Magnetic Resonance and Medical Imaging

Lect. 3- 4th year /Medical Physics

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Why Magnetic Resonance Imaging?

- When a plain radiograph of the abdomen is placed on a view box for interpretation, what can be seen?

- Not much. The image is gray and flat and shows little detail.

- A conventional tomogram or an angiogram may be done to improve image contrast.

Contrast Resolution

- **If such an image is unsatisfactory, what else can be done?**

A computed tomography (CT) image can be requested. The principal advantage of CT imaging over radiographic imaging is superior.

- **contrast resolution,** the ability to image differences among low-contrast tissues.

Contrast resolution allows visualization of soft tissue with similar characteristics, such as **liver–spleen or white matter–gray matter**

- The spatial resolution of a CT image is worse than that of radiographic imaging Because it is digital and limited by pixel size.

Likewise,

- The spatial resolution of MRI is worse than that of radiography. However, the contrast resolution is even better with MRI than with CT.

- **Contrast resolution is the principal advantage of MRI.**

TABLE 1-1 Approximate Spatial and Contrast Resolution Characteristics of Several Medical Imaging Systems

	Nuclear Medicine	Ultrasound	Radiography	Computed Tomography	Magnetic Resonance Imaging
Spatial resolution (mm)	5	2	0.05	0.25	0.25
Spatial resolution (lp/mm)	0.1	0.25	10	2	2
Contrast resolution (mm at 0.5% difference)	20	10	10	4	1

Spatial Resolution

- **Spatial resolution :** refers to the ability to identify an object, usually a small, dense object like a metal **fragment** or **microcalcification**, as separate and distinct from another object.
- Table 1-1 shows representative values of spatial resolution and contrast resolution for various medical imaging devices
- In x-ray imaging, spatial resolution is principally a function of the geometry of the system.

Two important geometric considerations include

- focal spot size
- source-to-image receptor distance(SID).

- In x-ray imaging, scatter radiation limits the contrast resolution.
- X-ray beam collimation and the use of radiographic grids reduce scatter radiation and therefore improve contrast resolution.
- تعمل موازاة حزمة الأشعة السينية واستخدام شبكات التصوير الشعاعي على تقليل الإشعاع المستطار وبالتالي تحسين دقة التباين.

- **CT** has superior contrast resolution compared to **radiography** because it uses a finely collimated (موازة بدقه) X-ray beam, which results in reduced scatter radiation.
- In x-ray imaging, the x-ray attenuation coefficient (μ) determines the differential x-ray absorption in body tissues.
- the x-ray attenuation coefficient depends on the energy of the x-ray beam (E) and the atomic number (Z)of the tissue being imaged.
- The basis for the MR image is different. It is a function of several intrinsic NMR characteristics of the tissue being imaged.
- The three most important tissue characteristics are

I. -proton density (PD)

II. -spin-lattice relaxation time(T1)

III. - spin-spin relaxation time (T2)

- **Secondary characteristics** include:
- flow
- magnetic susceptibility
- Paramagnetism
- and chemical shift.

There are many parameters to select in the production of an MR image:

- 1-The time sequence of energizing RF emissions (RF pulses)
- 2- gradient magnetic fields determines the contrast resolution.

- **The principal pulse sequences are :**
- partial saturation
- inversion recovery
- spin echo
- gradient echo
- and echo planar.

Multiplanar Imaging

❑An additional advantage to MRI is the ability to obtain

✓ direct transverse,

✓ sagittal

✓ coronal

✓oblique plane images

❑Conventional radiographs show superimposed anatomy regardless of the plane of the image.

❑In CT imaging, sagittal and coronal images are reconstructed either from a set of contiguous images or directly from the volumetric data of spiral CT.

❑ With MRI, a large data set is acquired during a single imaging sequence from which any anatomical plane can be reconstructed

- **Viewing images obtained from various anatomical planes requires a different kind of knowledge on the part of physicians and technologists.**

- **Except for CT images, most x-ray images are parallel to the long axis of the body. The MRI interpreter may view anatomical planes that have not been imaged before.**

- **The required interpretive skills come with experience.**

- **When students enroll in a radiologic technology program, the curriculum focuses on technique selection and positioning. Patient positioning in radiography is important to ensure that the structure being imaged is parallel and close to the image receptor.**

- **MR images are directly available as projections in any plane, when the patient is properly positioned at the magnet isocenter and with intended anatomy at the sensitive region of the RF coil.**

- Sensitivity describes how well an imaging system can detect subtle differences in anatomy. Specificity refers to the ability to precisely identify the nature of such differences

- MRI has excellent sensitivity. MR spectroscopy could provide increased specificity if there were a way to get enough signal

No Ionizing Radiation

- -Another advantage of MRI over x-ray imaging is that MRI does not require ionizing radiation. This lack of ionizing radiation has been effectively used to promote the safety of MRI to the medical community and public.

- -MRI uses RF electromagnetic radiation and magnetic fields, which do not cause ionization , and therefore do not have the associated potentially harmful effects of ionizing radiation.

- -Some bio effects of RF and magnetic fields are known to exist, but the MRI systems are carefully designed to ensure that the levels reached are not high enough to cause harm and none of the biological effects associated with MRI have been linked to the induction of malignant disease

Radiologist

- There will always be a need for radiologists trained in MRI to read the magnetic resonance images. A radiologist is a medical doctor that has specialized in the field of radiology. The need is expected to grow so much that there will be and increased use of Radiology Practitioner Assistants and Radiology Physician Assistants.
- An MRI technologist is an individual that operates the MRI scanner to obtain the images that a radiologist prescribes. Based on the number of current MRI systems.

Introduction

CT → Computerized Tomography

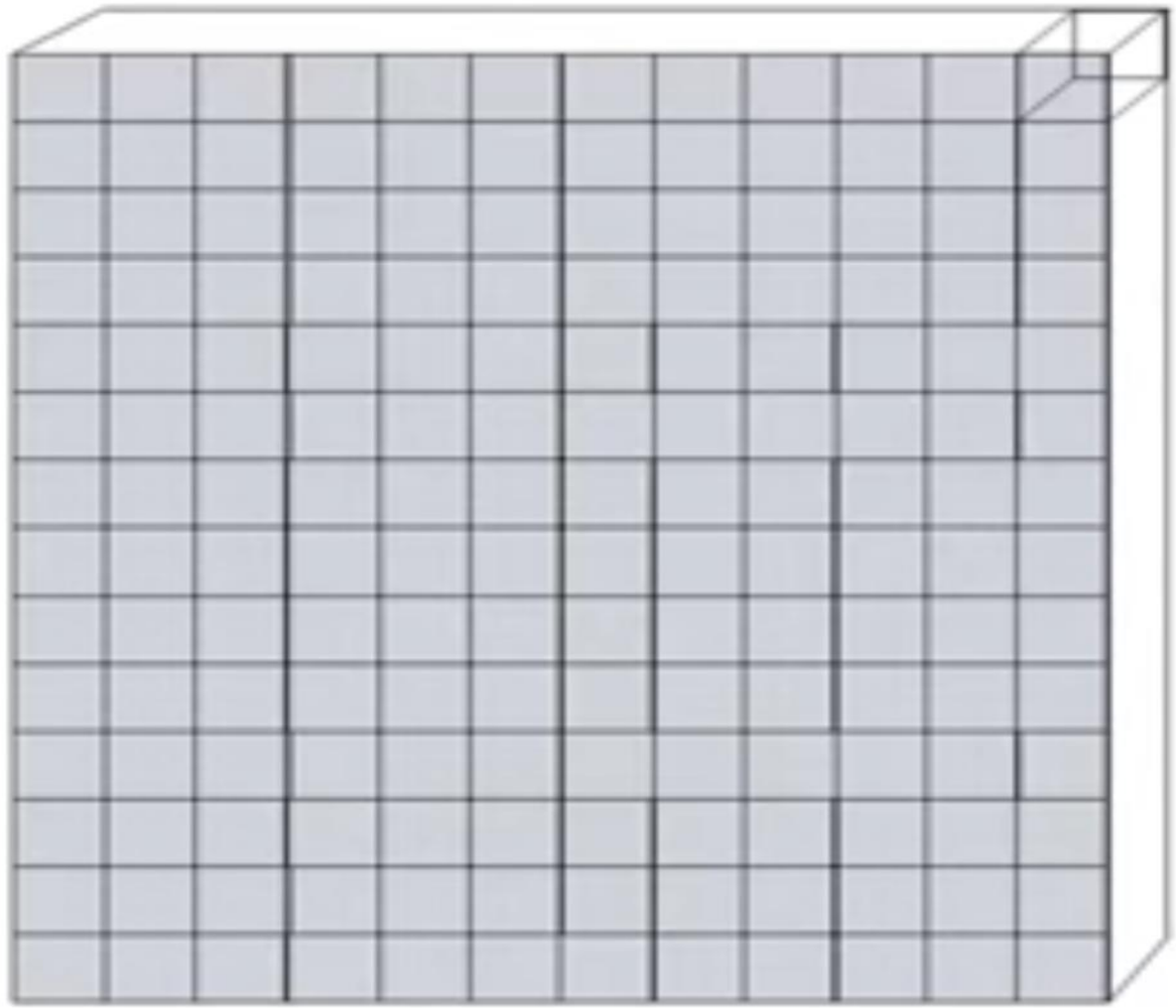
Tomography → Tomo + Graphy

↓ Picture

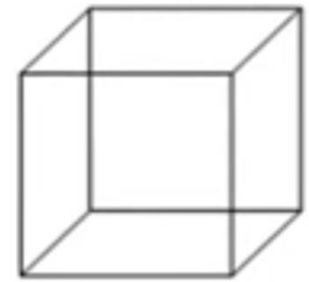
↓ To Write

Tomographic Imaging

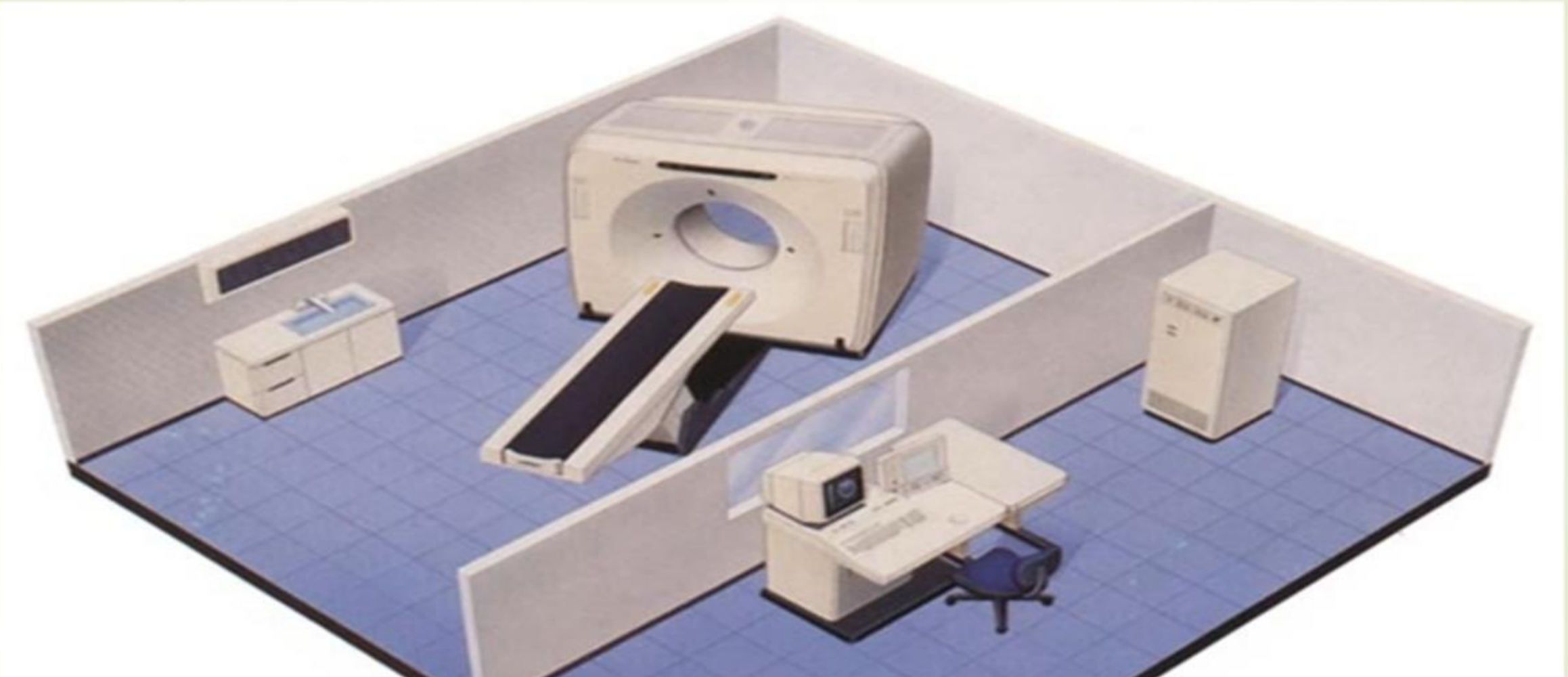
- This computer based teaching package will provide you with an understanding of the principles of MRI form both the microscopic, macroscopic, and imaging system perspective.
- Let's begin with a pictorial introduction to some basic MRI. Magnetic resonance started out as a tomographic imaging modality for producing NMR images of a slice through the human body.
- Each slice had a thickness (Thk). This form of imaging is in some respects equivalent to cutting off the anatomy above the slice and below the slice. The slice is said to be composed of several volume elements or voxels. The volume of a voxel is approximately 2 mm ^3.
- The magnetic resonance image is composed of several picture elements called pixels. The intensity of a pixel is proportional to the NMR signal intensity of the contents of the corresponding volume element or voxel of the object being imaged.



Voxel

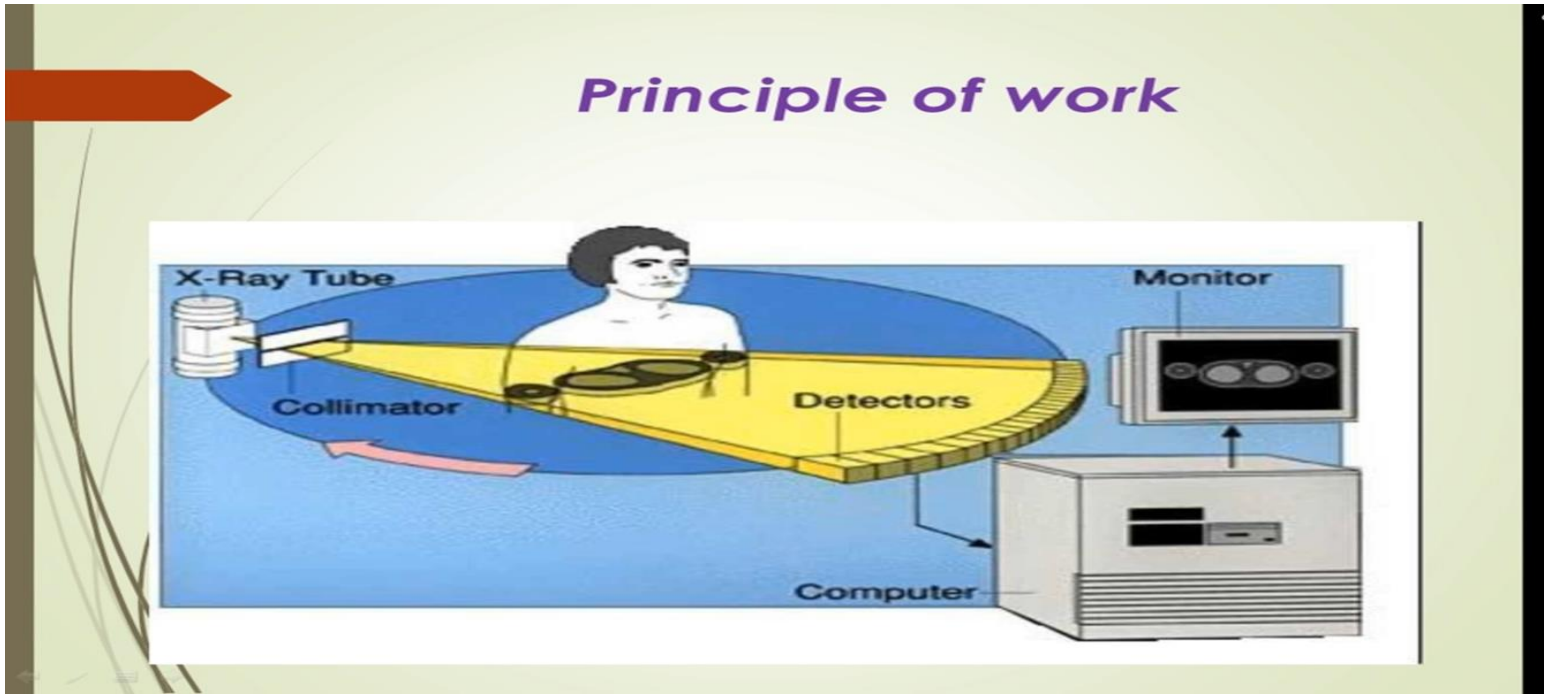


CT ROOM LAYOUT



A computerized X-ray imaging procedure in which a narrow beam of X-rays is aimed at a patient and quickly rotated around the body, producing signals that are processed by the machine's computer to generate cross-sectional images—or "slices"—of the body.

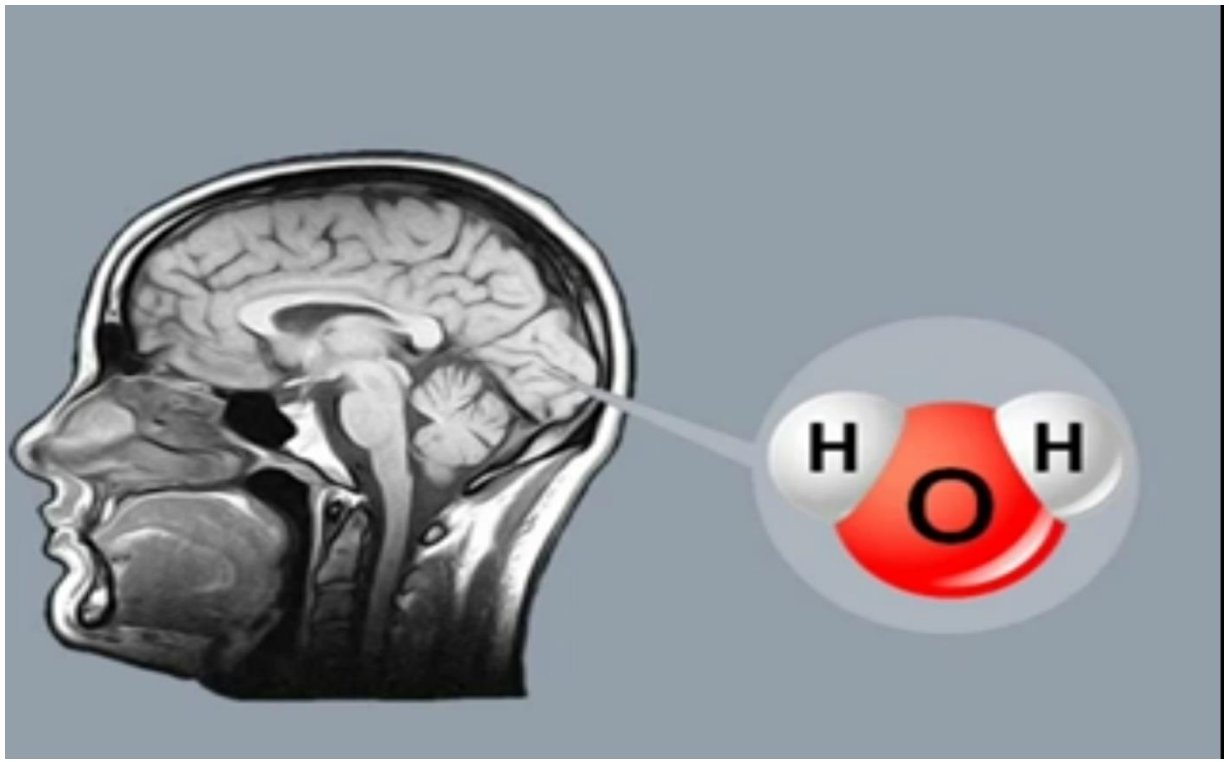
These slices are called tomographic images and contain more detailed information about the internal organs than conventional X-rays

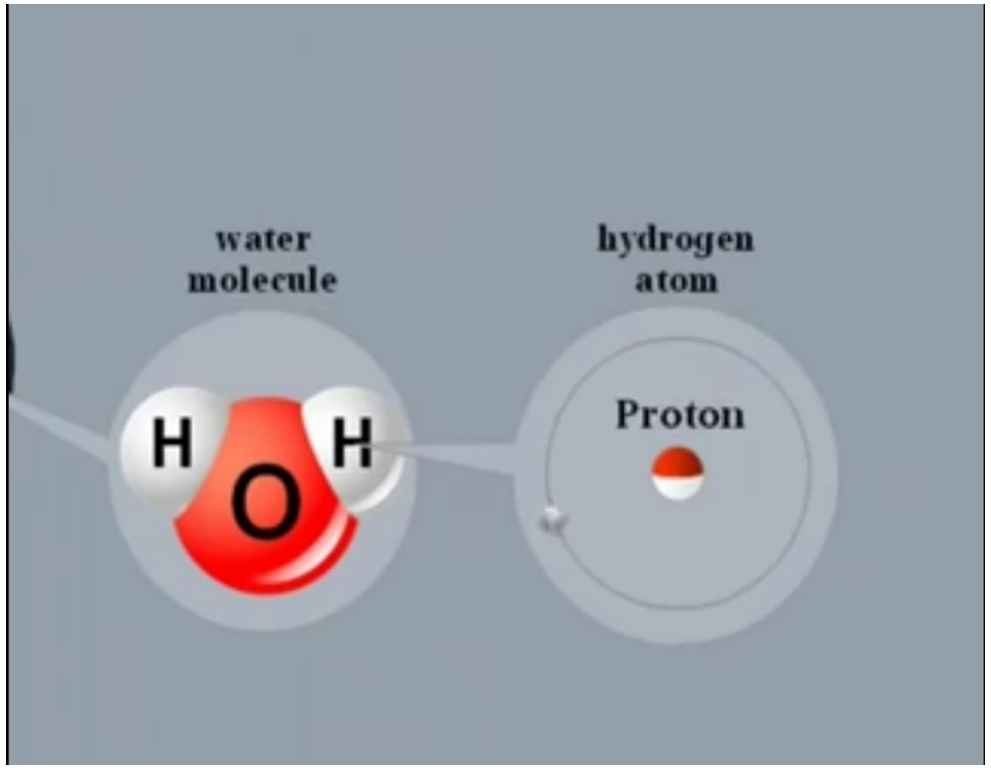


- Magnetic resonance imaging is based on the absorption and emission of energy in the radio frequency range of the electromagnetic spectrum. It is clear from the attenuation spectrum of the human body why x-rays are used, but why did it take so long to develop imaging with radio waves, especially with health concerns associated with ionizing radiation such as x-rays?
- Many scientists were taught that you can not image objects smaller than the wavelength of the energy being used to image. MRI gets around this limitation by producing images based on spatial variations in the phase and frequency of the radio frequency energy being absorbed and emitted by the imaged object.

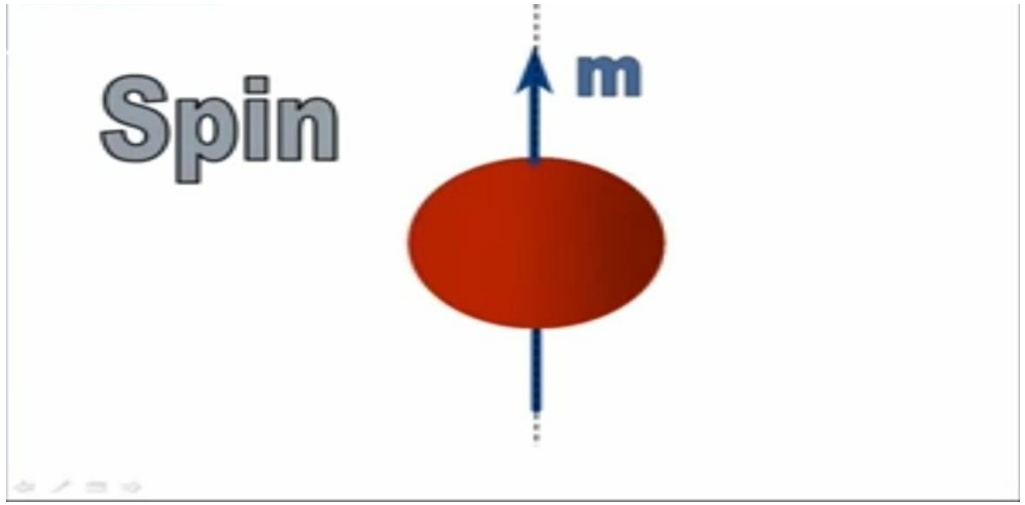
Microscopic Property Responsible for MRI

- The human body is primarily fat and water. Fat and water have many hydrogen atoms which make the human body approximately 63% hydrogen atoms.
- Hydrogen nuclei have an NMR signal. For these reasons magnetic resonance imaging primarily images the NMR signal from the hydrogen nuclei.
- Each voxel of an image of the human body contains one or more tissues. For example here is a voxel with one tissue inside.
- Zooming in on the voxel reveals cells. Within each cell there are water molecules. Here are some of the water molecules. Each water molecule has one oxygen and two hydrogen atoms. If we zoom into one of the hydrogen's past the electron cloud we see a nucleus comprised of a single proton. The proton possesses a property called spin which:
- 1. can be thought of as a small magnetic field, and
- 2. will cause the nucleus to produce an NMR signal.


H
O
H


water molecule
hydrogen atom
Proton
H
O
H


P


Spin
m

- Are all nuclei have possess the property called spin ?

Units Review

- **Before you can begin learning about MRI, you must be versed in the language of MRI. MRI scientists and clinicians use a set of units when describing temperature, energy, frequency, etc. Please review these units before advancing to subsequent chapters in this text.**
- **Units of time are seconds (s).**
- **Angles are reported in degrees (°) and in radians (rad). There are 2π radians in 360°.**
- **The absolute temperature scale in Kelvin (K) is used in MRI. The Kelvin temperature scale is equal to the Celsius scale reading plus 273.15. 0 K is characterized by the absence of molecular motion. There are no degrees in the Kelvin temperature unit.**
- **Magnetic field strength (B) is measured in Tesla (T). The earth's magnetic field in Rochester, New York is approximately 5x10^-5 T.**
- **The unit of energy (E) is the Joule (J). In MRI one often depicts the relative energy of a particle using an energy level diagram.**
- **The frequency of electromagnetic radiation may be reported in cycles per second or radians per second.**
- **Frequency in cycles per second (Hz) have units of inverse seconds (s-1) and are given the symbols ν or f. Frequencies represented in radians per second (rad/s) are given the symbol ω. Radians tend to be used more to describe periodic circular motions. The conversion between Hz and rad/s is easy to remember. There are 2π radians in a circle or cycle, therefore**

$$2\pi \text{ rad/s} = 1 \text{ Hz} = 1 \text{ s}^{-1}.$$

- **Power is the energy consumed per time and has units of Watts (W).**
- **Finally, it is common in science to use prefixes before units to indicate a power of ten. For example, 0.005 seconds can be written as 5x10-3 s or as 5 ms. The m implies 10^-3. The animation window contains a table of prefixes for powers of ten.**

ولأنه من الضروري أن تتوافق شدة المجال المغناطيسي مع الأمواج الراديوية ، سميت هذه الظاهرة بالرنين المغناطيسي النووي ؛ واستخدم التعبير " نووي " لأن أنوية الذرات فقط هي التي تتفاعل ، بينما استخدم التعبير " مغناطيسي " لأنها حدثت في مجال مغناطيسي ، أمّا كلمة " رنين " فجاءت بسبب الاعتماد المتبادل بين قوة المجال والأمواج . والحقيقة هي أن العزم المغناطيسي للأنوية يتفاعل مع المجال المغناطيسي الخارجي المؤثر على الأنوية ، وعندما تتساوى طاقة الأمواج الراديوية مع فرق الطاقة الناتج عن هذا التفاعل يحدث إمتصاص كلي لطاقة الأمواج الراديوية وهذا ما يسمى بالرنين .