X-ray , CT, &MRI

By:

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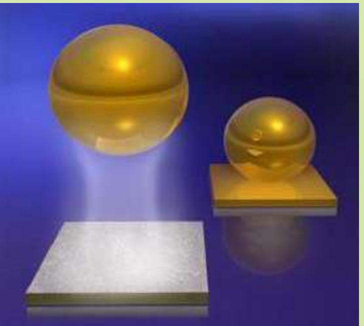
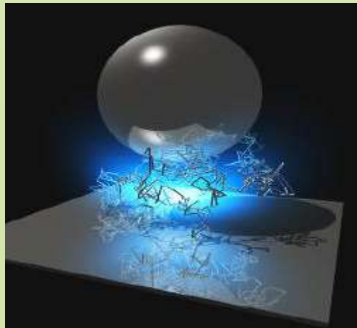




Outline

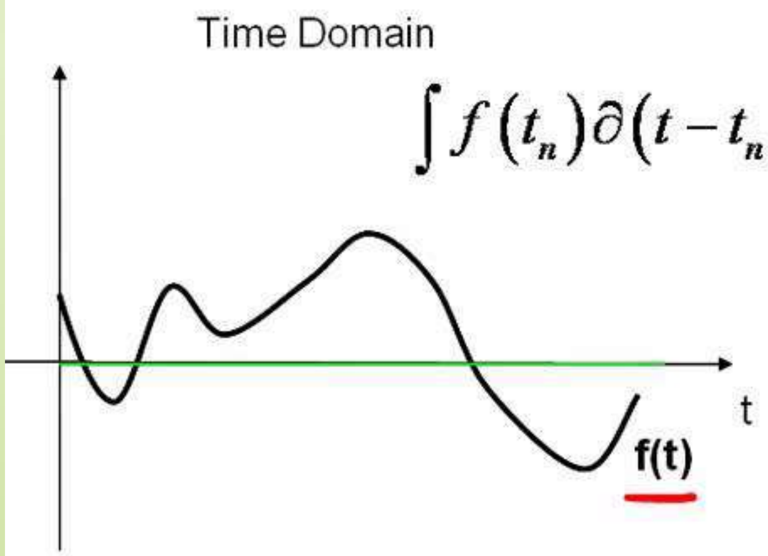
- INTORDUCTION
- X-RAY
- CT SCAN
- MRI

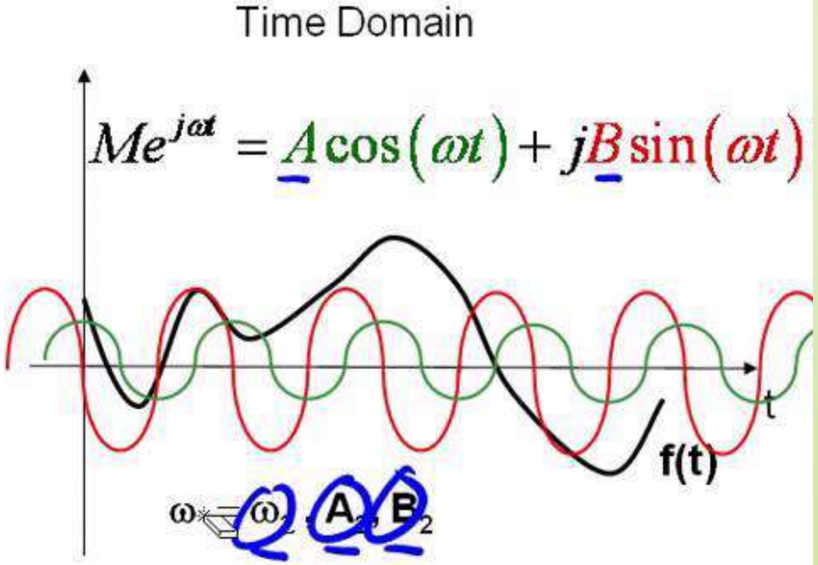
Fourier Transformation

The Fourier Transform: Why and How Does it Work?

$$F(\omega)=\int_{-\infty}^{\infty} f(t)\,e^{j\omega t}\,\partial t$$

The Fourier Transform changes ___ from time domain to frequency domain and back again.





Physics of Diagnostic and Therapy

- The field of radiology has three major braches

❖ Diagnostic radiology

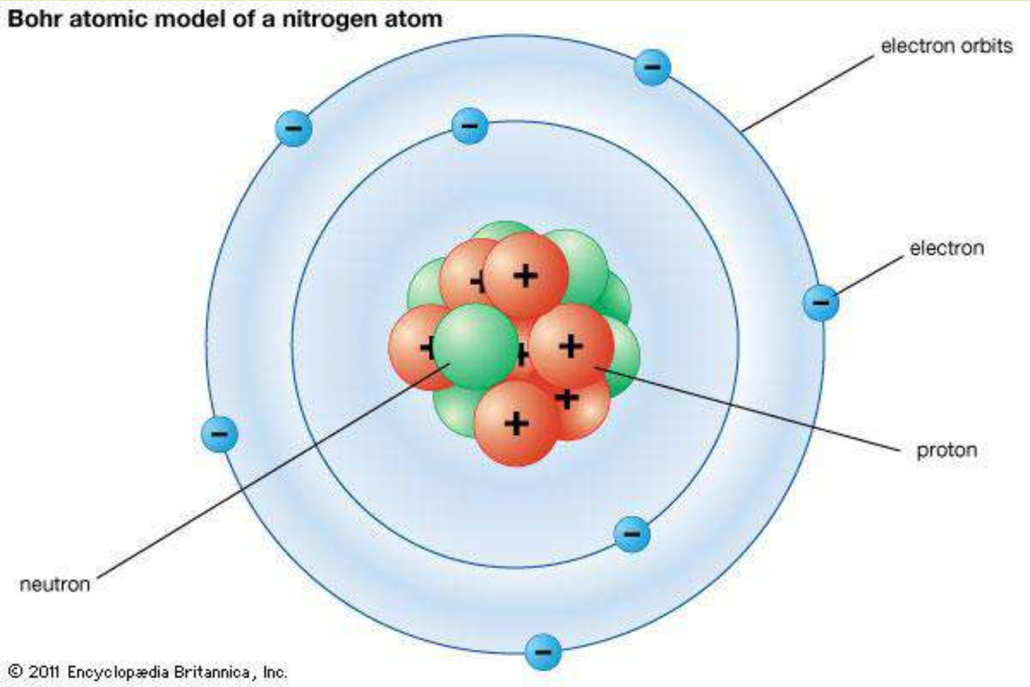
❖ radiation therapy

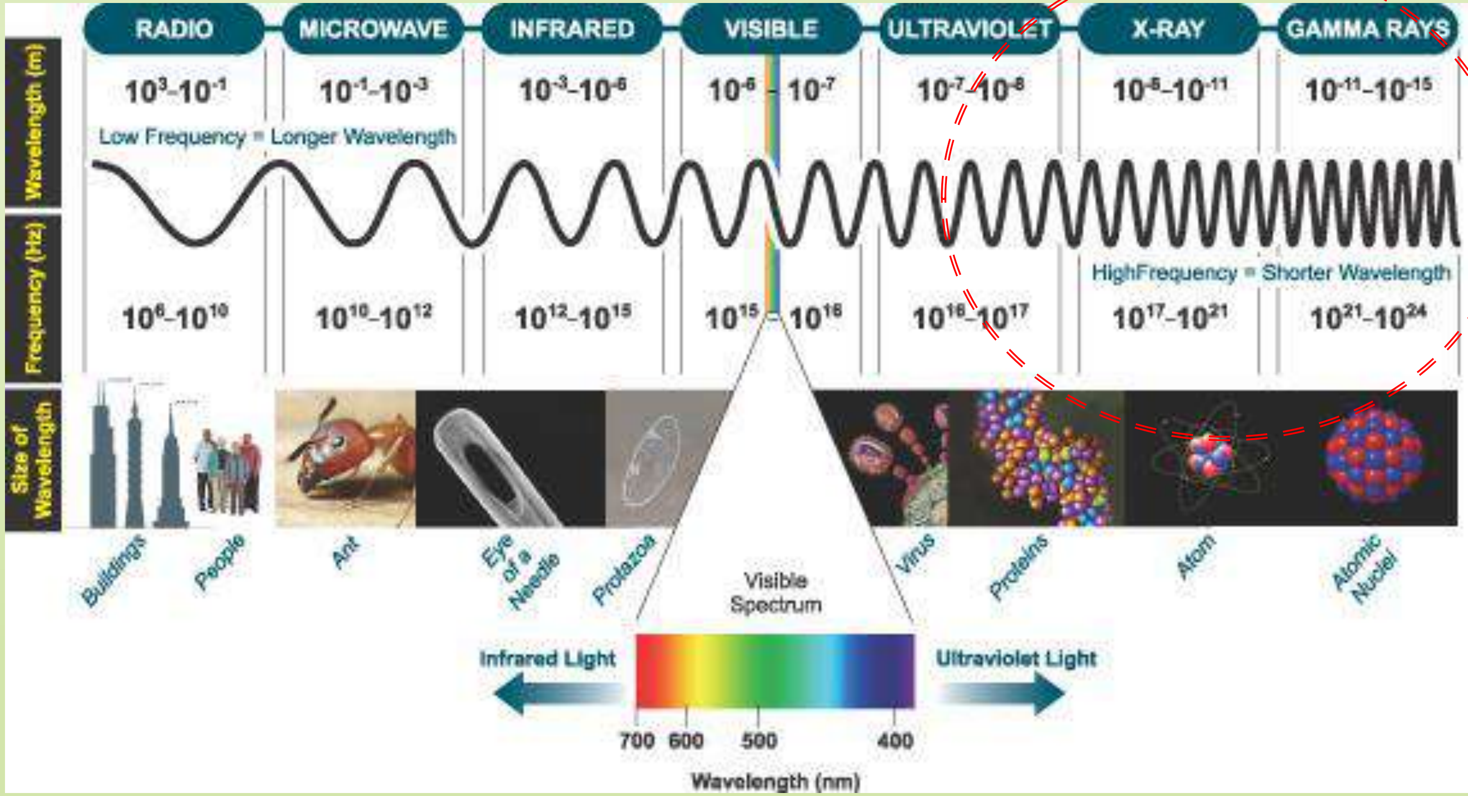
❖ nuclear medicine

The nuclei of most naturally occurring atoms are stable. They do not change when left alone. There are, however, many unstable nuclei which undergo transformations accompanied by the emission of energetic radiation.

The atom

Radiation is the emission or transmission of **energy** in the form of **waves** or **particles** through space or through a material medium. This includes **electro-magnetic radiation** such as radio wave , visible waves, visible light , and x-ray , particle radiation such as such as α, β, and neutron radiation.

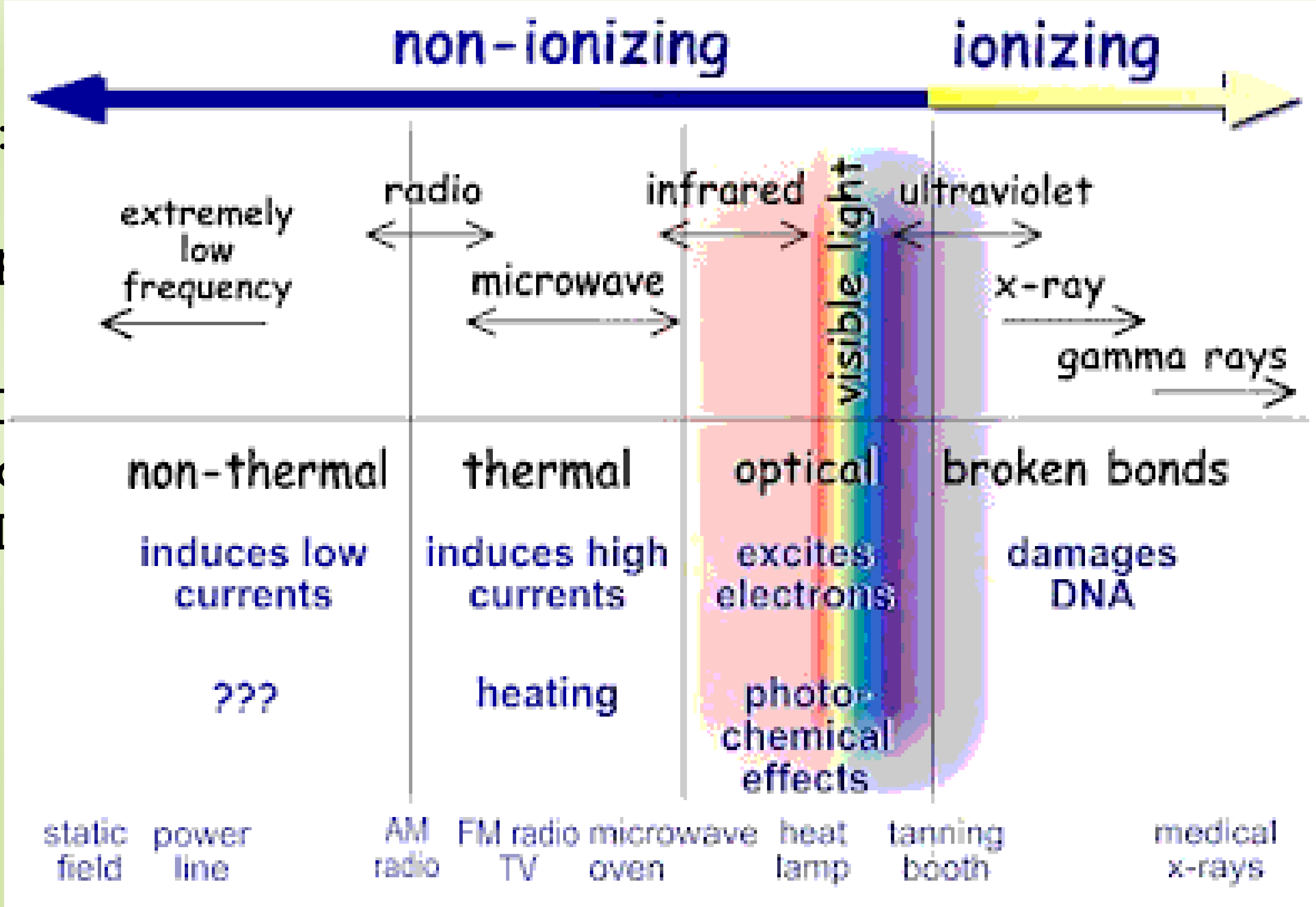




Type of radiation

- Non Ionizing radiation: ionizing radiation . enough energy to

- Ionizing Radiation: It if can knock electr process known as I
- Alpha particles
- Beta Particales
- Gamma rays
- Nutrons



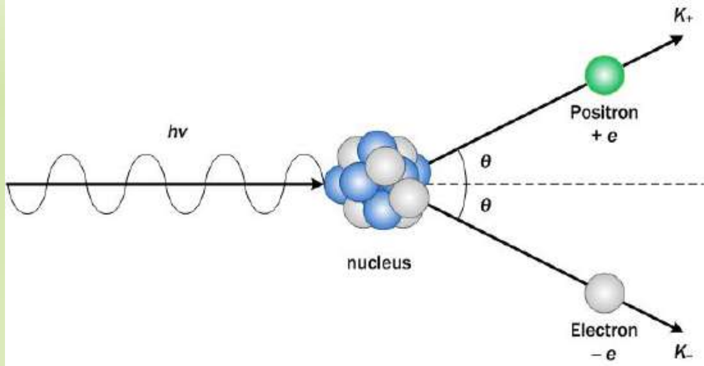
sources of radiation

- **Natural sources**

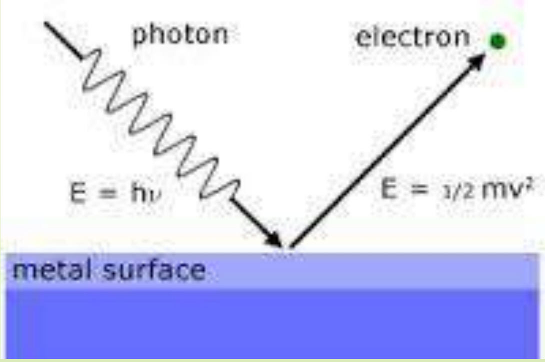
- Cosmic rays
- Terrestrial radiation
- Internal radiation (^{40}K , ^{14}C)

- **Man-Made sources**
- Medical sources
- Industrial sources
- Nuclear Power
- Nuclear and radiation accidents

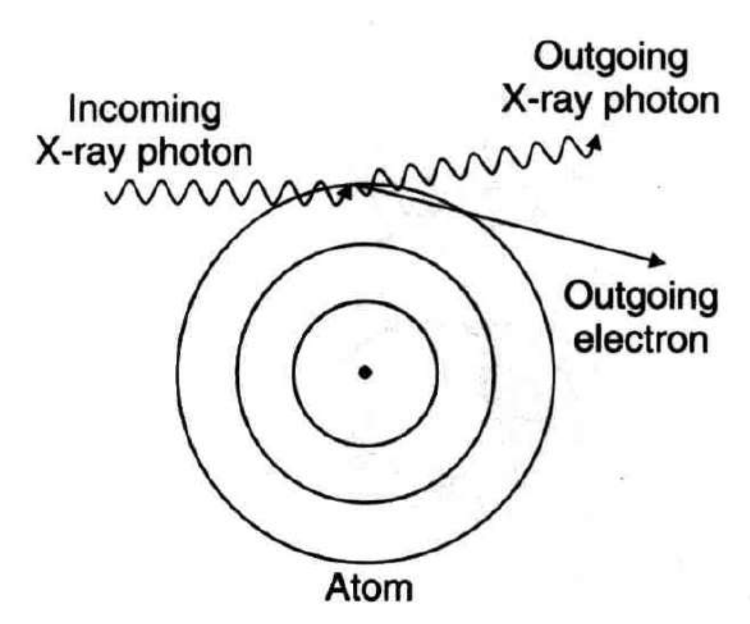
The phenomena



- pair production



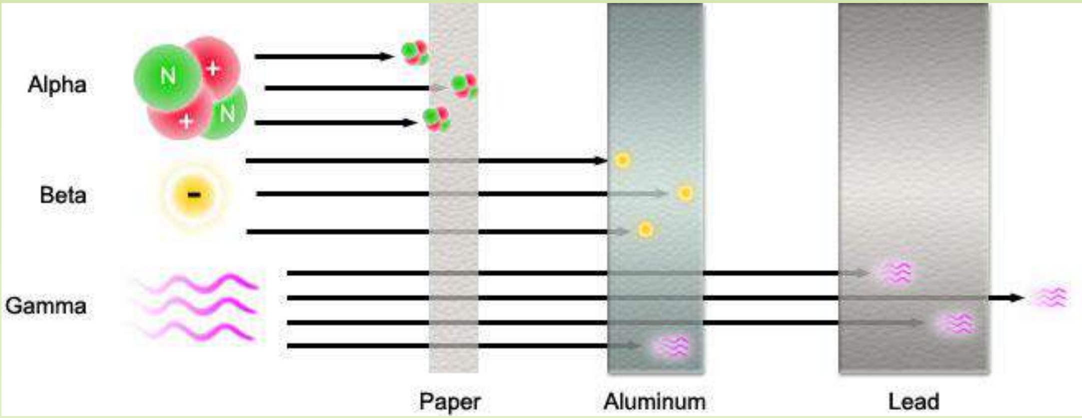
- photoelectric effect



- compton effect

radioactive nuclei three categories

- **alpha (α) particles**, which are high-speed helium nuclei consisting of two protons and two neutrons Such as helium nucleus
- **beta (β) particles**, which are very high speed electrons emitted from the nuclei of decaying radioisotopes. Since these are electrons, they have a negative charge and a small mass; Beta particles may travel 2 or 3 meters through air
- **gamma (γ) rays**, which are highly energetic photons. It is electromagnetic radiation of the shortest wavelength and highest energy



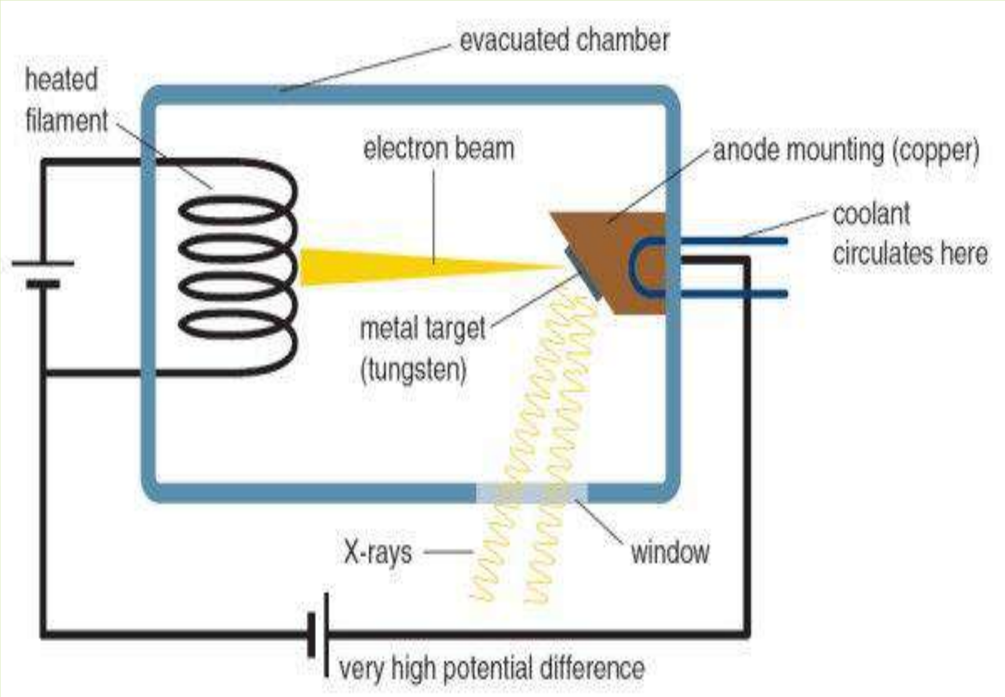
Gamma rays typically have energies above 100 keV, and therefore have frequencies above 10 exahertz (or $>10^{19}$ Hz) and wavelengths less than 10 picometers (10^{-11} m)

The x-ray

- X-rays are a form of ionizing electromagnetic radiation frequency and a very short wavelength.
- Their wavelengths range between 0.001 to 10 nm.
- When a patient has an X-ray, they are usually scanned at a frequency of approximately 7×10^8 Hz because body tissues absorb this frequency the best

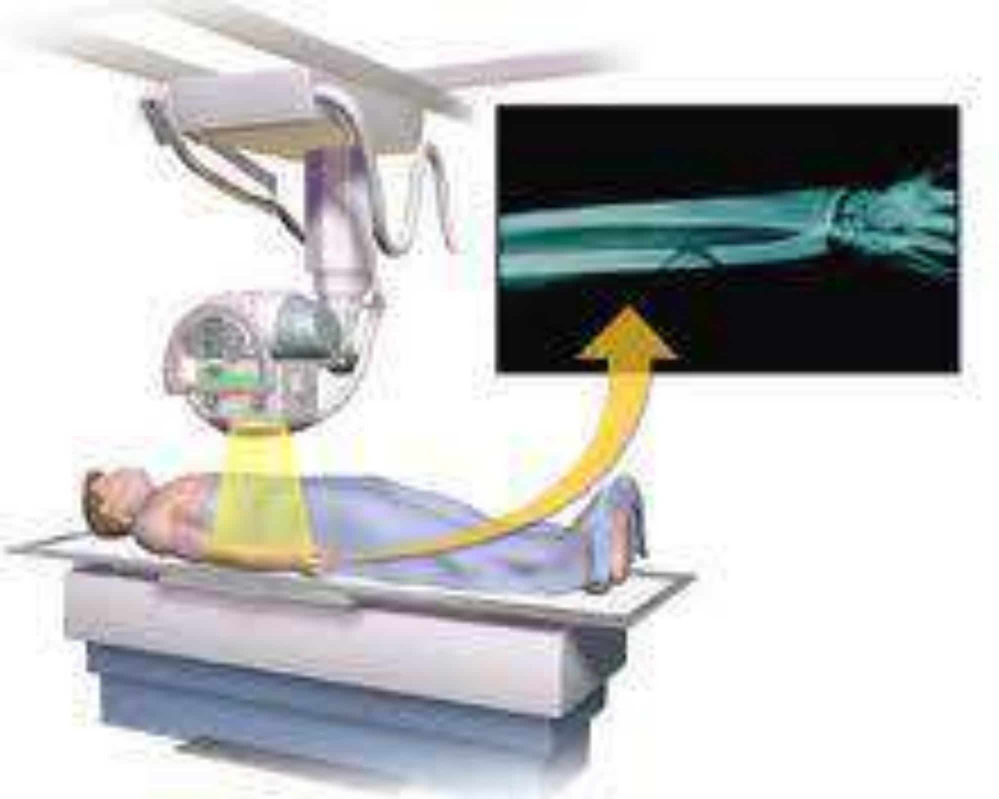
The x-ray

- Medical x-rays are used to generate images of tissues and structures inside the body.
- If x-rays travelling through the body also pass through an x-ray detector on the other side of the patient, an image will be formed that represents the “shadows” formed by the objects inside the body.
- One type of x-ray detector is photographic film, but there are many other types of detectors that are used to produce digital images. The x-ray images that result from this process are called **radiographs**.

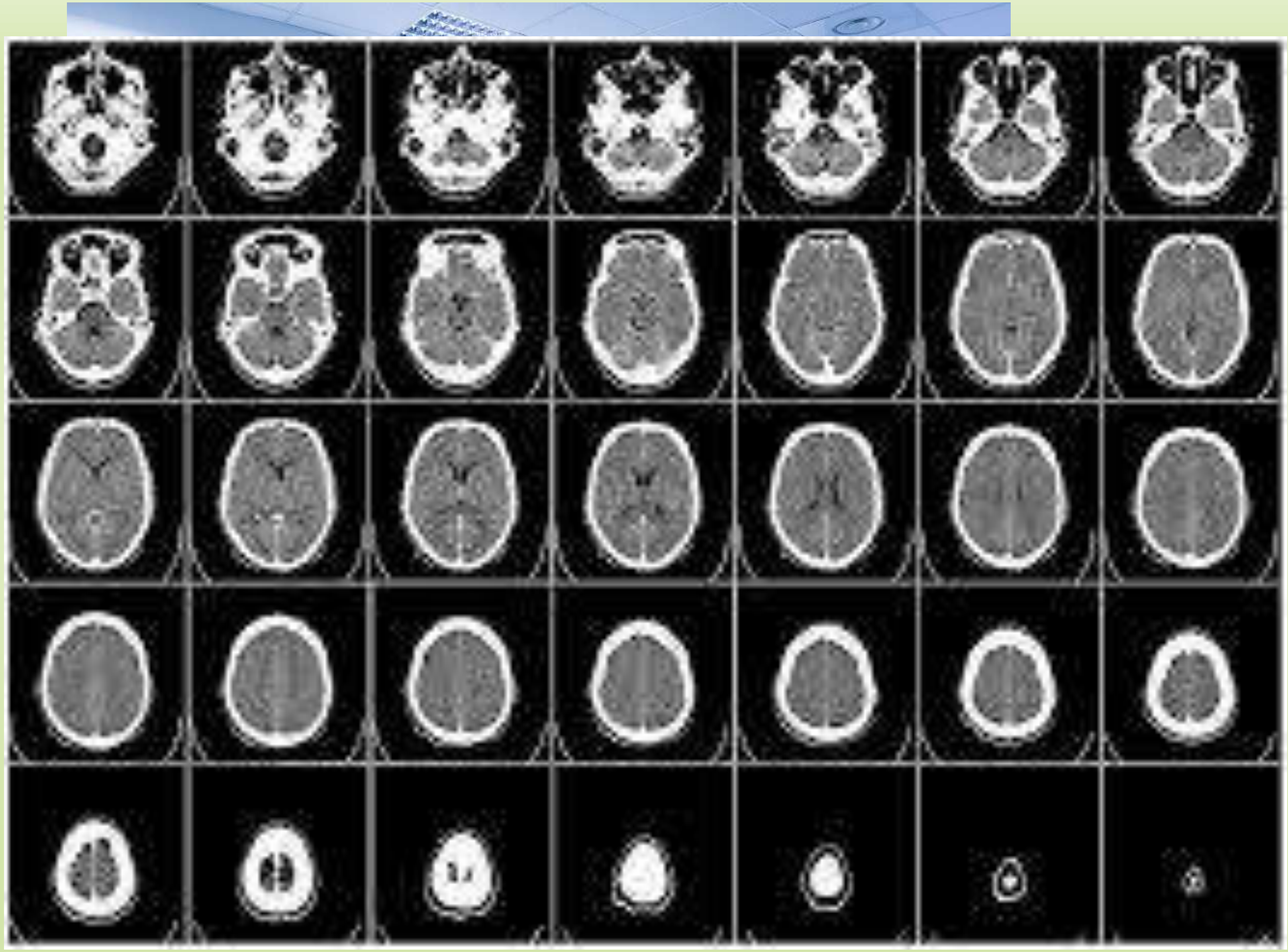


How do medical x-rays work?

- To create a radiograph, a patient is positioned so that the part of the body being imaged is located between an x-ray source and an x-ray detector.
- Radiological density is determined by both the density and the atomic number of the materials being imaged. For example, structures such as bone **contain calcium, which has a higher atomic number than tissues**. Because of this property, bones readily absorb x-rays and, thus, produce high contrast on the x-ray detector. As a result, bony structures appear whiter than other tissues against the black background of a radiograph.

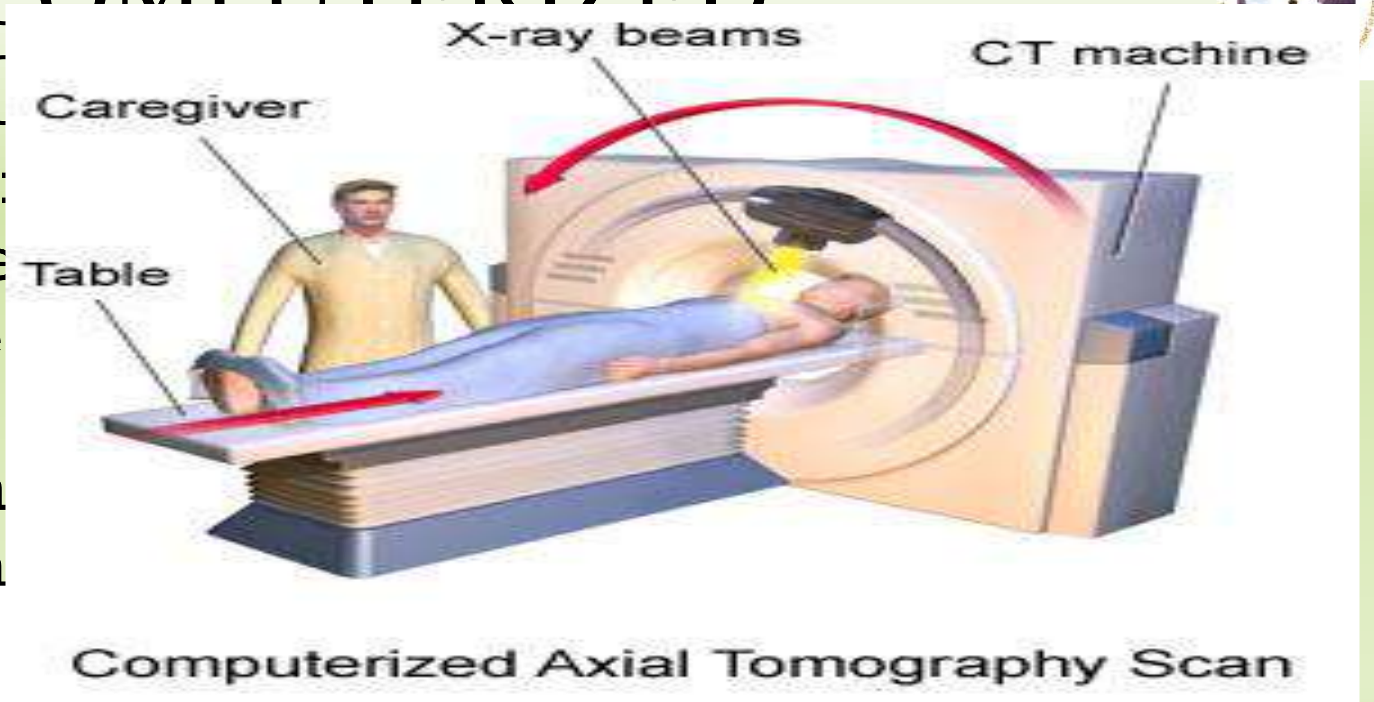


The COMPUTERIZED TOMOGRAPHY

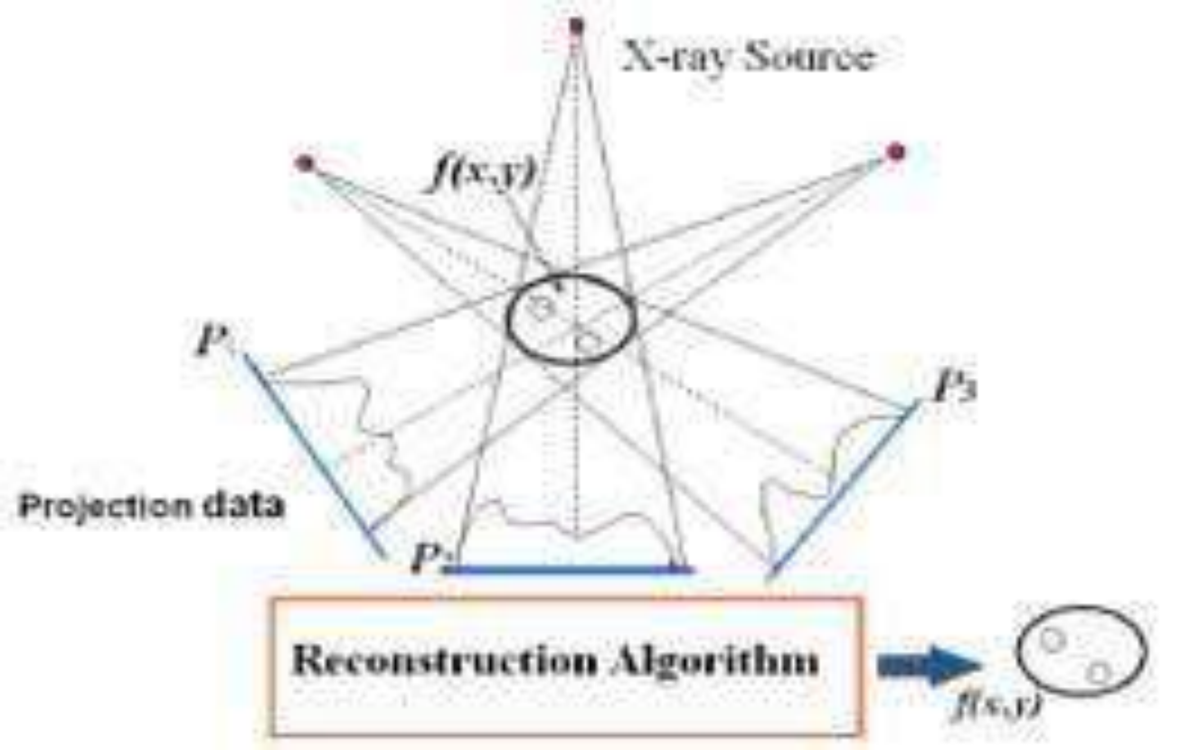


The X-RAY COMPUTERIZED TOMC

- The usual X-ray picture does not provi
information. The image represents the
as the X-ray beam passes through the



- A thin beam of X-rays passes through
want to visualize and is detected by a



amount (about 1◦)
around the

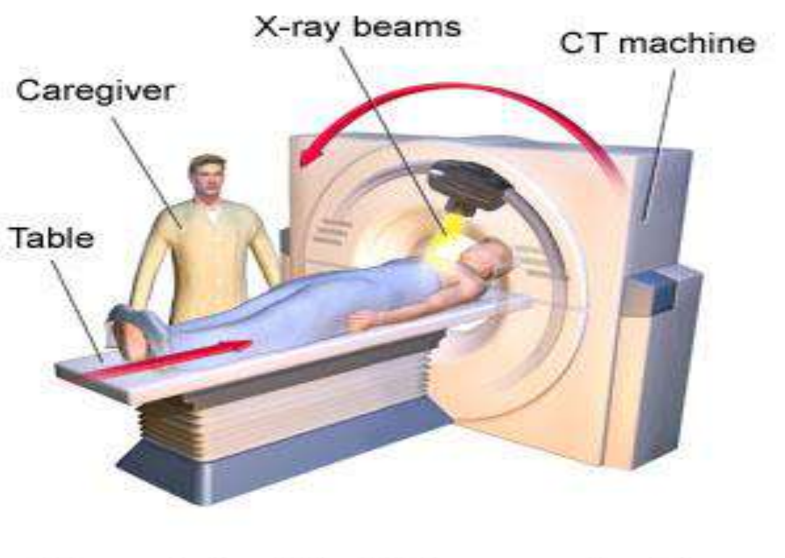
y processing to
of the inside of

The X-RAY COMPUTERIZED TOMOGRAPHY

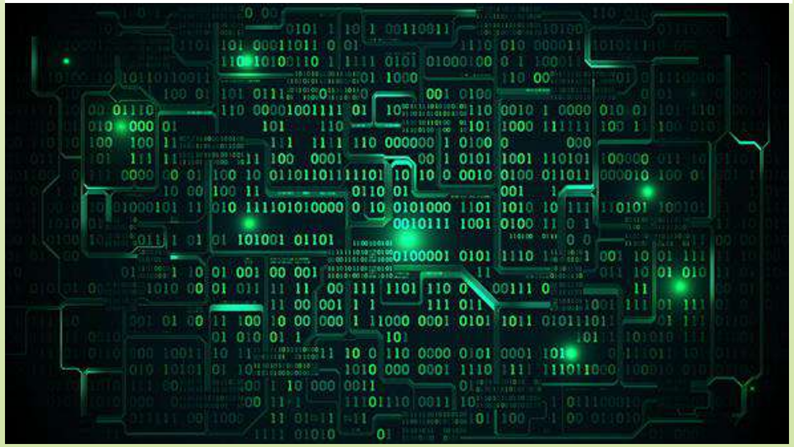
- The usual X-ray picture does not provide depth information. The image represents the total attenuation as the X-ray beam passes through the object in its path

- A thin beam of X-rays passes through the plane we want to visualize and is detected by a diametrically opposing detector

- The angle is then changed by a small amount (about 1◦) and the process is repeated full circle around the object. By rotation
- The CT scanner uses digital geometry processing to generate a 3-dimensional (3D) image of the inside of an object



Computerized Axial Tomography Scan



The X-RAY COMPUTERIZED TOMOGRAPHY

- What are the benefits vs. risks

Benefits

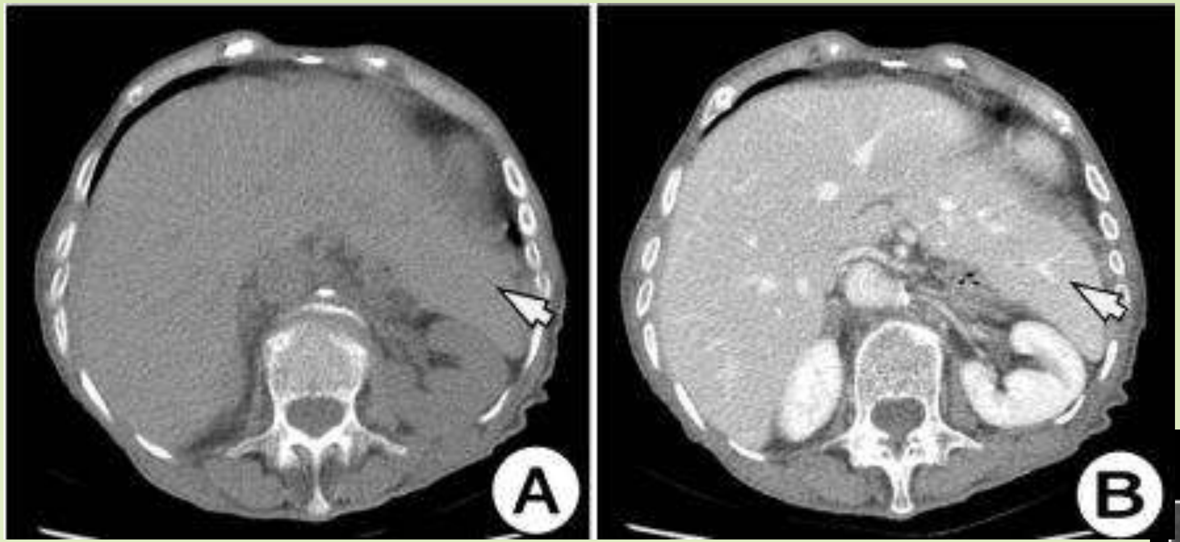
- ✓ CT scanning is painless, noninvasive and accurate.
- ✓ A major advantage of CT is its ability to image bone, soft tissue and blood vessels all at the same time.
- ✓ CT examinations are fast and simple; in emergency cases, they can reveal internal injuries and bleeding quickly enough to help save lives.
- ✓ CT is less sensitive to patient movement than MRI.
- ✓ CT can be performed if you have an implanted medical device of any kind, unlike MRI.

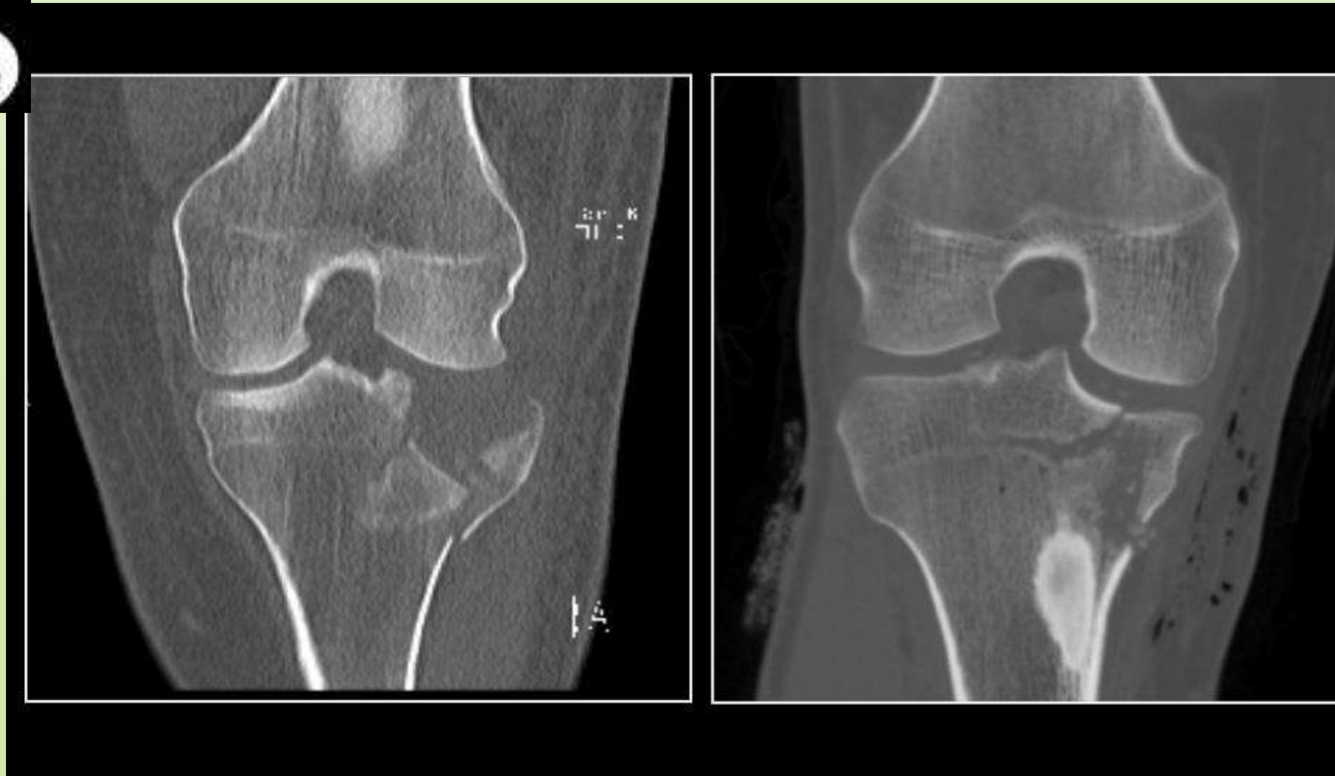
What are the benefits vs. risks

Risks

- ✓ evidence that radiation at small amounts delivered by a CT scan causes cancer
- ✓ CT scanning is, in general, not recommended for pregnant women
- ✓ Because children are more sensitive to radiation, they should have a CT exam only if it is essential for making a diagnosis and should not have repeated CT exams unless absolutely necessary. CT scans in children should always be done with low-dose technique.
- ✓ Soft-tissue details in areas such as the brain, internal pelvic organs, and joints (such as knees and shoulders) can often be better evaluated with magnetic resonance imaging (MRI). **the limitations of CT Scanning of the Body**

What are the benefits vs. risks





Contrast Media

help highlight blood vessels and to enhance the tissue structure of various organs

Contrast is used depending upon the patient's age, weight, area being imaged and cardiovascular health.

What are the benefits vs. risks

HOUNSFIELD REVIEW SERIES

Cancer risks from diagnostic radiology

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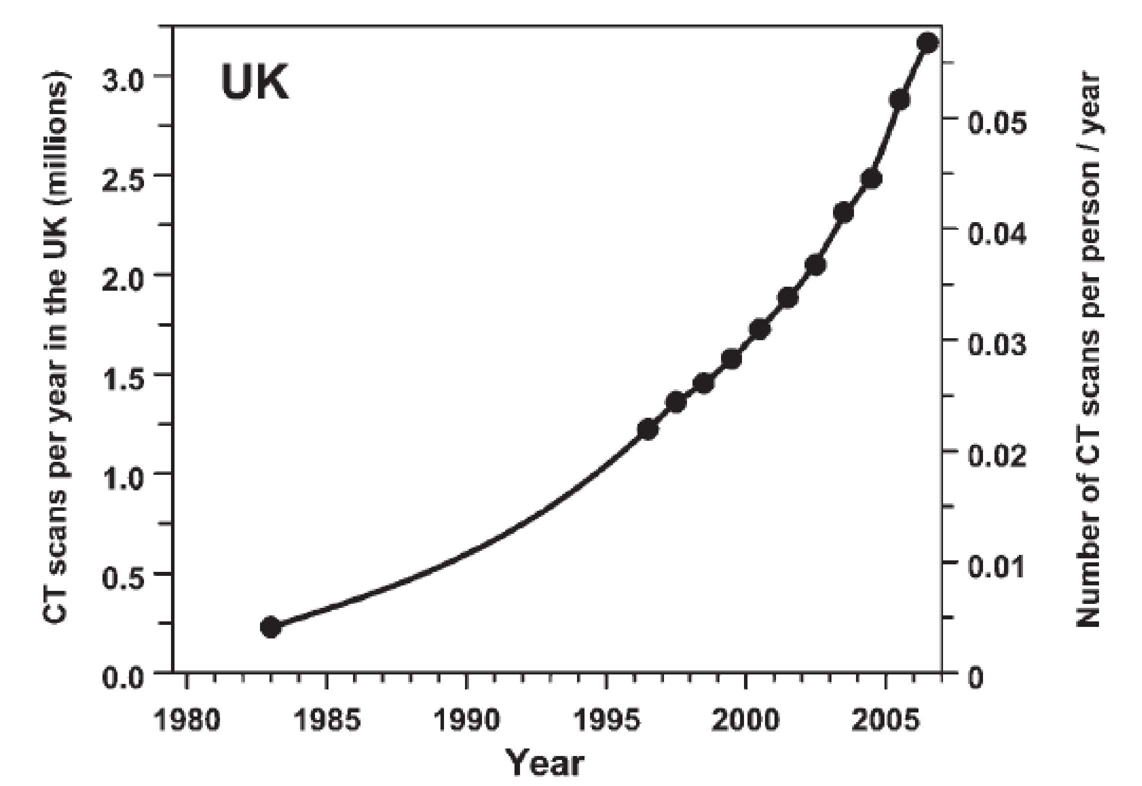
ABSTRACT. In recent years, there has been a rapid increase in the number of CT scans



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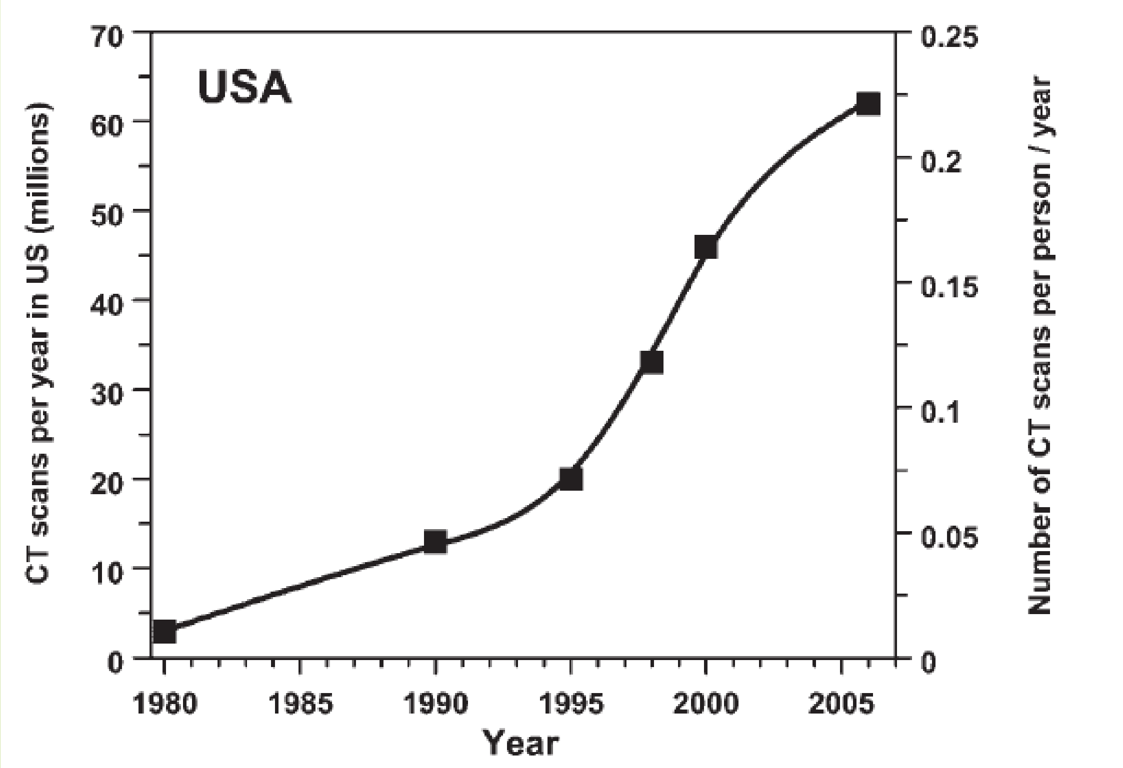
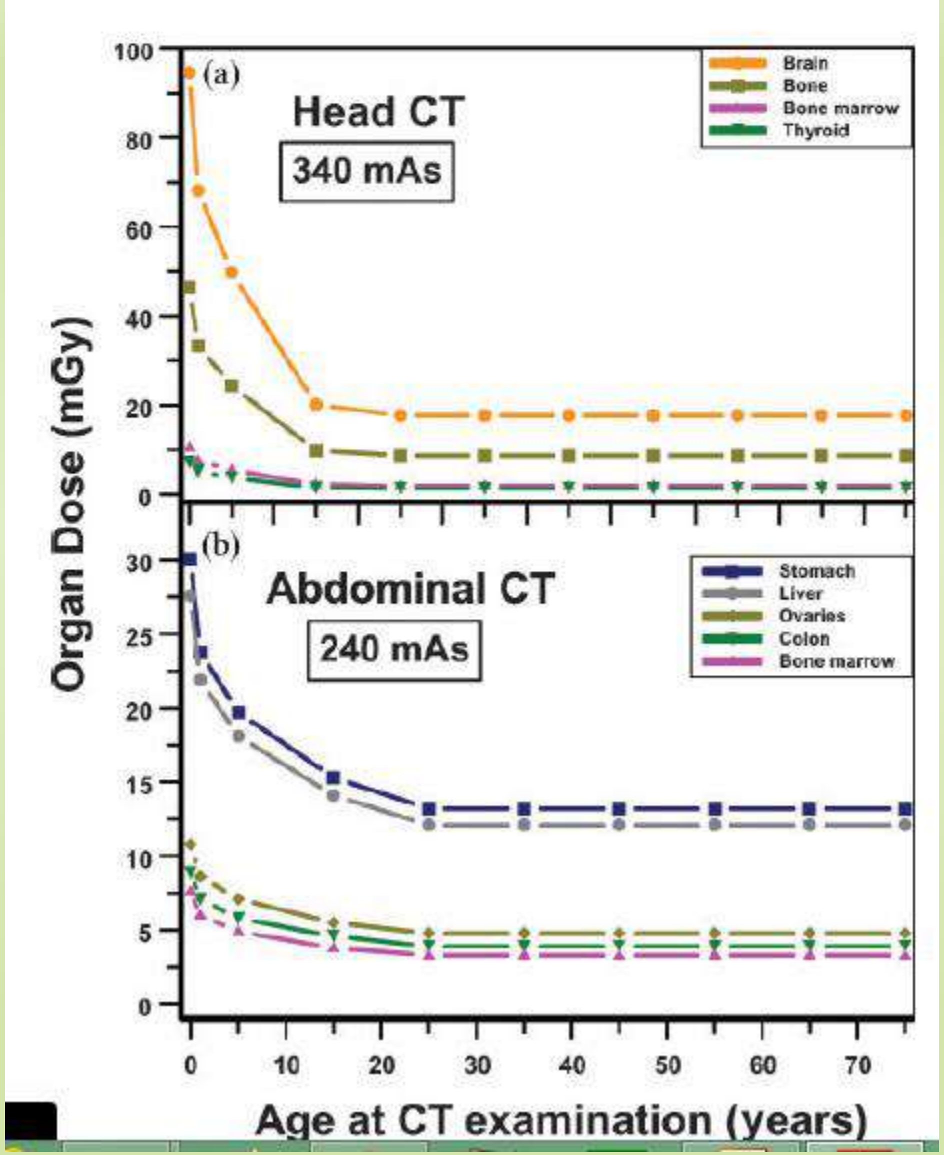
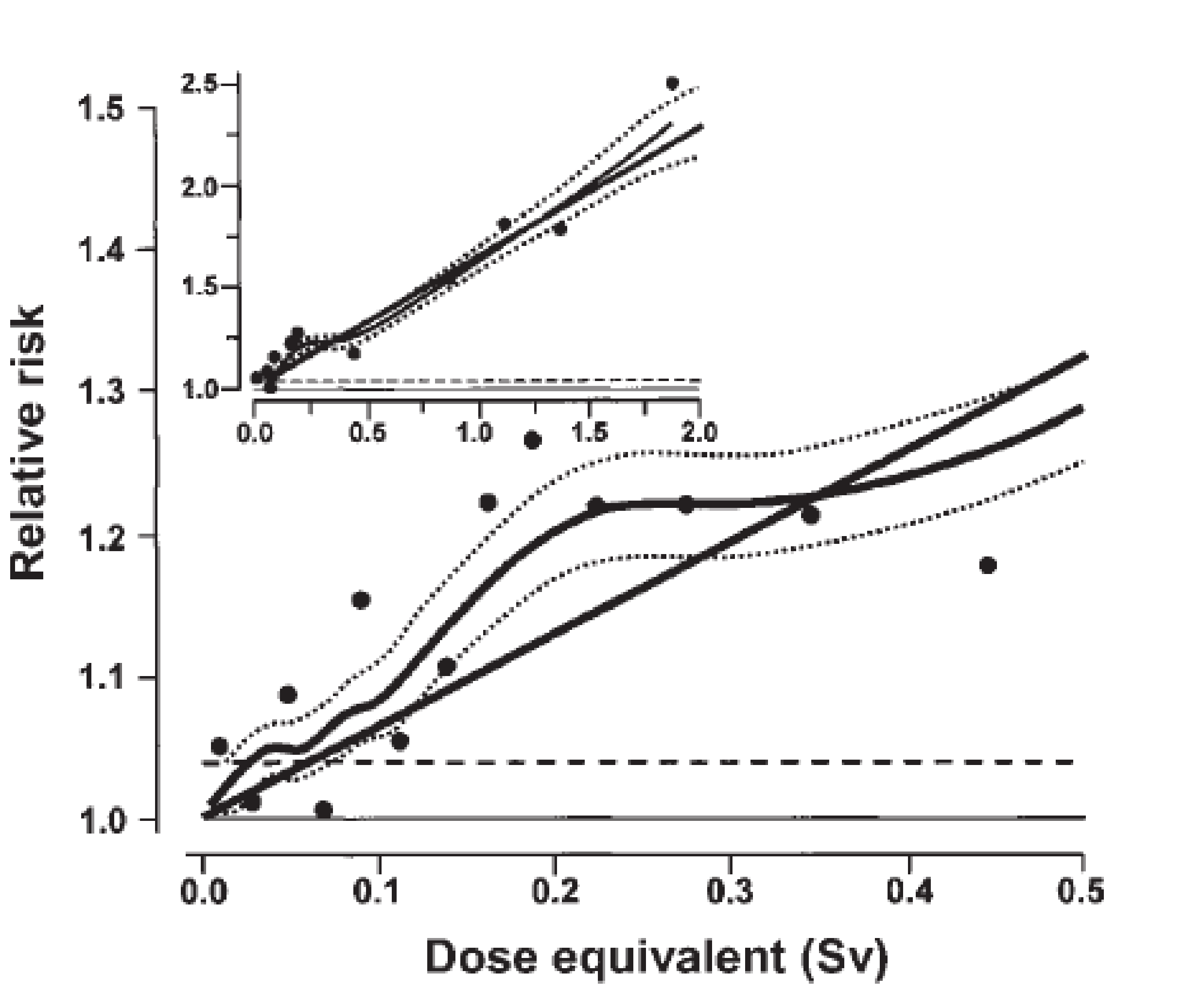
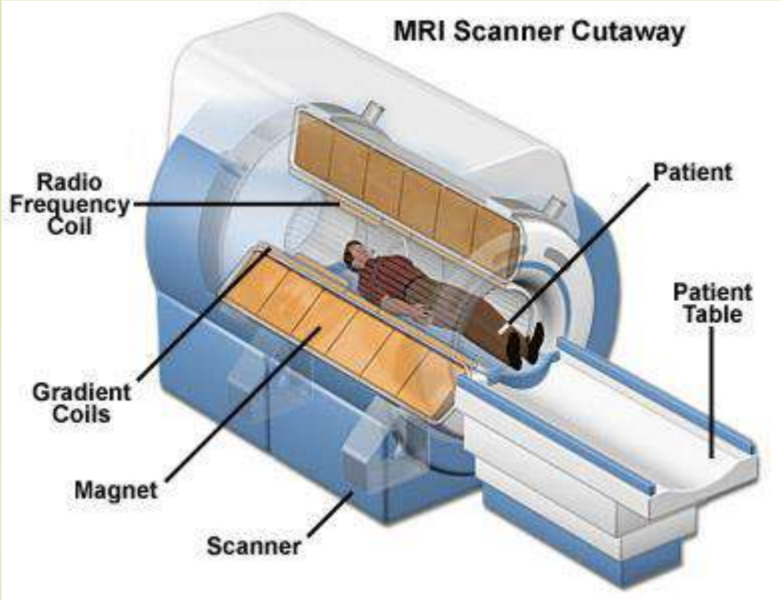


What are the benefits vs. risks





MAGNETIC RESONANCE IMAGING



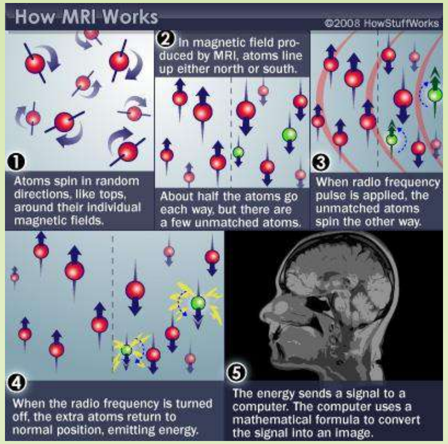
- X-rays, do not provide information about the internal structure of tissue
- CT scans may therefore, miss changes in tissue structure and pathological alteration
- *Magnetic resonance imaging* (*MRI*)

- When the body is placed in a strong magnetic field, such as an MRI scanner, the protons' axes all line up
- The radio wave frequency (RF) that causes the hydrogen nuclei to resonate is dependent on the element sought

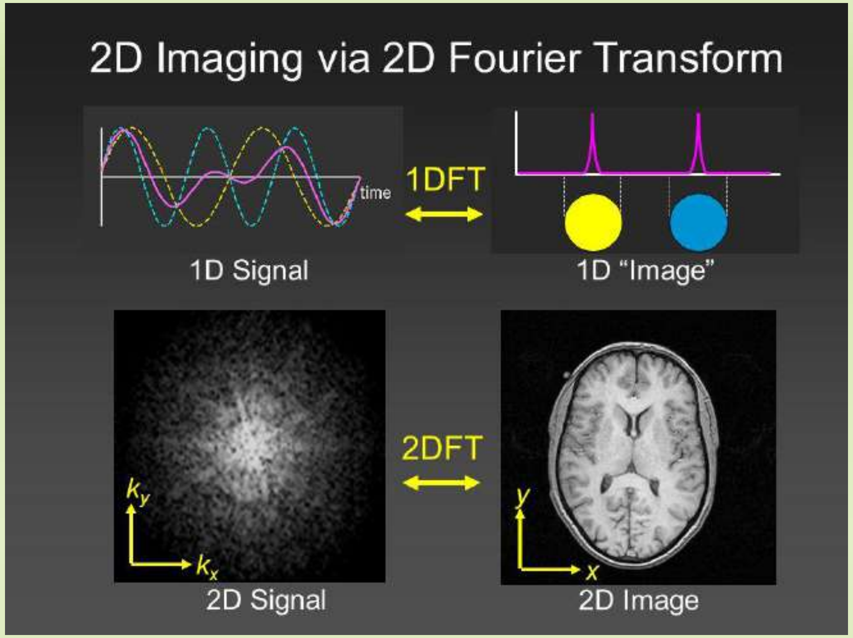
How it works

- The human body is mostly water. Water molecules (H_2O) contain hydrogen nuclei (protons) because of its abundance in water and fat.
- behaves like a small bar magnet and spin in the body with their axes randomly aligned.

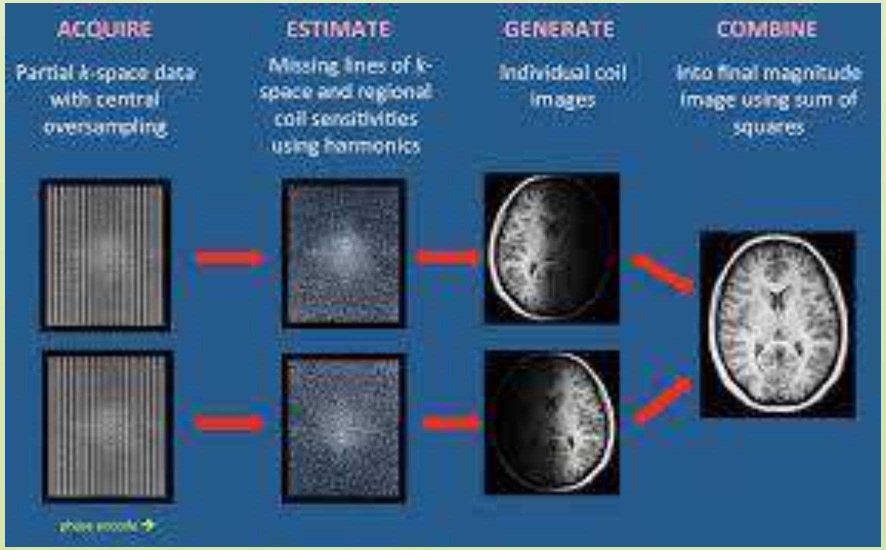
- When the body is placed in a strong magnetic field, such as an MRI scanner, aligns the proton "spins."
- The scanner also produces a radio frequency current (RF)
- When the field is turned off, the protons gradually return to their normal spin, a process called precession. The return process produces a radio signal that can be measured by receivers in the scanner and made into an image



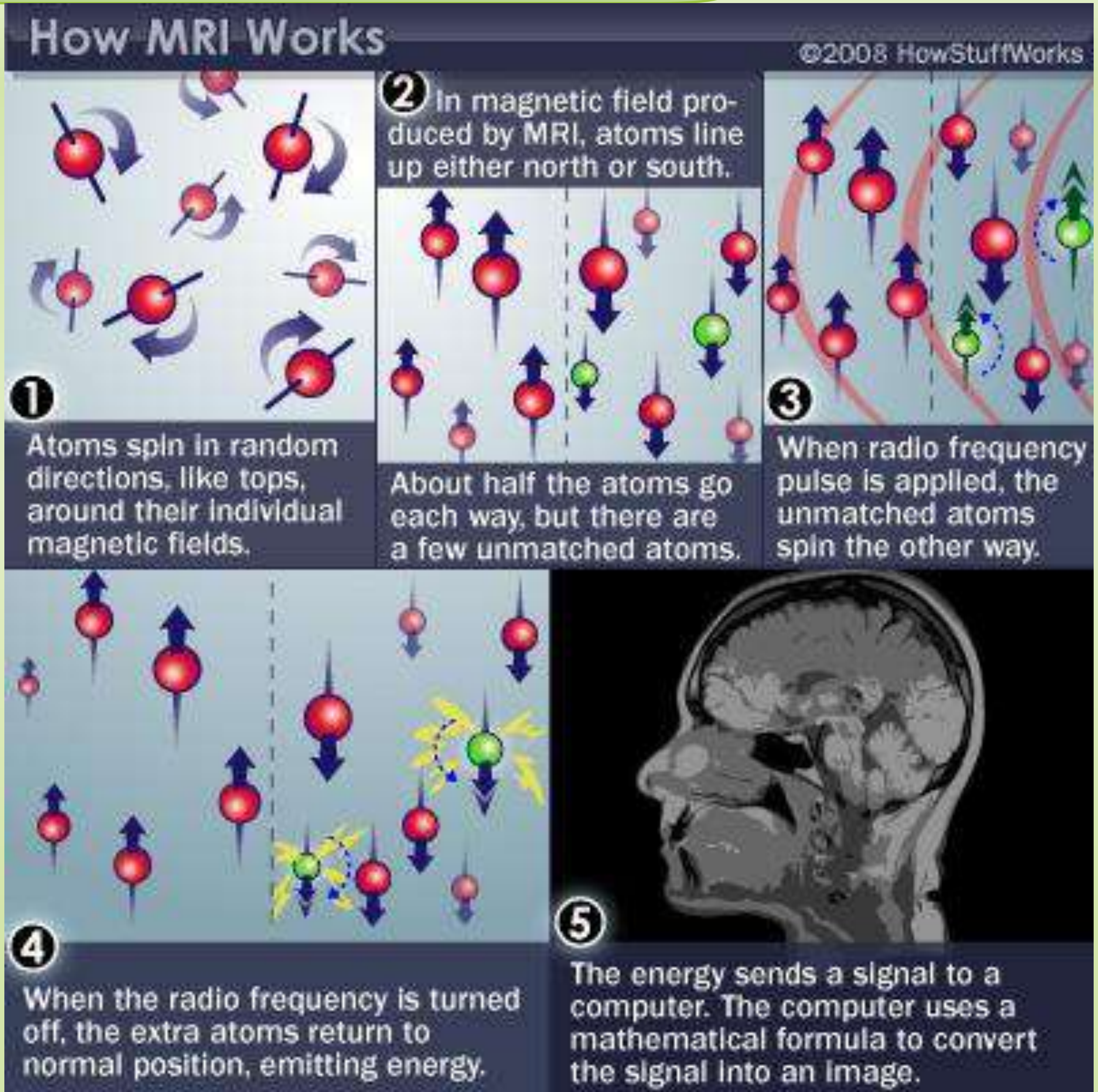
How it works



2D Imaging via 2D Fourier Transform
time
1DFT
1D Signal
1D "Image"
2DFT
k_y
k_x
y
x
2D Signal
2D Image



ACQUIRE
Partial k-space data with central oversampling
ESTIMATE
Missing lines of k-space and regional coil sensitivities using harmonics
GENERATE
Individual coil images
COMBINE
Into final magnitude image using sum of squares



How MRI Works
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1
Atoms spin in random directions, like tops, around their individual magnetic fields.
2
In magnetic field produced by MRI, atoms line up either north or south.
About half the atoms go each way, but there are a few unmatched atoms.
3
When radio frequency pulse is applied, the unmatched atoms spin the other way.
4
When the radio frequency is turned off, the extra atoms return to normal position, emitting energy.
5
The energy sends a signal to a computer. The computer uses a mathematical formula to convert the signal into an image.

Most diseases manifest themselves by an increase in water content, so MRI is a sensitive test for the detection of disease. The exact nature of the pathology can be more difficult to ascertain:

for example, infection and tumour can in some cases look similar. A careful analysis of the images by a radiologist will often yield the correct answer.

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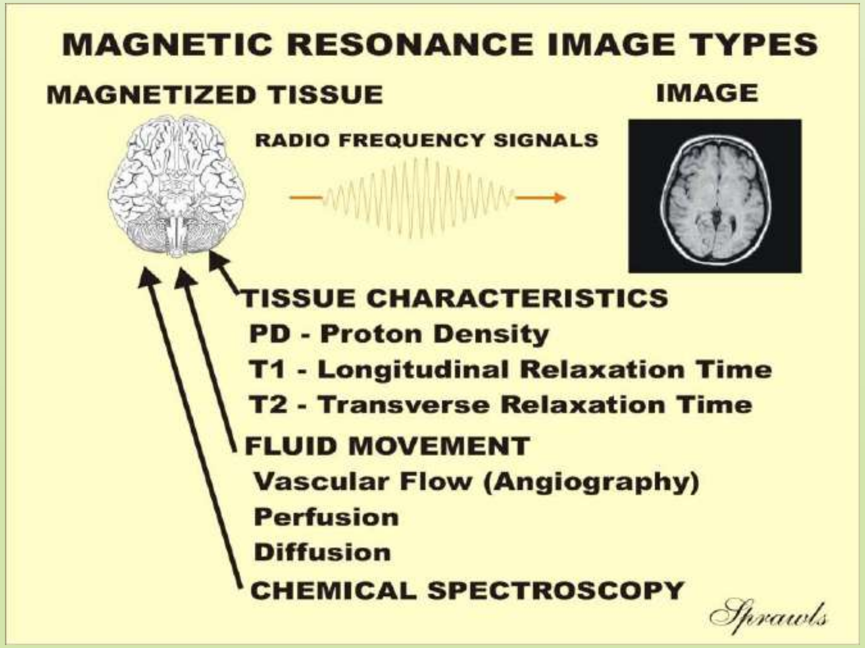
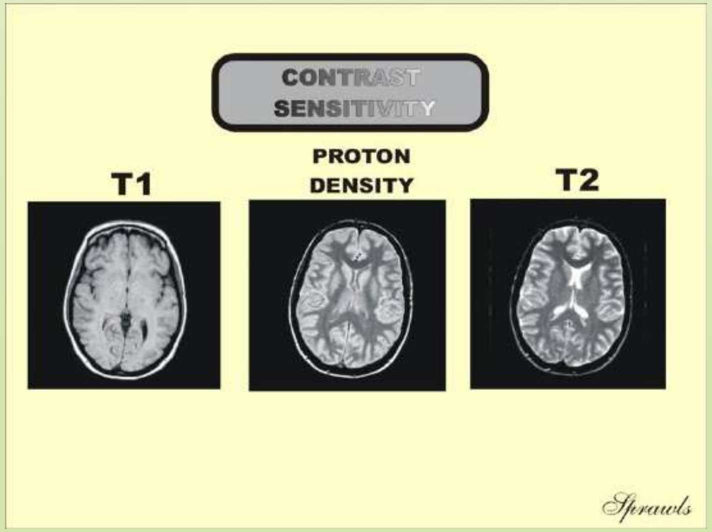
Typical Relaxation Times

Material	T1 (ms)	T2 (ms)
Fat	250	80
Liver	400	40
White Matter	650	90
Grey Matter	800	100
CSF	2000	150
Water	3000	3000
Bone, Teeth	Very long	Very short

*Abnormal tissue has higher PD, T1 & T2 than normal tissue, due to increased water content or vascularity





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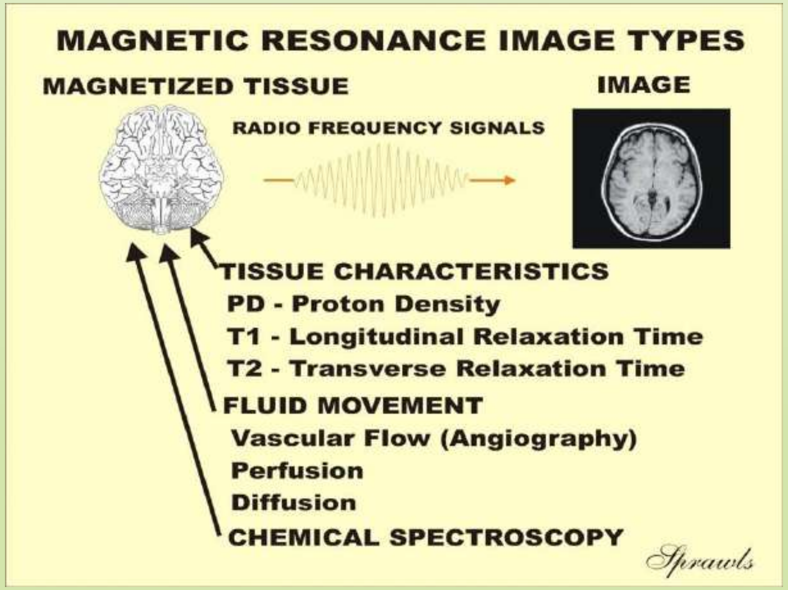
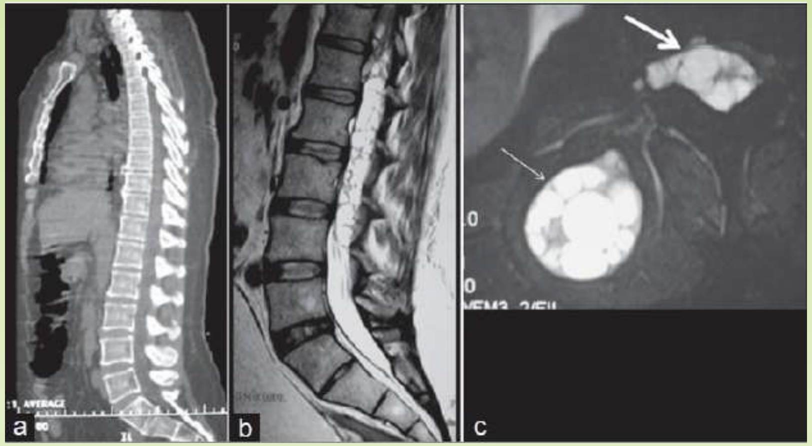
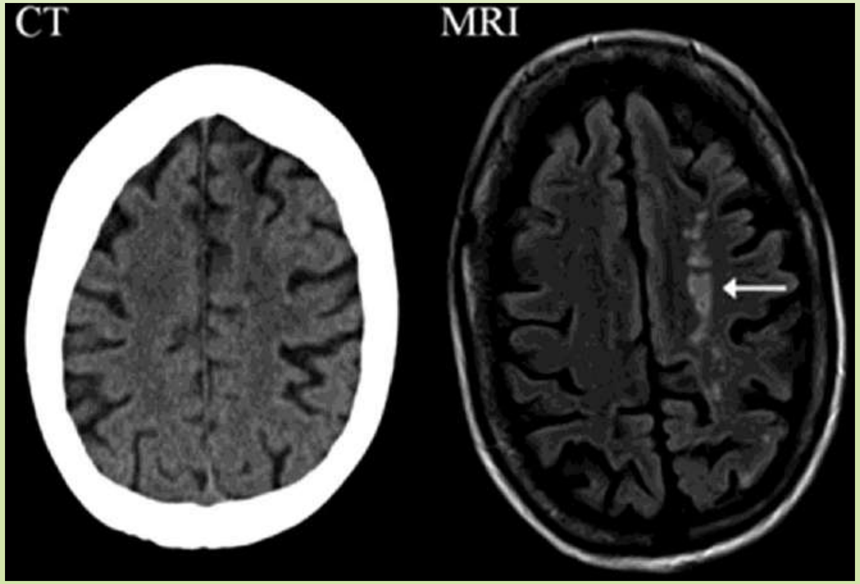
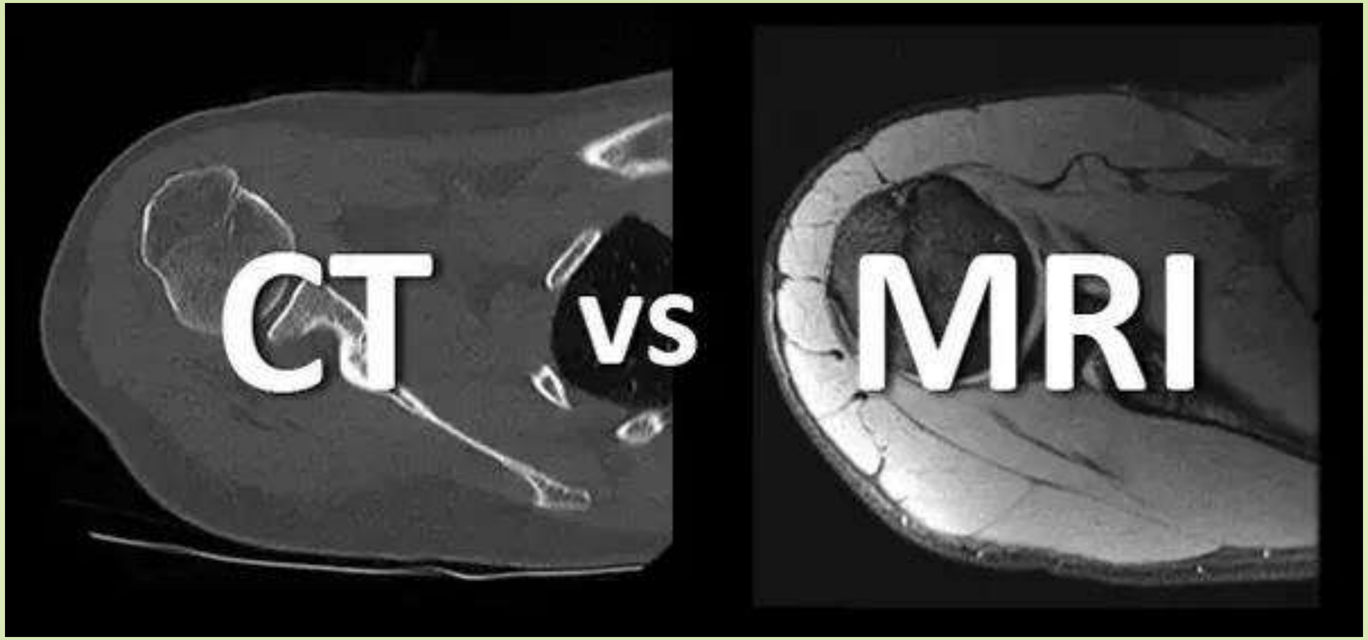


Differences between CT and MRI







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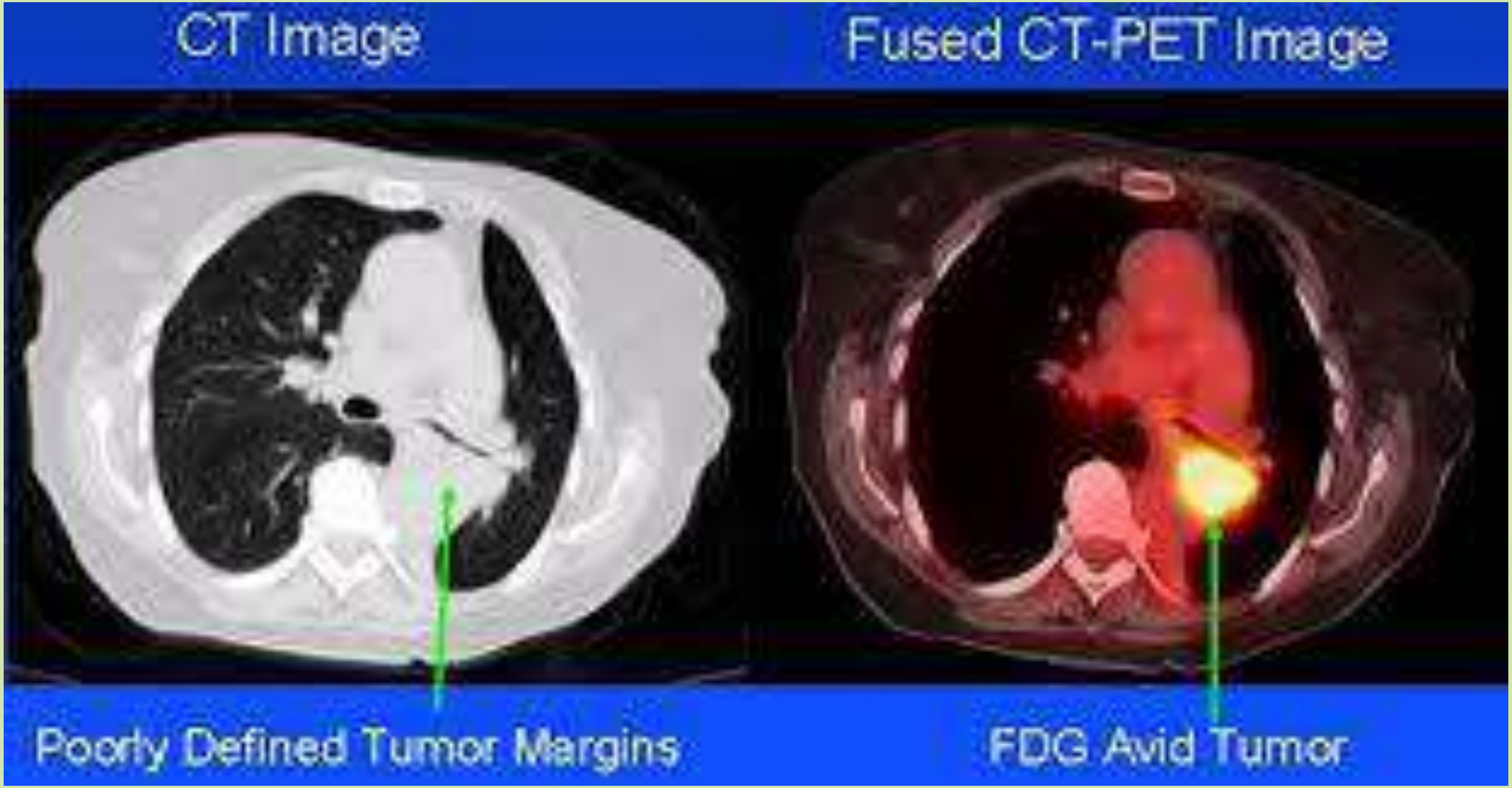


Thank you