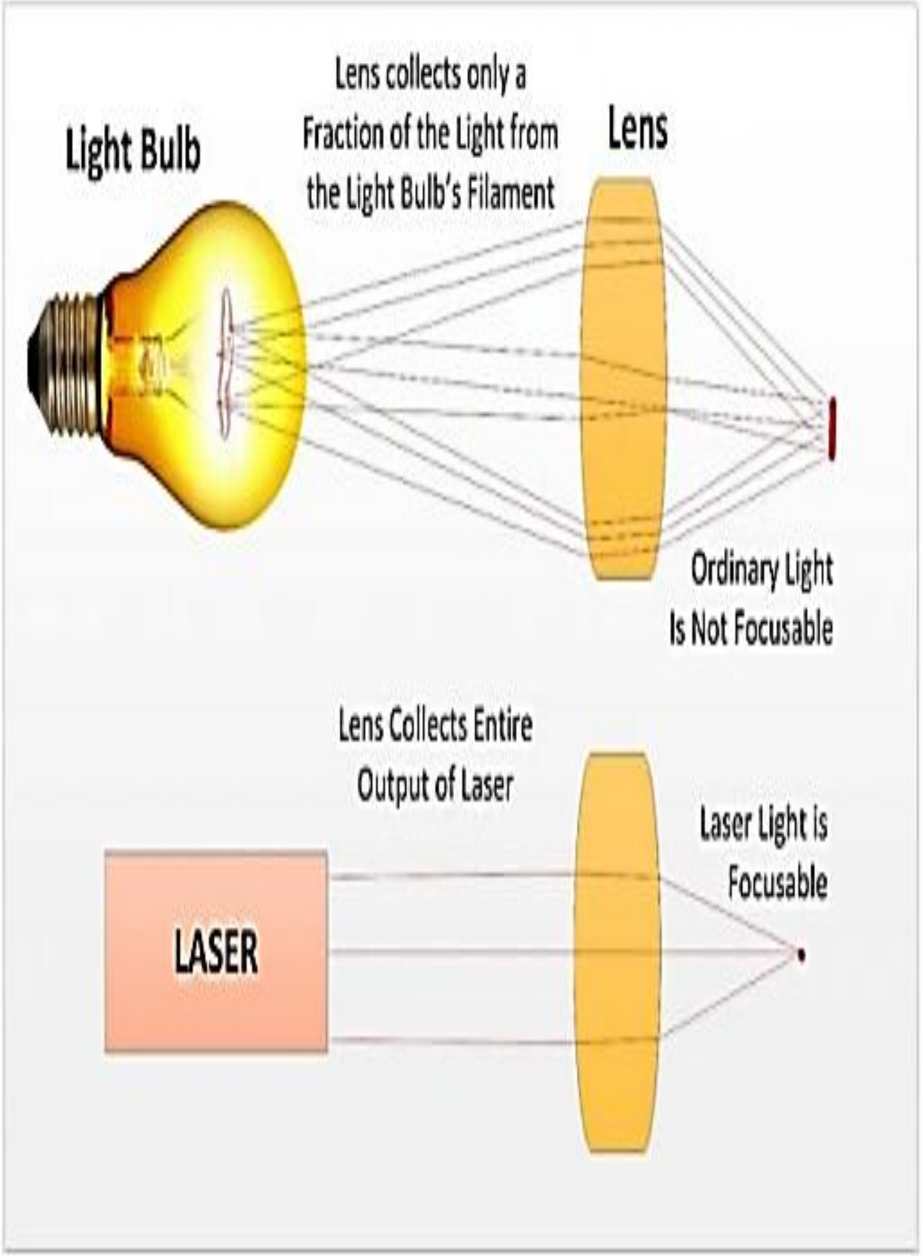
Laser stimulates atoms or molecules to emit light at particular wavelengths and amplifies that light, typically producing a very narrow beam of radiation.

The Unique Properties of Laser Light

1. **Monochromaticism:** **Laser light is generated as only one colour, This colour can be either visible or invisible to the human eye, but is described as the measurement of the wavelength.**
2. **Coherent:** **Each wave is identical in physical size and shape.**
3. **Directionality:** **It has a very narrow and collimated ray, and hence it is very powerful. In contrast, lamp light diverges towards different directions and has a low intensity.**




Laser light differs from ordinary light
Laser Light
Ordinary Light
• Mono-chromatic
• Directional
• Coherent
Light Amplification by Stimulated Emission of Radiation


Light Bulb
Lens collects only a Fraction of the Light from the Light Bulb's Filament
Lens
Ordinary Light Is Not Focusable
Lens Collects Entire Output of Laser
LASER
Laser Light is Focusable

Components of a Laser system

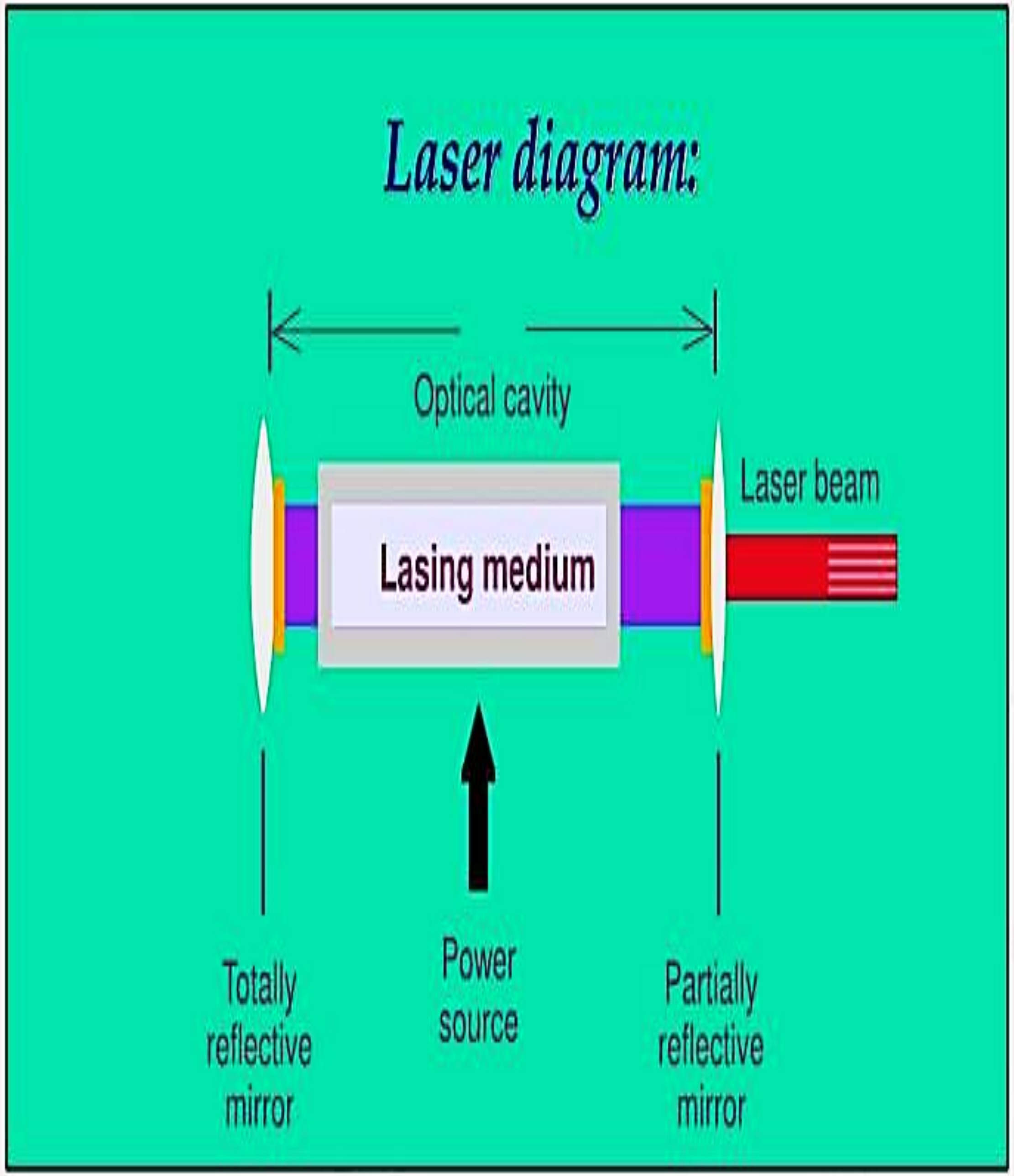
There are four basic components to every laser:

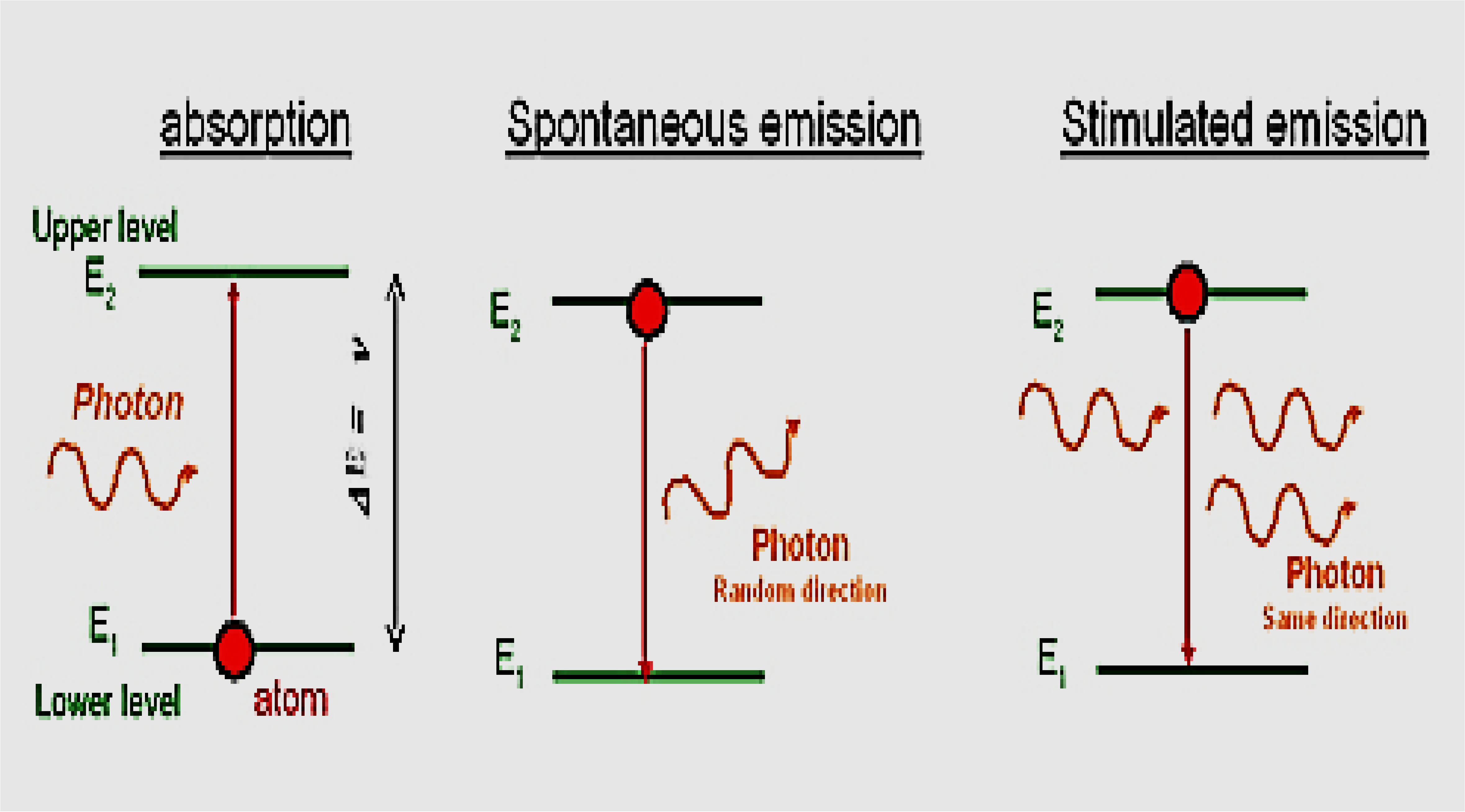
1.The lasing medium (located inside the optical cavity) is the substance that produces the laser beam. •This could be a GAS (argon, krypton, CO_2), a SOLID (ruby crystals, alexandrite crystals), or a LIQUID (dye). •The lasing medium determines the wavelength of the laser.

2. Optical cavity: It consists of a pair of parallel mirrors enclosing the active medium in between them. The reflectivity of one of the mirrors near to 100% and the other is partially transparent.

3. The power source is used to stimulate the lasing medium to produce the laser beam. Power sources include: Electricity , Flashlamps and other lasers.

4. The delivery system modifies the laser beam and brings it from the optical cavity to the patient. Delivery systems include: Articulated arms, Optical fibers , Micromanipulators , Focusing handpieces and Lenses.




absorption
Spontaneous emission
Stimulated emission
Upper level
E2
Photon
ΔE = hν
E1
Lower level
atom
E2
Photon
Random direction
E1
E2
Photon
Same direction
E1

Physics of Laser

The three different mechanisms are shown below:

1.Absorption: An atom in a lower level absorbs a photon of frequency hv and moves to an upper level.

2.Spontaneous emission: An atom in an upper level can decay spontaneously to the lower level and emit a photon of frequency hv if the transition between E2 and E1 is radiative. This photon has a random direction and phase.

3.Stimulated emission: An incident photon causes an upper level atom to decay, emitting a "stimulated" photon whose properties are identical to those of the incident photon. The term "stimulated" underlines the fact that this kind of radiation only occurs if an incident photon is present. The amplification arises due to the similarities between the incident and emitted photons.

Population inversion and pumping

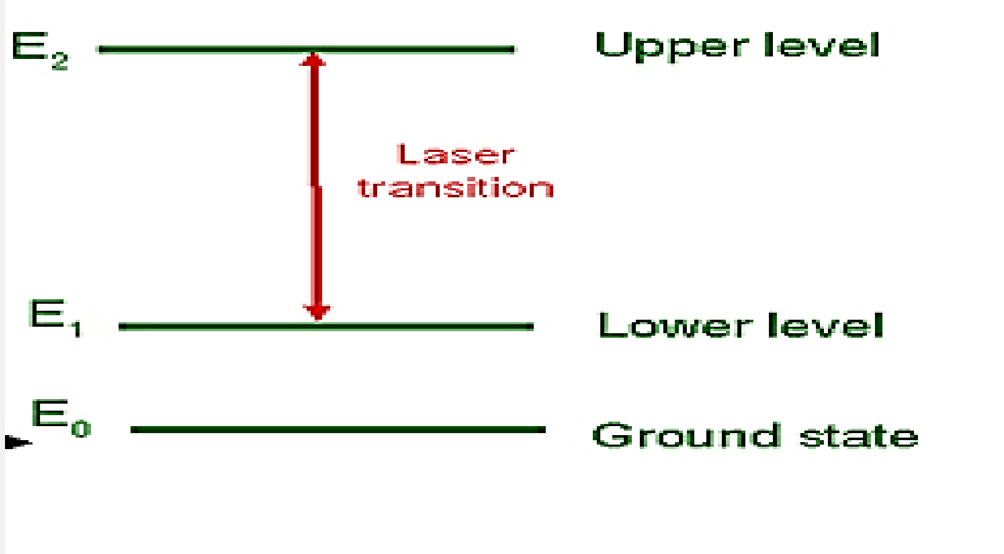
If there are more atoms in the upper level (N2) than in the lower level (N1), the system is not at equilibrium.

In this case, N2 is always less than N1. A situation not at equilibrium must be created by adding energy via a process known as "pumping" in order to raise enough atoms to the upper level.

This is known as population inversion and is given by:

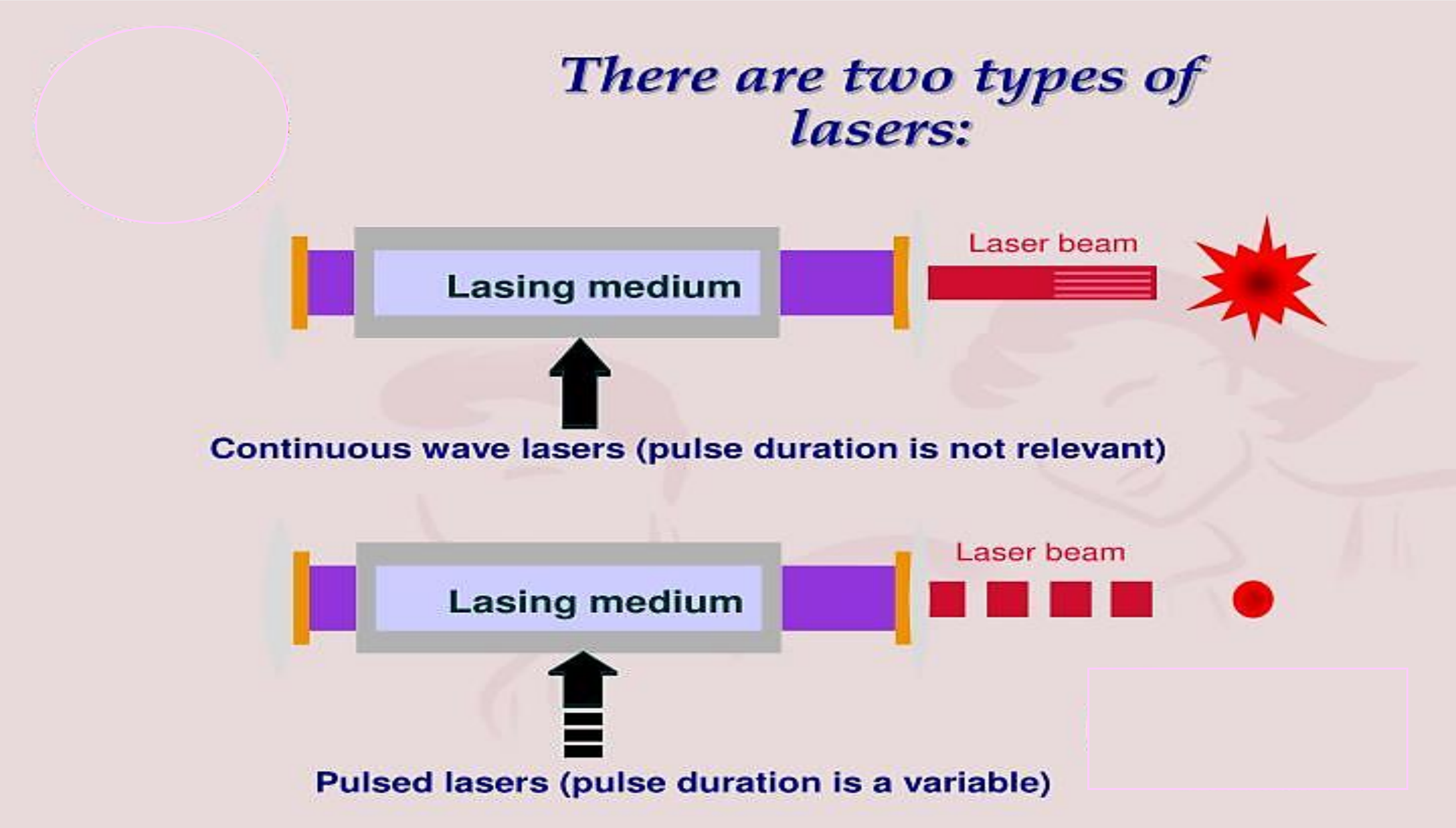
$$\Delta = N_2 - N_1$$

Light is amplified when the population inversion is positive. Pumping may be electrical, optical or chemical.



Modes of Operation

Laser sources can emit light continuously or in pulsed fashion. The difference is related to the time –limited emission of such a system.



Classification of laser

A- It can be classified according to the active medium (material):

1. 1. Solid state lasers:- e.g: neodymium lasers – Ruby laser.
2. Gas lasers:- e.g - He-Ne: Ionic gas laser(argon), Molecular gas laser, Chemical laser.
3. Semiconductor laser or diode laser. Emitting the I.R.) : Gallium – Arsenide (Ga-As)
4. Liquid (dye lasers).
5. Free Electron laser, very high power.
6. Metal vapor lasers, e.g Helium cadmium & Copper vapor.

B- It can also be classified according to the amount of output power and wavelength output deliver.

1. High power lasers (Hot): e.g., Co2 laser.

- High intensity LASER.
- It generates heat and destroys only selected tissue directly in the beam while avoiding damage to surrounding tissues.
- Hot laser has a cutting power so, it is used clinically to make incisions in surgical procedures.

Classification of laser

2. Mid power laser: (cold) e.g., IR laser.

- This type of laser used by physical therapist.
- Low intensity laser.
- It doesn't generate heat or destroy the tissues.
- This form of laser may be biostimulative and facilitate healing.
- Mid power laser has 2 main types:

a- Helium neon (He Ne): has superficial effect (0.8-1.5)mm.

b- Infra red (IR): has deep effect with penetration up to 30 mm.

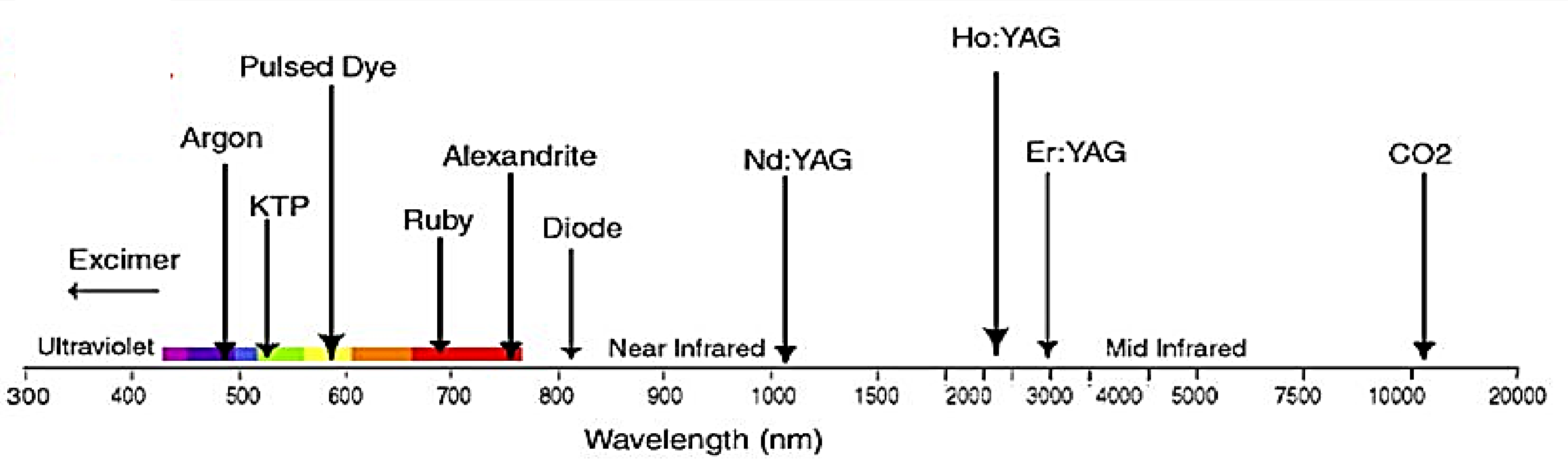
3. Low power lasers(soft laser): This type of laser used by dermatologist.

C- It can also be classified according to the **potential danger** posed to the exposed skin and to the eye into four classes as in figure:

	Class I	Class II	Class III	Class IV
Power	<0.5 mW	Up to 1mW	1 mW to 500 mW	More than 500mW
Hazards to skin & eyes	No danger	Direct interbeam viewing may have ocular hazards	Significant ocular hazard .	Significant hazard to skin & eye
Utilization	No therapeutic uses	Very low power rarely used in Physiotherapy	Low &Mild power lasers used in Physiotherapy	High power lasers used in surgery

Laser Parameters

1. **Wavelength (nm):** Wavelength refers to the physical distance between crests of successive waves in the laser beam. The energy of each photon in the light beam is related to the wavelength; at a shorter wavelength, the energy of the photon is higher. In figure, laser light wavelengths of common medical lasers



2. Power(W):

Laser power refers to the rate at which energy is generated by the laser. Laser power of 1 Watt means that 1 Joule of energy is emitted in 1 second.

Laser Parameters(cont.)

3.Frequency, Pulse Repetition Rate (Hz): Medical lasers are usually operated in a repetitive pulse mode. Laser pulses are emitted periodically at a pulse repetition rate, for example, 10 pulses per second. Hertz (Hz) is the most commonly used unit for pulses per second.

4.Pulse width – Pulse Duration (ns, µs or ms): Pulse duration and pulse width are synonymous terms, which refer to the temporal length of the laser pulse; that is, the time during which the laser actually emits energy.

5. Pulse Energy (J): Pulse energy implies the radiant energy in a laser pulse. When the laser is working in pulsed mode, the pulse energy, measured in Joules, is a more frequently used parameter than laser power, because some of its clinical effects are not directly influenced by the frequency or repetition rate of the laser pulses.

Laser Parameters(cont.)

6.Peak Power (W): Peak power refers to the power level during an individual laser pulse.

Peak power = Pulse energy / Pulse duration

7. Spot Size (mm): Laser beam spot size refers to the diameter of the laser beam on the target. By changing the laser beam spot size while keeping the laser pulse energy constant, the fluence can be changed substantially and thus the basic mechanism

8.Fluence (J/cm^2): Fluence refers to the amount of laser energy delivered to the treated surface area (in square centimeters). It is also called a dose of energy or energy density. **Fluence = Energy/Area**

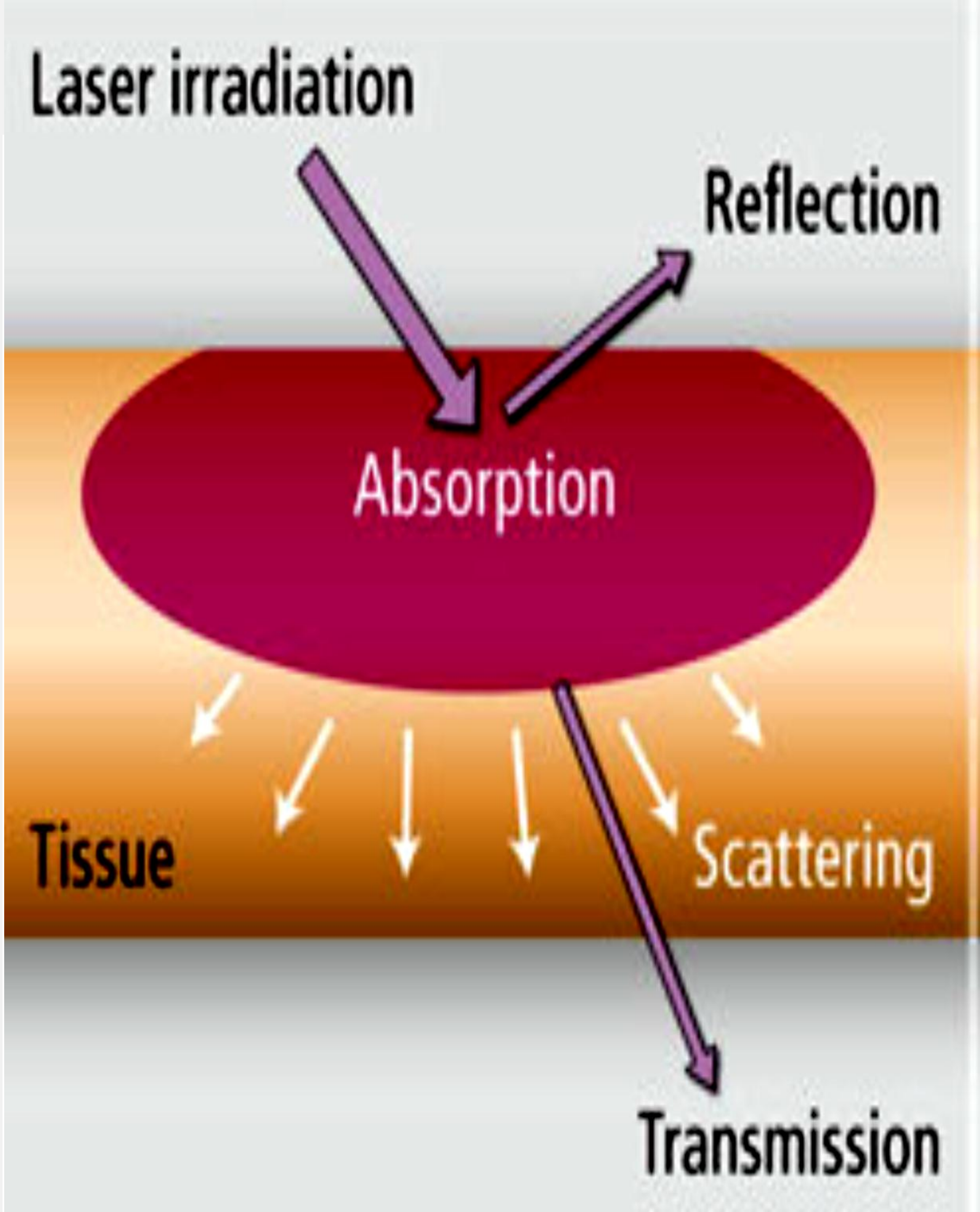
the fluence increases at the same energy settings if the spot size decreases. Vice versa, the fluence decreases at the same energy settings if the spot size increases.

Laser – Tissue interaction

When electromagnetic radiation hits biological tissue, different interactions occur as a function of various physical parameters.

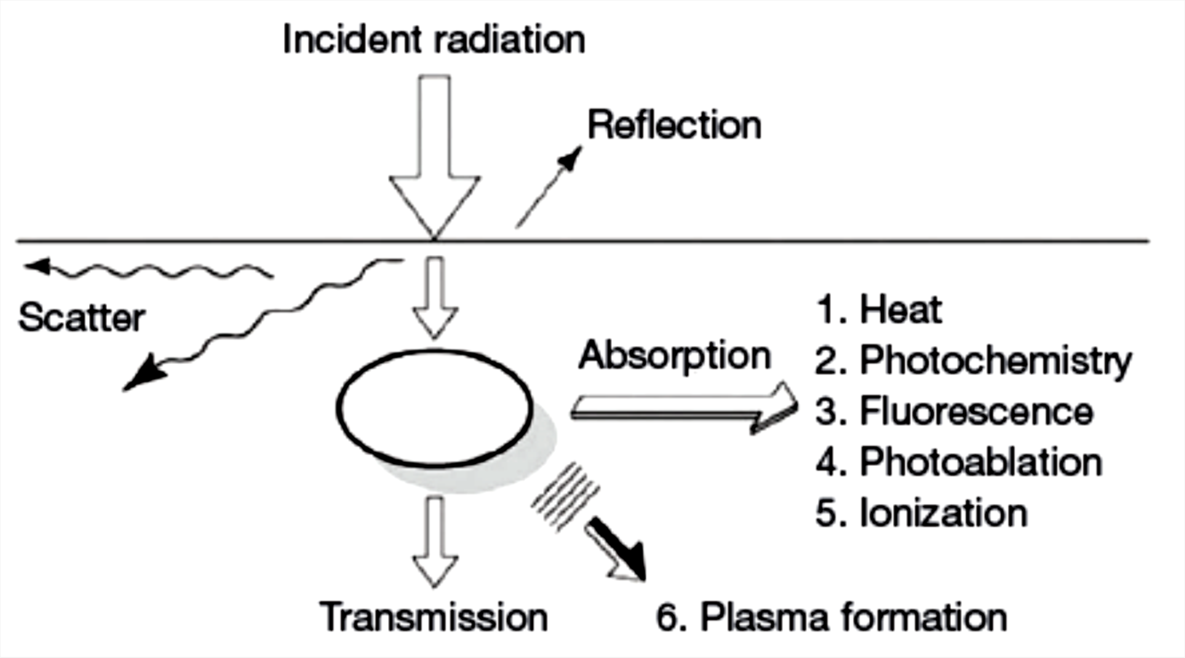
The variety of interaction mechanisms may occur when applying laser light to biological tissue due to specific tissue characteristics as well as laser parameters.

When laser light strikes a tissue surface, it can be reflected and refracted, scattered, absorbed or transmitted .The fractional intensity that goes into these different processes depends on the optical properties of the tissue like it's reflectivity, scattering and absorption coefficients, particle size , as well as the laser parameters like wavelength, energy, pulse. duration, operation mode and output spectral profile. In medical laser applications, refraction plays a significant role when irradiating transparent media like corneal tissue. In opaque media, usually, the effect of refraction is difficult to measure due to the absorption and scattering .



Laser – Tissue interaction(cont.)

During absorption, the intensity of an incident light is attenuated by passing through a medium due to a partial conversion of light energy into heat motion or certain vibrations of molecules of the absorbing material. The ability of a medium to absorb laser depends on a number of factors, mainly the electronic constitution of its atoms and molecules, the wavelength of radiation, the thickness of the absorbing layer and internal parameters such as temperature or concentration; Fig. shows these processes.



Laser – Tissue interaction(cont.)

Laser-tissue interactions depend on the interplay of irradiation parameters:

1. **Wavelength of laser source.**
2. **Physical properties of the tissue irradiated with that particular wavelength or wavelength band.**
3. **Irradiance or pulse energy.**
4. **Continuous wave (CW) or pulsed irradiation.**
5. **Laser beam size on the tissue.**
6. **Irradiation duration or laser pulse length and repetition rate.**
7. **Any change in the physical properties of the tissue as a result of laser irradiation with the parameters above.**

Medical applications of laser

Laser has many different applications in medicine, some of the most common medical procedures using laser include:

1.Laser surgery – This is a type of surgery that uses the laser rather than a scalpel to make bloodless cuts in the tissue, or to remove things such as tumors from the surface of the tissue. A number of different types of laser can be used in surgery, depending on the requirements and the type of surgery. The most common types include CO_2 laser, pulsed-dye laser, argon laser, excimer laser and diode laser.

2.Laser skin treatment – Laser has been used in dermatology for many years, and there are numerous ways it can be applied. Lasers can be used to treat vascular conditions such as thread veins, varicose veins and spider veins, where the laser is used to burn away the veins or to shrink the veinous tissues.

3. Laser hair removal – The removal of unwanted hair on the face and body is a common procedure using lasers. The laser emits a green light that is absorbed into the hair follicle and destroys the hair. The surrounding skin is unharmed.

Medical applications of laser

4.Skin pigmentation issues - **Lasers are also used to treat skin pigmentation issues such as birthmarks, sun spots and freckles, and it can be used to rejuvenate the skin and remove unwanted marks such as acne scars. It is now common practice for lasers to be used to remove unwanted tattoos.**

5. Laser eye surgery – **Corrective eye surgery using lasers is now almost as common as having contact lenses. The surgery involves reshaping the cornea, either by flattening or by increasing the curvature, to correct the vision. Lasers can also be used to repair damage to the eye such as a detached retina.**

6. Laser teeth whitening – **Lasers are used in dentistry in a number of ways, most commonly, they are used alongside a bleaching agent to whiten the teeth. The bleach is applied to the teeth, and the laser is used to heat the bleach and speed up the bleaching process.**

Medical applications of laser

7.In place of a drill - Lasers are more becoming more commonly used in place of a drill to remove the material that forms in a cavity, so that the tooth can be filled. This adds benefits as many people do not like the sound of the drill, the laser can also seal blood vessels leading to decreased bleeding when a laser is used compared with a drill.

8.Clearing arteries using lasers - Lasers are increasingly being applied to clear plaque from people’s arteries. The laser is fed through the patient's arteries, usually from a small incision in the groin, and moved to the correct position where there is a blockage in the artery. The laser can then burn away the fatty plaque, helping to increase blood flow.

Ministry of Higher Education
and Scientific Research

UNIVERSITY OF ANBAR
Applied Science College – Heet
Dept. of Medical Physics

Medical Devices

Fourth Stage- Lecture 3

Mammography

Dr.Nasrin Nadher Jamil

What is Mammography

Mammography is a radiographic procedure optimized for examination of the breast. For many women, mammography is a highly effective means of detecting early stage breast cancer. Depending upon the diagnosis, mammography is of two types:

Screening Mammography: It is the procedure that is done as a routine test to check for any cancer or changes in the breast.

Diagnostic Mammography: A procedure which is conducted if you have a lump or any other symptom of breast cancer.

Depending upon the process used, mammography is again categorized into 4 types:

Digital Mammography: This is a specialized form of mammography that uses digital receptors and computers instead of x-ray film to help examine breast tissue for breast cancer and detect it in the early stages.

3D Mammography: Also known as digital breast tomosynthesis (DBT), tomosynthesis, or 3D breast imaging, 3D mammography chiefly creates a 3D image of the breast using X-rays.

Photon-Counting Mammography: This process predominantly uses lesser dose of X-ray to create image than conventional methods. It mainly uses spectral imaging to further improve image quality, that helps to distinguish between different tissue types and to measure breast density.

Galactography: Also known as breast ductography, galactography is a type of mammography that is mainly used to visualize the milk ducts using a radiopaque substance that is injected into the duct system.

A screening mammogram is a routine (usually annual) mammogram that healthcare providers recommend to look for signs of cancer or abnormal breast tissue before you have symptoms. Screening mammography helps with the early detection of breast cancer. Early detection allows for early treatment, which may be more effective than if the cancer is found at a later stage.

A routine screening mammogram usually includes at least two pictures of each breast taken at different angles, typically from top to bottom and from side to side. If you have breast implants, you'll need additional images.

Healthcare providers order a diagnostic mammogram if a screening mammogram shows abnormal tissue or there's a new breast issue. While both types of mammograms use the same machines, diagnostic mammography uses additional imaging techniques, such as spot compression, supplementary angles or magnification views and is supervised by the radiologist at the time of the study.

Breast cancer is detected on the basis of four types of sign on the mammogram:

(i) The characteristic morphology of a tumour mass, which can include irregular margins and spiculations.

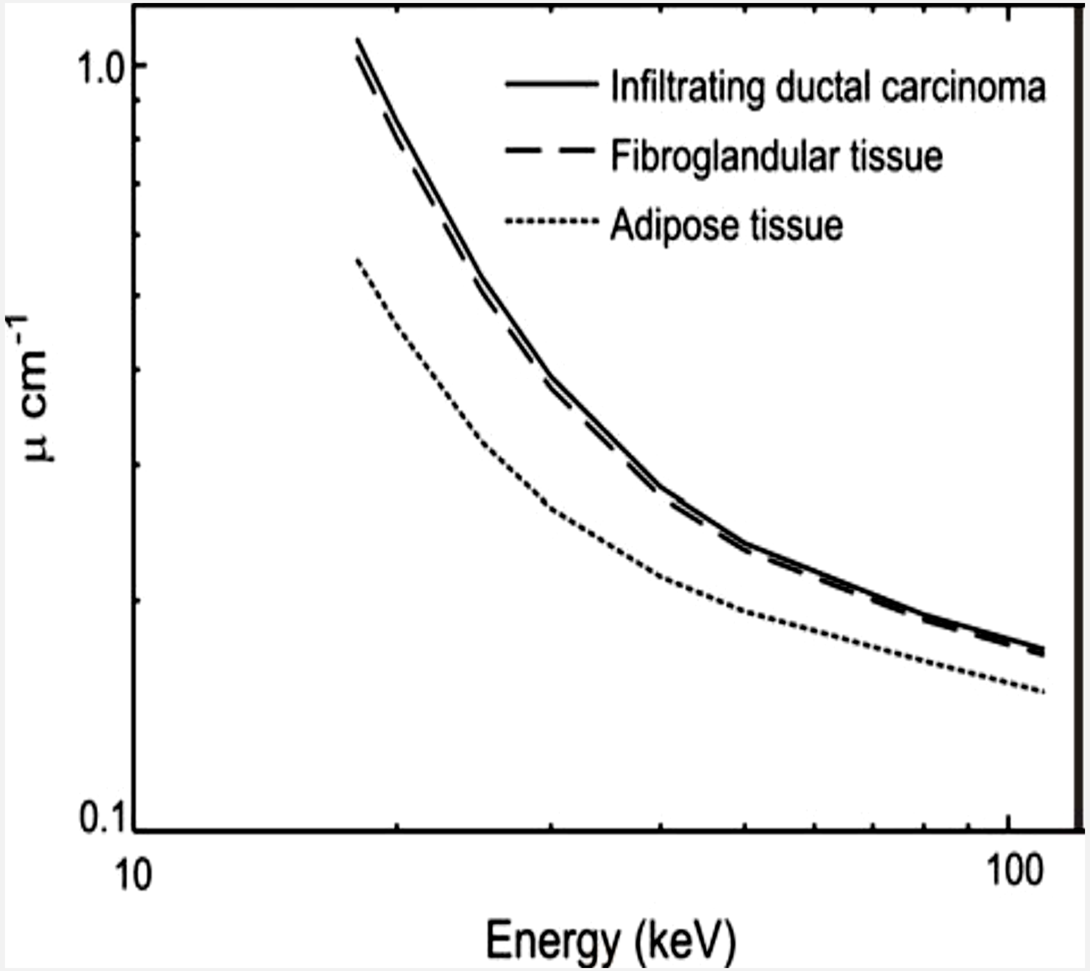
(ii) Certain presentations of mineral deposits, visualized as specks called microcalcifications.

(iii) Architectural distortion of normal tissue patterns caused by the disease.

(iv) Asymmetry between corresponding regions of the left and right breasts.

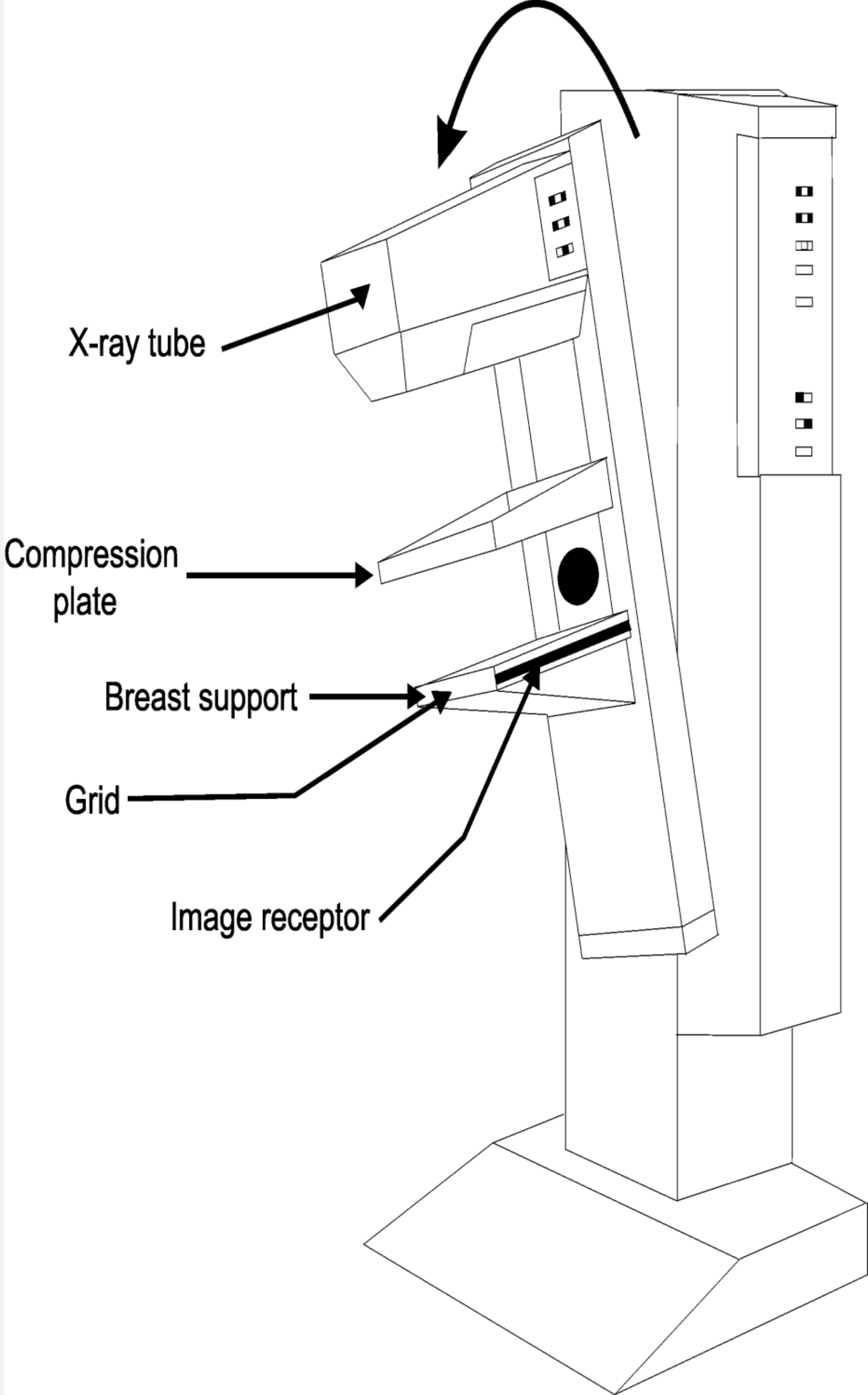
Figure below shows X ray attenuation coefficients measured versus energy on samples of three types of material found in the breast: adipose tissue, normal fibroglandular breast tissue and infiltrating ductal carcinoma (one type of breast tumour). Both the attenuation coefficients themselves, and their difference, decrease with increasing energy, resulting not only in a reduction in the radiation dose required to produce an image, but also a decrease in image contrast.

Mammography is chiefly recommended for every woman above the age of 40, in every 1 or 2 years. But in case, you have a personal or family history of breast cancer, the doctor may recommend you to start breast screenings earlier in life, and have them more often, or use additional diagnostic tools.



Mammography Imaging System

- Specialised gantry to accommodate the breast : Rotation and vertical movement
- Specialised beam geometry: Improves visualisation of chest wall edge.
- X ray generator
  - High frequency
  - Near constant potential waveform
- X ray tube
  - Rotating anode
  - Dual focus 0.3/0.1 mm
- Beryllium exit window (low attenuation)
- FID (focus image distance) generally in the range 60 to 65 cm.



- X ray spectrum should provide a range of energies that give an appropriate compromise between radiation dose and image quality for the tissues under examination
- X ray spectrum determined by target material, filter material, and tube voltage (kV)
- For screen-film mammography optimum beam energy lies between 18 and 23 keV depending on breast thickness and composition. Characteristic X rays from molybdenum and rhodium are suitable
- Higher energies may be more optimal for digital mammography 9.3.
- Metallic filters used in mammography.
- Molybdenum (Mo) filter (30 to 35 µm thick) commonly employed with Mo anode.
- Filter acts as energy window:
- Greater attenuation of X rays at low energies and at energies above the K-absorption edge of Mo at 20 keV
- Mo characteristic X rays from the target and X rays of similar energy produced by bremsstrahlung pass through the filter
- Resultant spectrum enriched with X rays in the range 17 to 20 keV.
- Higher energies are desirable for imaging thick, dense breasts.

Compression

There are several reasons for applying firm (but not painful) compression to the breast during the mammographic examination. Compression causes the various breast tissues to be spread out, minimizing superposition from different planes and thereby improving the conspicuity of structures. This effect may be accentuated by the fact that different tissues (fatty, fibroglandular and cancerous) have different elasticities, resulting in the various tissues being spread out by different amounts and potentially making a cancer easier to see.

As in other areas of radiography, scattered radiation will degrade contrast in the mammogram. The use of compression decreases the ratio of scattered to directly transmitted radiation reaching the image receptor.

Compression also decreases the distance from any plane within the breast to the image receptor, and in this way reduces geometric unsharpness. The compressed breast provides lower overall attenuation to the incident X ray beam, allowing the radiation dose to be reduced.

The compressed breast also provides more uniform attenuation over the image, this reduces the exposure range that must be recorded by the imaging system, and in screen film mammography allows a film of higher gradient to be employed.

Finally, compression provides a clamping action, which reduces anatomical motion during the exposure, thereby reducing this source of image unsharpness. It is important that the breast be compressed as uniformly as possible and that the edge of the compression plate at the chest wall be straight and aligned with both the focal spot and image receptor to maximize the amount of breast tissue that is included in the image (see Figure).

The mechanical properties of the breast are non-linear; after a certain reduction in thickness, application of additional pressure provides little benefit in terms of improved image quality and only contributes to patient discomfort. Specialized mechanisms have been introduced by several manufacturers to try to achieve better compression, while minimizing the risk of over compression.

How does it work?

Unlike most general radiography equipment, which is designed such that the image field is centered below the X ray source, in mammography, the system's geometry is arranged as in above figure. A vertical line from the focal spot of the X ray source grazes the chest wall of the patient and intersects orthogonally with the edge of the image receptor closest to the patient. If the X ray beam were centered over the breast ,some of the tissue near the chest wall would not be imaged.

The machine takes X-rays at lower doses than X-rays used to look at your bones. During a mammogram, you place your breast on a support plate attached to the X-ray machine. A technologist then squeezes your breast with a parallel plate called a paddle. The machine produces X-rays that pass through your breast to a detector located on the opposite side. The detector transmits electronic signals to a computer to form a digital image. These images are called mammograms.

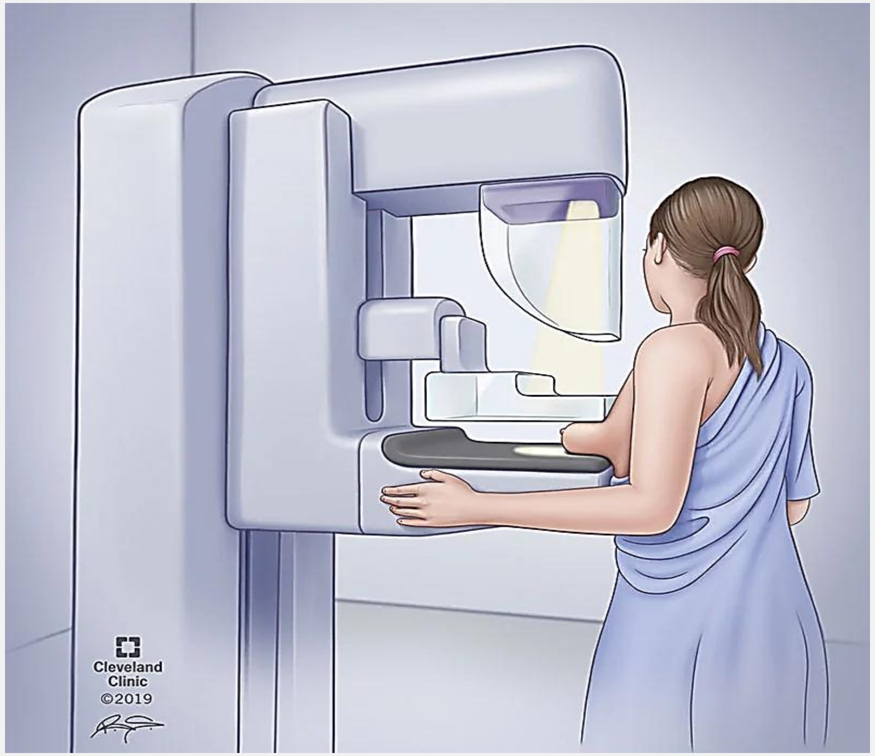
Breast compression is necessary for a mammogram to hold your breast still and minimize movement, which can cause the X-rays to look blurry. Compression also evens out the shape of your breast so that the X-rays can travel through a shorter path to reach the detector. This allows for a lower radiation dose and improves the quality of the image.

Radiation leaving the X ray tube passes through a metallic spectral shaping filter, a beam defining aperture and a plastic plate, which compresses the breast on to the breast support platform. Those X rays transmitted through the breast and breast support are incident on a specially designed antiscatter grid, and then are incident on the image receptor, where they interact and deposit most of their energy locally.

In screen film and cassette based digital mammography systems, a fraction of the X rays passes through the receptor without interaction and these X rays impinge upon the sensor of the automatic exposure control (AEC) mechanism of the mammography unit. In other digital mammography systems, the AEC mechanism is typically integral with the digital image receptor. In all systems, any remaining primary X rays are attenuated by a primary beam stop.

In modern mammography systems, the power supply is typically of the high frequency type and provides a nearly constant potential waveform during the exposure. The X ray tube employs a rotating anode design in which electrons from the cathode strike the anode target material at a small angle from normal incidence.

On modern equipment, the typical nominal focal spot size for contact mammography is 0.3 mm, while the smaller focal spot used primarily for magnification is 0.1 mm. The nominal focal spot size is defined relative to the effective spot size at a reference axis.



As shown in fig. this reference axis, which may vary from manufacturer to manufacturer, is normally specified at some midpoint in the image.

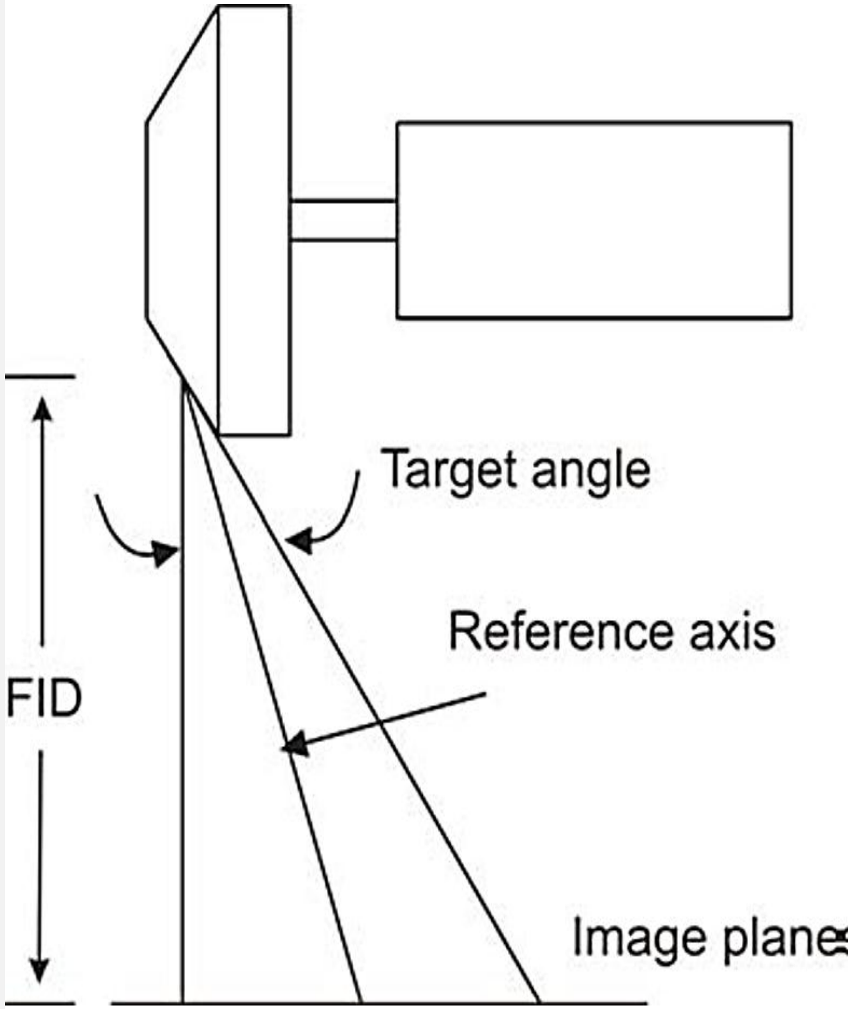
Magnification mammography

Magnification mammography can be used to improve the diagnostic quality of the image. Breast supported above the image receptor

- Focus object distance reduced
- Object to image receptor distance increased
- Magnification results

Benefits of magnification mammography

- Increased SNR(Signal-to-Noise Ratio).
- Improved spatial resolution.
- Dose-efficient scatter rejection.



The geometry of an X ray tube (FID: focus to image distance). The perpendicular line abuts the chest wall. The reference axis on a particular system will be specified by the manufacturer

Main benefit of magnification is to increase the size of the projected anatomic structures compared to the granularity of the image

- SNR in the image is improved
- Improvement can be valuable, particularly for the visualization of fine calcifications and spiculations.

Magnification in Digital Mammography

- Film grain noise eliminated
- Limiting spatial resolution of detector lower than that provided by the screen-film image receptor
- Benefits of magnification may be different in nature
- Increase in projected size of anatomical features does improve the effective resolution of the detector, which in some cases is a limiting factor.

Spatial resolution in magnification mammography is limited by focal spot size.

- Use of a small spot (typically 0.1 mm) is critical

As the breast is closer to the X ray source in magnification mammography

- Dose to breast increases (compared to contact mammography)
- Air gap between the breast and image receptor provides some scatter rejection.
- Anti-scatter grids not employed for magnification (partially offsets increase in dose)

Digital mammography

Digital and conventional mammography both use X-rays to produce an image of your breast. The difference is that the image is stored directly on film in conventional mammography, whereas digital mammography provides an electronic image that's stored as a computer file. Digital mammography allows healthcare providers to save the file electronically and to more easily evaluate and share the images.

A digital mammogram usually involves at least two pictures of each breast taken at different angles - typically from top to bottom and from side to side - and provides a two-dimensional (2D) view. Able to overcome many of the technical limitations of screen-film mammography.

In digital mammography, image acquisition, processing, display, and storage are performed independently, allowing optimisation of each.

Acquisition performed with low-noise X ray detectors with wide dynamic range.

As the image is stored digitally:

- **It can be displayed with contrast independent of the detector properties**
- **Image processing techniques that are found to be useful can be applied prior to image display.**

Challenges in creating a digital mammography system with improved performance are mainly related to the X ray detector and the display device.

How to prepare for your mammogram

- On the day of the exam, don’t apply deodorant, antiperspirant, powders, lotions, creams, or perfumes under your arms, or on or under your breasts. Some of these contain substances that can show up on the x-ray as white spots.
- You might find it easier to wear a skirt or pants, so that you’ll only need to remove your top and bra for the mammogram.
- Make sure your provider is aware of any part of your medical history that could affect your breast cancer risk-such as surgery, hormone use, breast cancer in your family, or if you’ve had breast cancer before.

To help ensure you have a good quality mammogram, make sure your technologist knows:

- About any breast changes or problems you’re having.
- If you have breast implants
- If you have trouble standing and holding still alone (without the aid of a cane or walker)
- If you’re breastfeeding or if you think you might be pregnant.
- Tell the technologist right away if you start feeling lightheaded or dizzy during the mammogram

How Is A Mammography Done?

A mammography test is quite a simple procedure. The patient or person undergoing the procedure is first asked to remove the clothes from the waist up and keep aside any jewellery items if the person is wearing. The breasts are then placed or fitted on a resting plate, and a compression device is used to push the breast down to flatten the tissue to get a clearer picture of the breast. The person may feel some amount of discomfort but it is usually temporary and does not cause any damage to the breast tissue. Typically, the technician takes two views of each breast. Once the films are developed, these radiographs are checked by the technicians for clinical accuracy before the person leaves.

How To Interpret The Results?

Once the procedure is conducted, the person will usually get the films within a week. The films are then examined by radiologists who have specialised training in the interpretation of breast images.

Apart from detection of cancer, a mammography can help find calcifications, or calcium deposits, in the breasts. It can also find cysts within the breast tissue which may come and go normally during some people’s menstrual cycles and also presence of any cancerous or noncancerous lumps.

If the mammography is normal, continue to do the process every year as a routine check-up.

If the results are abnormal, the doctor may suggest the patient to go for additional mammograms, tests, exams or other imaging techniques such as MRI or Ultrasound. The doctor may also refer the patient to a specialist or a surgeon in case the procedure detects cancer and the person needs a surgery.

تشرين الأول هو شهر التوعية
بسرطان الثدي

سرطان الثدي هو من
أكثر أنواع السرطان
شيوعاً في العراق

قد يصيب كلًا من النساء
والرجال، إلا أنه أكثر شيوعاً
بين النساء

الوقاية من سرطان الثدي
الرضاعة الطبيعية
الإقلاع عن التدخين
ممارسة الأنشطة البدنية
التحكم في الوزن
تجنب التعرض للإشعاع
إجراء الفحص المبكّر بشكل دوري