S. S. College, Jehanabad

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Subject: Zoology

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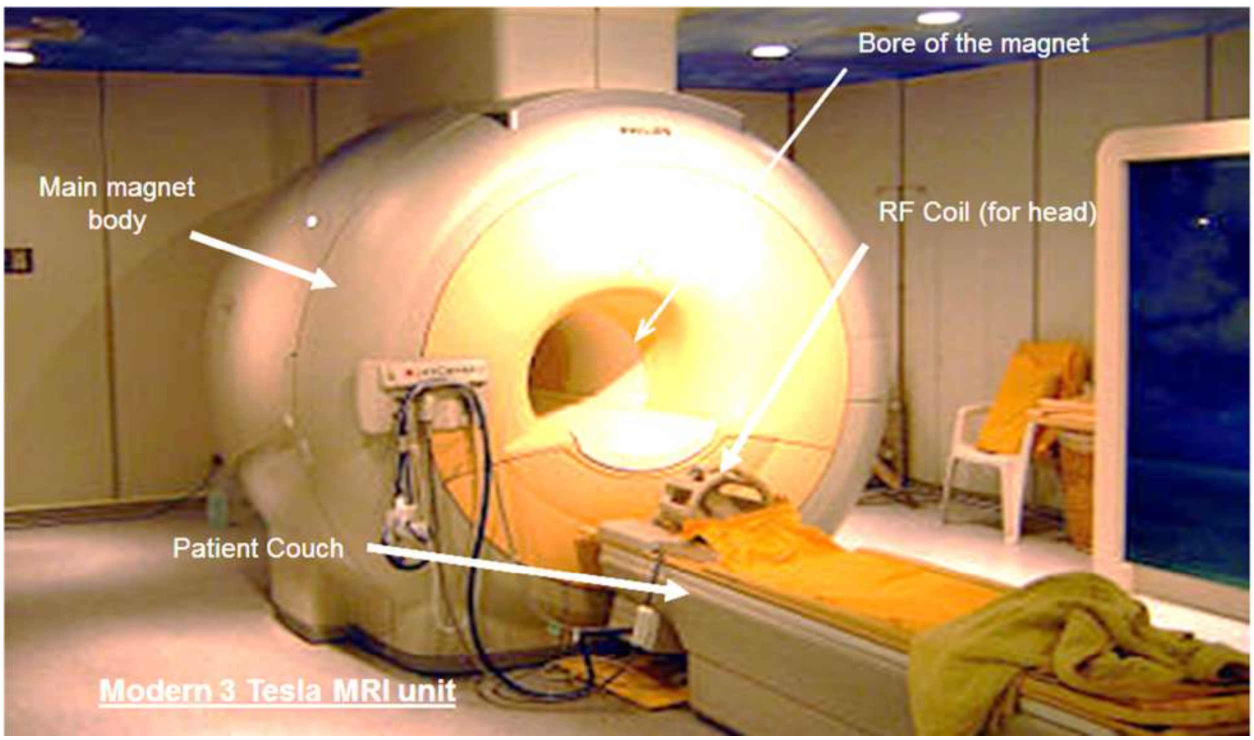
MAGNETIC RESONANCE IMAGING (MRI)

Magnetic resonance imaging (MRI), which is also known as nuclear magnetic resonance imaging (NMRI), is a scanning technique for creating detailed images of the human body. It is a non-invasive method for mapping internal structure within the body which uses non-ionizing electromagnetic radiation and employs radiation frequency radiation in the presence of carefully controlled magnetic field to produce high quality cross-sectional images of the body in any plane[1]. It means that MRI machine uses a strong magnetic field and radio waves to generate images of parts of the body that can't be seen as well with X-rays, CT scans or ultrasound. For example, it can help doctors to see inside joints, cartilage, ligaments, muscles and tendons, which make it helpful for detecting various sports injuries. Moreover, it is also used to examine internal body structures and diagnose a variety of disorders, such as strokes, tumors, aneurysms, spinal cord injuries, multiple sclerosis and eye or inner ear problems, etc. It is also widely used in research to measure brain structure and function, among other things.

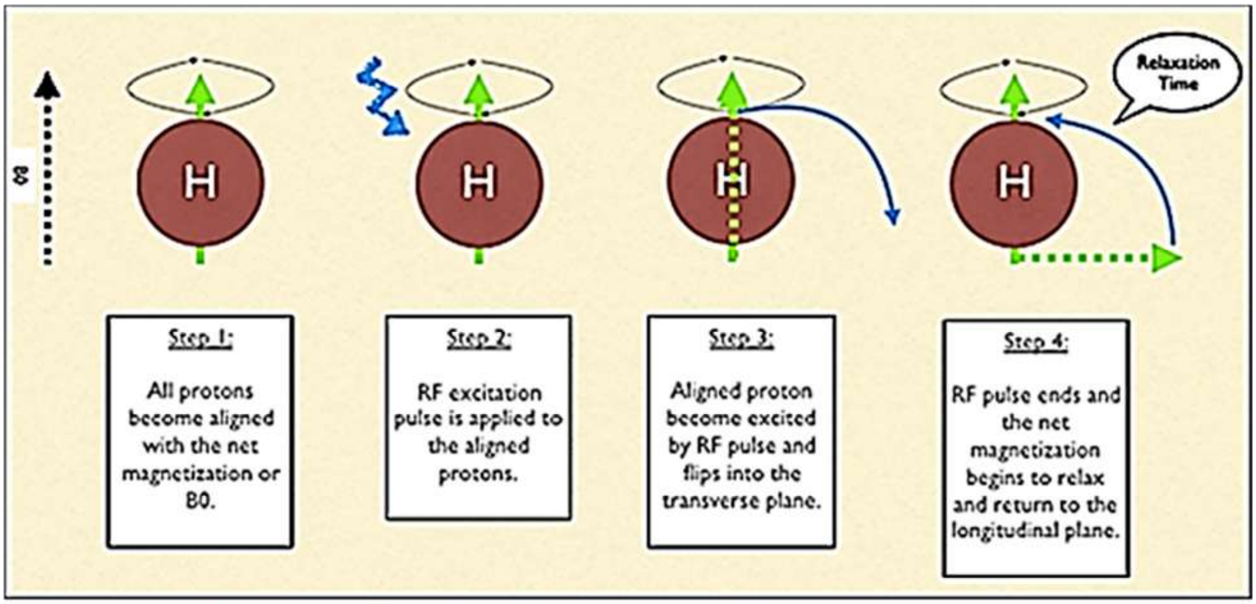


It differs from CT (Computed Tomography) scan in various aspects. It provides much greater contrast between the different soft tissues of the body than CT does, making it especially useful in neurological (brain), musculoskeletal, cardiovascular, and oncological (cancer) imaging. Unlike CT, it uses no ionizing radiation, but uses a powerful magnetic field to align the nuclear magnetization of (usually) hydrogen atoms in water in the body. It is a relatively new technology, which has been in use for little more than 30 years (compared with over 110 years for X-ray radiography). The first MR Image was published in 1973 and the first study performed on a human took place on July 3, 1977. Magnetic resonance imaging was developed from knowledge gained in the study of nuclear magnetic resonance.

[1] See detail about cross-sectional plane of the body in the last of this chapter.

Principles of MRI

MRI scans work as an imaging method due to the unique make-up of the human body. We are comprised entirely of cells which are mainly composed of water molecules (H_2O). Each water molecule contains two hydrogen nuclei or protons. The magnet embedded within the MRI scanner can act on these positively charged hydrogen ions (H^+ ions) and cause them to **'spin'** in an identical manner. By varying the strength and direction of this magnetic field, we can change the direction of 'spin' of the protons, enabling us to build layers of detail. When the magnet is switched off, the protons will gradually return to their original state in a process known as **precession**. Fundamentally, the different tissue types within the body return at different rates and it is this that allows us to visualize and differentiate between the different tissues of the body.



MRI scanning is based on the excitation and relaxation of protons

When a person goes inside the powerful magnetic field of the scanner (about 0.2 to 3 teslas, or roughly a thousand times the strength of a typical fridge magnet), these protons align with the direction of the field. 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.

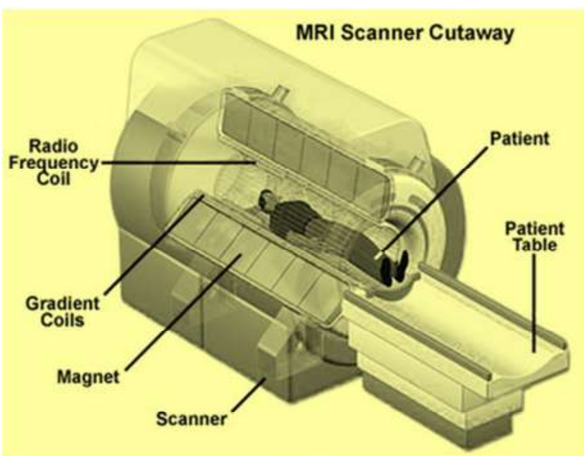
Protons in different body tissues return to their normal spins at different rates, so the scanner can distinguish among various types of tissue. The scanner settings can be adjusted to produce contrasts between different body tissues. Additional magnetic fields are used to produce 3-dimensional images that may be viewed from different angles. There are many forms of MRI, but diffusion MRI and functional MRI (fMRI) are two of the most common.

Diffusion MRI (dMRI): It is also known as diffusion-weighted imaging (DWI). It is a form of MRI which is based upon measuring the random Brownian motion of water molecules within a voxel[2] of tissue or how water molecules diffuse through body tissues. In generalized view, highly cellular tissue or those with tissue swelling exhibit lower diffusion coefficients. Certain disease processes, such as a stroke or tumor, can restrict this diffusion, so this method is often used to diagnose them.

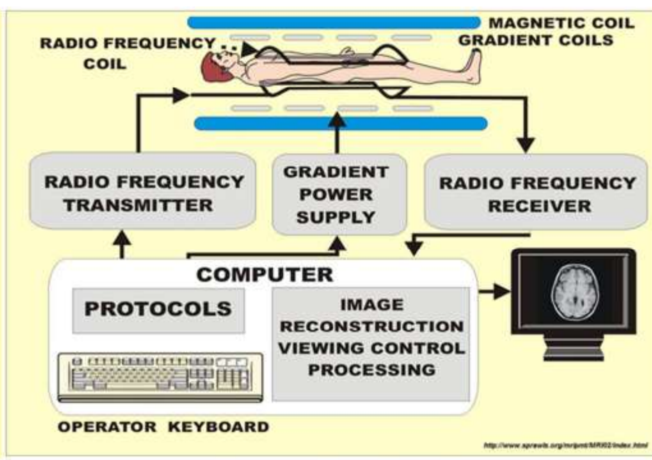
Functional MRI (fMRI): In addition to structural imaging, MRI can also be used to visualize functional activity of the brain by visualizing cortical activity. It is the type of MRI technique, which measures changes in blood flow to different parts of the brain. It is generally used to observe brain structures and to determine which parts of the brain are handling critical functions. Functional MRI may also be used to evaluate damage from a head injury or Alzheimer's disease. fMRI detects subtle alteration in blood flow in response to stimuli or actions.

Instrumentation of MRI

MRI machines vary in both size and shape. The older designs had a more compact and small space and were much closed. However, the new MRI has improved design and now it open and and has more space in the scanner than the original models. The basic design of a MRI machine consists of a 24 inch wide tube, inside which the examination takes place, a magnet, a Radio Frequency (RF) coil, three Gradient coils, patient table, and a computer system.



A MRI system



Components of a MRI system

Magnet: The magnet is the most important and biggest part of the MRI device. It is said to be heart of the MRI machine. It is basically an electromagnet, which is super-cooled with liquid helium, to produce a static magnetic field. It is this magnet that allows the MRI machine to produce high quality images. There is a horizontal tube that runs through the magnet and is called a bore. The magnet is extremely powerful and its strength is measured in either "tesla" or "gauss" (1.0tesla = 10,000gauss). Most MRI magnets use a magnetic field of 0.5 to 2.0tesla, while the Earth's magnetic field is only 0.5gauss. The magnetic field is produced by passing current through multiple coils that are inside the magnet, resulting in a state of superconductivity, which produces a lot of energy by reducing the resistance in the wires to zero.

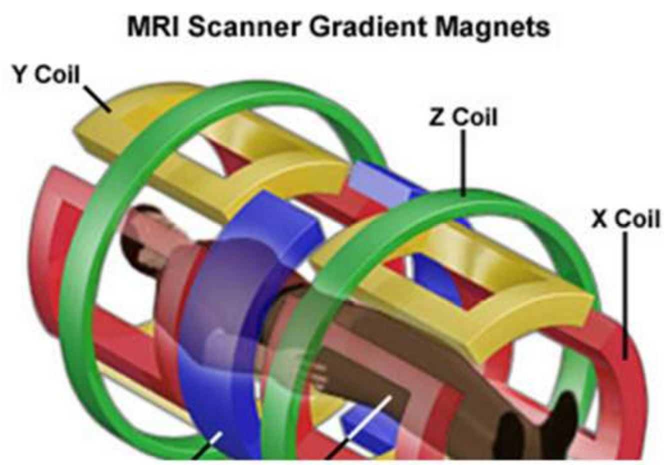
[2] It is a computer-based modeling or graphic simulation in which each of an array of elements of volume that constitutes a notional three-dimensional space.

Types of magnets: There are three types of electromagnets that are used in MRI machines, which are as follows;

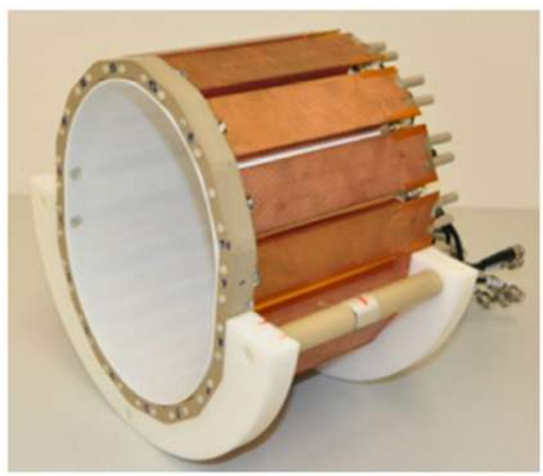
- *Superconducting electromagnets:* It is most commonly used electromagnet that produces strong, homogeneous magnetic fields. However, it is expensive and require regular maintenance.
- *Resistive electromagnets:* It is cheaper, easier to maintain and less powerful which requires a cooling system.
- *Permanent (fixed):* It is almost inexpensive, easy to maintain but it is heavy and has weak intensity.

Types of coils: The coils used in the electromagnet are also of different kinds. It is categorized into two types, which are as follows;

- *Gradient coils:* There are *three* different gradient coils that are inside the MRI machine and are located within the main magnet. Each one of these produce three different magnetic fields that are each less strong than the main field. The gradient coils create a variable field (x, y, z) that can be increased or decreased to allow specific and different parts of the body to be scanned by altering and adjusting the main magnetic field.
- *Radio frequency (Rf) coils:* The basic function of the RF coils is to transmit radio frequency waves into the patient's body. There are different coils located inside the MRI scanner to transmit waves into different body parts. If a certain area of the body is specified, then all the RF coils usually become focused on the body part being imaged to allow for a better scan.



A Gradient Coil


A Radio Frequency Coil
https://snc2dmri.weebly.com/components--functions.html

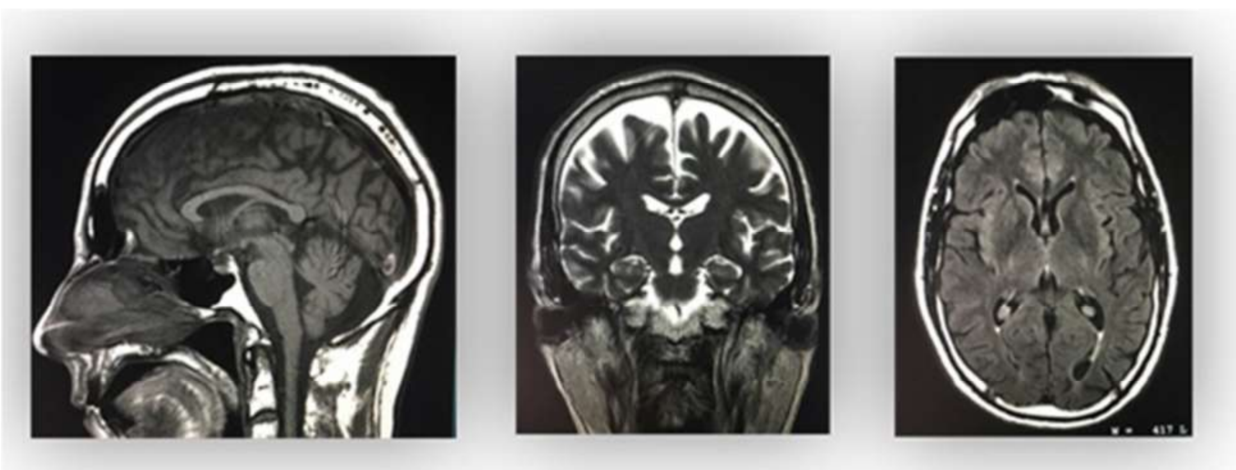
Patient table: This component simply slides the patient into the MRI machine. The position at which the patient lies down on the table is determined by the part of the body that is being scanned. Once the part of the body under examination is in the exact center of the magnetic field, which is referred to as the isocenter, the scanning process is started.

Antenna and computer system: The antenna is a very sensitive device that easily detects the RF signals emitted by a patient's body while undergoing examination and feeds this information into the computer system. The computer system is a powerful system, whose major function is to receive, record, and analyze the images of the patient's body that have been scanned. It interprets the data sent in by the antenna and then, helps to produce an understandable image of the body part being examined.

Computers are used to control the gradient fields and RF pulses with precise timing and accurate amplitude, whose patterns is known as the sequence. It must also be able to be reprogrammed for different imaging protocols like that for transaxial and saggital images. Computer Storage is also crucial as well as processor powers since many images are needed to be stored in a short time (e.g. 40 images in 6.5 minutes for a head scan). It is critical for data analysis computing not to interfere with the data acquisition for the next patient to be diagnosed; hence it is sensible for separate consoles with different functions like physician display console, data acquisition and image reconstruction.

Interpretation of MRI scan

Image View: MRI scans, much like computed tomography, typically produce three anatomical views; **sagittal, coronal** and **axial** (similar to the planes of the body). When interpreting axial views, it is important to appreciate that the image is viewed from the feet upwards – and so the left-hand side of the image refers to the patient's right (and vice versa).



The three main views obtained when MRI scanning. Left to right: Sagittal, coronal and axial.

Image weight: Once the view of the scan has been determined, the second step is to work out the weight of the image. The magnetic fields produced by the scanner can be manipulated to produce two distinct types of image – **T1 weighted** and **T2 weighted**. The resulting images will show different tissue types in different densities:

Appearance	T1 Weighted Image	T2 Weighted Image
White	Fat Protein Rich Fluid	Water Content E.g. Inflammation, Tumour,

		Haemorrhage, Infection
Intermediate	Gray Spinal Matter darker than White	White Spinal matter darker than gray spinal matter.
Dark	Bone Air Water Content e.g. Inflamation, Tumour, Haemorrhage	Bone Air Fat

Note: It can help to remember that a TtWo wighted image shows water as white.

Procedure of MRI

During the exam, it's important to stay still to obtain the clearest images. Children who have difficulty staying still may need sedation, administered either orally or through an IV line. Sedation can also be helpful for adults who are claustrophobic. One has to lie down on a table that slides into the MRI machine. The table slides through a large magnet shaped like a tube. One may have a plastic coil placed around your head. After the table slides into the machine, a technician takes several pictures of your brain, each of which takes a few minutes. There is a microphone in the machine that allows you to communicate with staff. The test normally takes 30 to 60 minutes. One may receive a contrast solution, usually gadolinium, through an IV to allow the MRI machine to see certain parts of brain more easily, particularly blood vessels. The MRI scanner will make loud banging noises during the procedure.

Applications of MRI

Magnetic resonance imaging produces highly sophisticated and highly detailed images of the human body. Generally speaking, MRI scanning is excellent for visualizing soft tissue and so it is often used in the detection of tumors, strokes and bleeds. It is also used to visualize the functionality of suspected masses and tumors through IV, gadolinium-based agents. Thus, its major applications are in medical diagnosis procedure for following ailments or conditions;

- neurological conditions,
- disorders of the muscles and joints,
- for evaluating tumors and
- showing abnormalities in the heart and blood vessels.

Use of contrast agent

Contrast agents may be injected intravenously to enhance the appearance of blood vessels, tumours or inflammation. Contrast agents may also be directly injected into a joint, in the case of arthrograms, MRI images of joints.

Advantages of MRI

The magnetic resonance imaging has following advantages;

- It is a non-ionising radiation imaging modality.
- It provide detailed images of the brain contrasting differing tissue types which comprise the brain through multiple cross-sections.
- It is relatively safe; painless; and non-invasive.
- For the most part, no special preparation is required of the patient. Patients will having eating and drinking restrictions for studies examining the gastro-intenstial tract and associated organs and glands (an MRCP (Magnetic Resonance Choliangiopancreatography) would be one instance) for example; but for the most part there will be few pre-examination preparation procedures to follow.

Disadvantages of MRI

The magnetic resonance imaging has following disadvantages too;

- MRI machines are expensive to buy and run compared to other modalities such as Ultrasound (another imaging modality which does not use ionising-radiation) or CT.
- Generally, it cannot be used in patients with metallic devices (pacemakers, although newer pacemakers which are being fitted are 'MRI-Safe'); it is not contra-indicated in patients with numerous types of orthopaedic implants, however the operator must be aware of the heating of the prosthesis during the scan; furthermore, it can be possible to undergo an MRI scan with metal surgical implants in soft-tissues, however it is very dependent on the type of implant and where it is.
- It cannot be used with uncooperative patients (MRI scans are highly sensitive to movement (due to k-space filling, it can distort an the images from an entire scan sequence)) or those who are claustrophobic; however, in the former case (and the latter one too), sedatives can be used if it is deemed that the information gained from the MR scan sufficiently deems their application..

Safety precautions

Unlike CT scanning MRI uses no ionizing radiation and is generally a very safe procedure. But patients with some metal implants, cochlear implants, and cardiac pacemakers are prevented from having an MRI scan due to effects of the strong magnetic field and powerful radiofrequency pulses.

Reference

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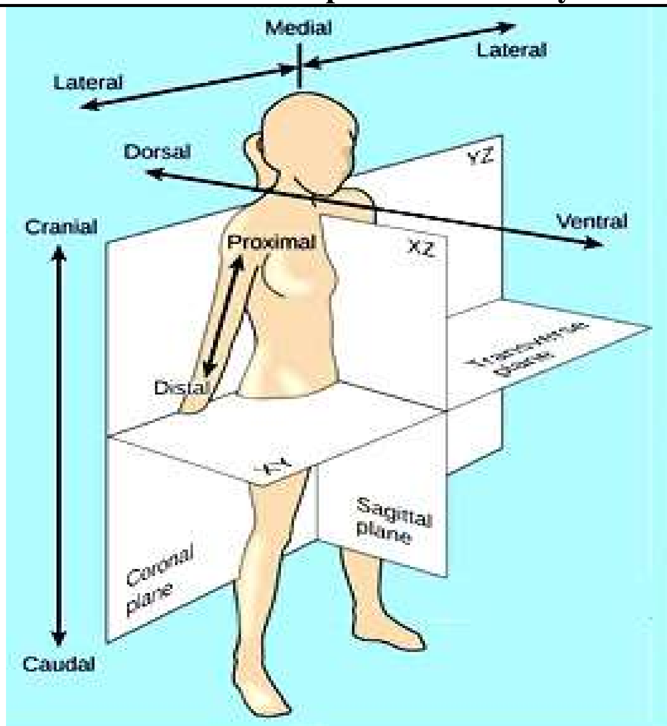
Different cross-sectional planes of the body



Major reference planes of the body

The sagittal plane (lateral or Y-Z plane): It divides the body into sinister and dexter (left and right) sides. The midsagittal (median) plane is in the midline through the center of the body, and all other sagittal planes are parallel to it.

The coronal plane (frontal or Y-X plane): It divides the body into dorsal and ventral (back and front) portions. It also separates the anterior and posterior portions.

The transverse plane (axial or X-Z plane): It divides the body into superior and inferior (head and tail) portions. It is typically a horizontal plane through the center of the body and is parallel to the ground.

Other planes of the body

Other planes are commonly used in relation to these three reference planes.

Longitudinal plane: It is any plane perpendicular to the transverse plane.

Parasagittal plane: It is parallel to the saggital plane.

The coronal plane, the sagittal plane, and the parasaggital planes are examples of longitudinal.

A human in the anatomical position, can be described using a coordinate system with the Z-axis going from front to back, the X-axis going from left to right, and the Y-axis going from up to down.