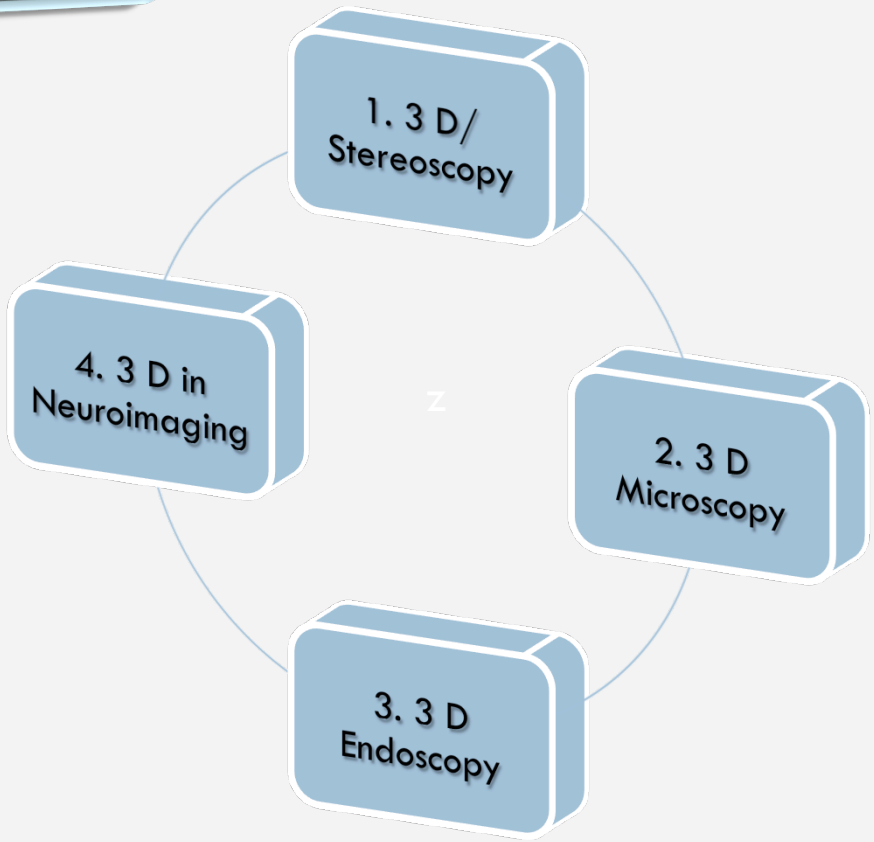
3 D in Neurosurgery

An overview

Britty Baby

Objective


1. 3 D/ Stereoscopy
2. 3 D Microscopy
3. 3 D Endoscopy
4. 3 D in Neuroimaging

1. Introduction

- 3 D (Three Dimension)- say length, breadth and height.
- 2 D or an image +depth
- Depth perception
- Neurosurgery requires precision and accessing deep structures inside the body requires good depth perception.

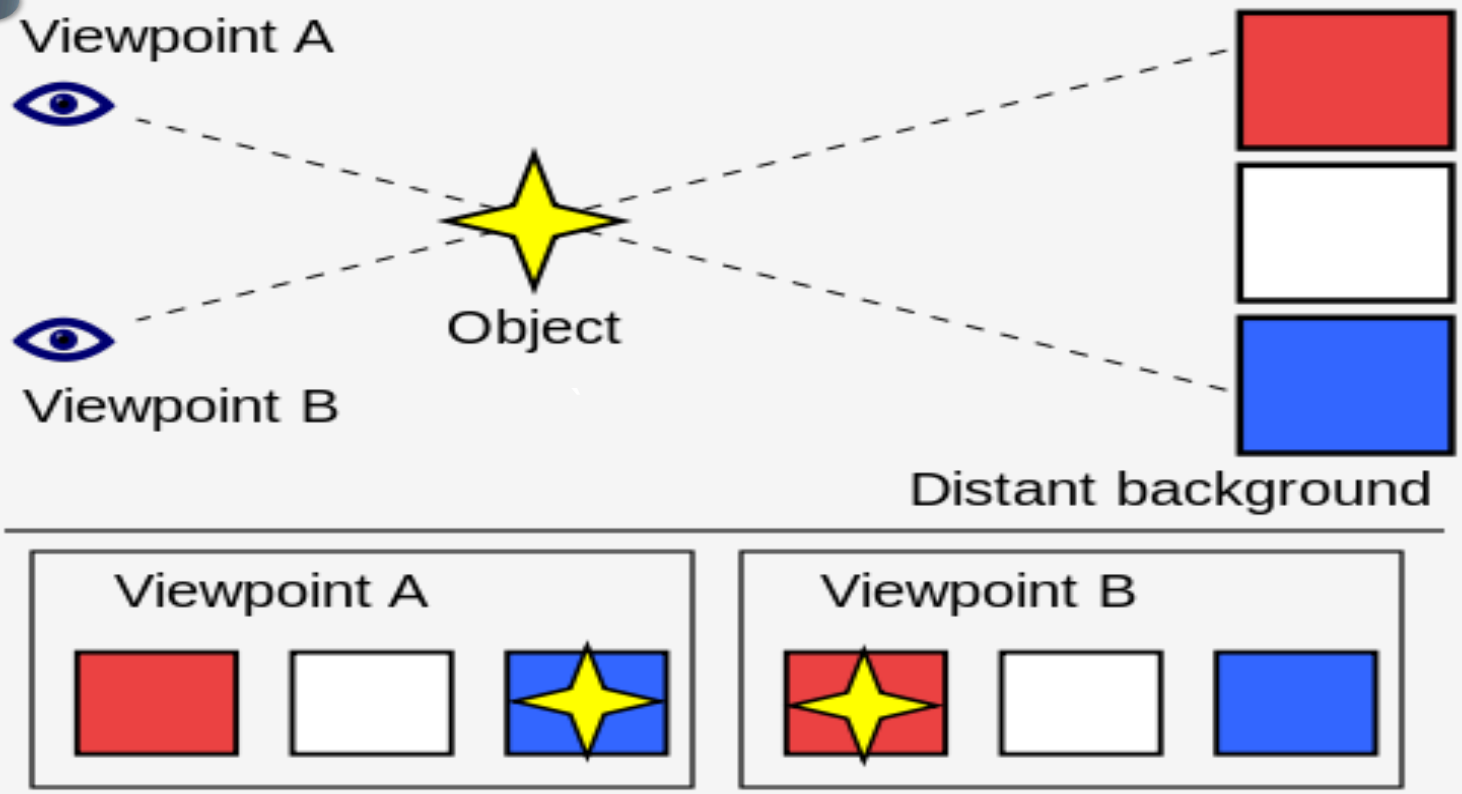
2. 3 D imaging/ Stereoscopy

- The word *stereoscopy* derived from the Greek (*stereos*), "firm, solid" (*skopeō*), "to look", "to see“
- Concerned with, or relating to, seeing space three-dimensionally as a result of binocular disparity.
- Stereo vision, or ‘Stereopsis’, is a result of good binocular vision, wherein the separate images from two eyes are successfully combined into one 3D image in the brain.

3. Stereoscopy

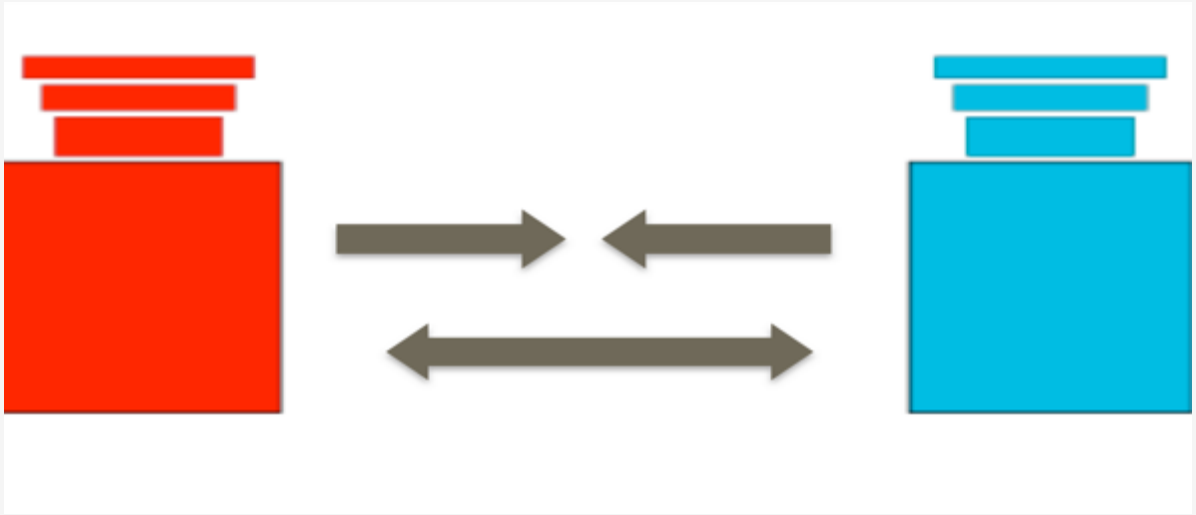
- Stereoscopy creates the illusion of three-dimensional depth from images on a two-dimensional plane
- Terms
  - Parallax
  - Interocular & interaxial
  - Accommodation
  - Convergence & Divergence

3.1. Parallax

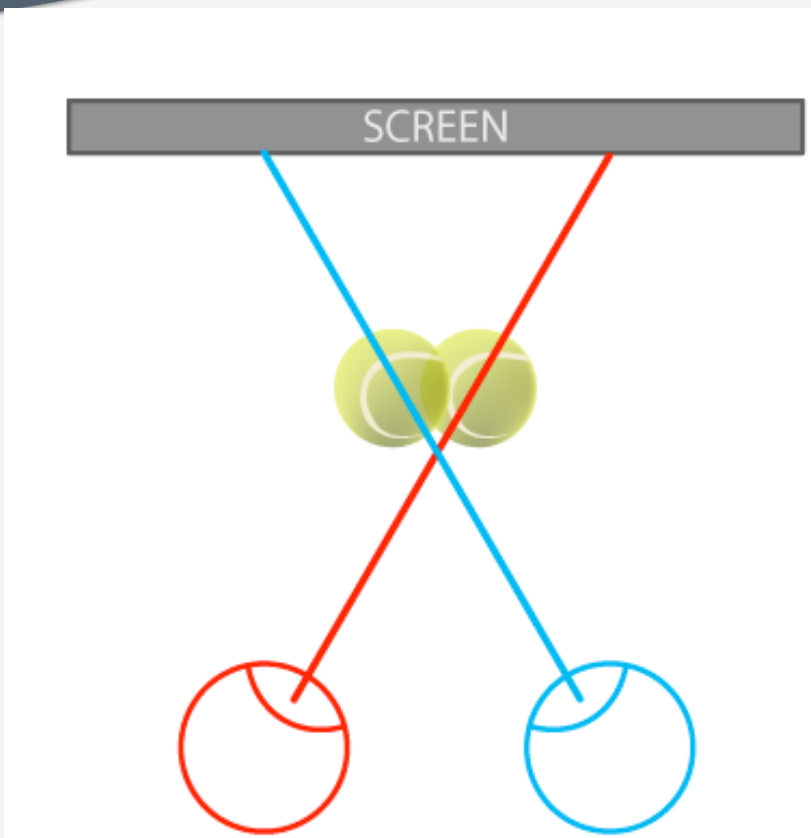


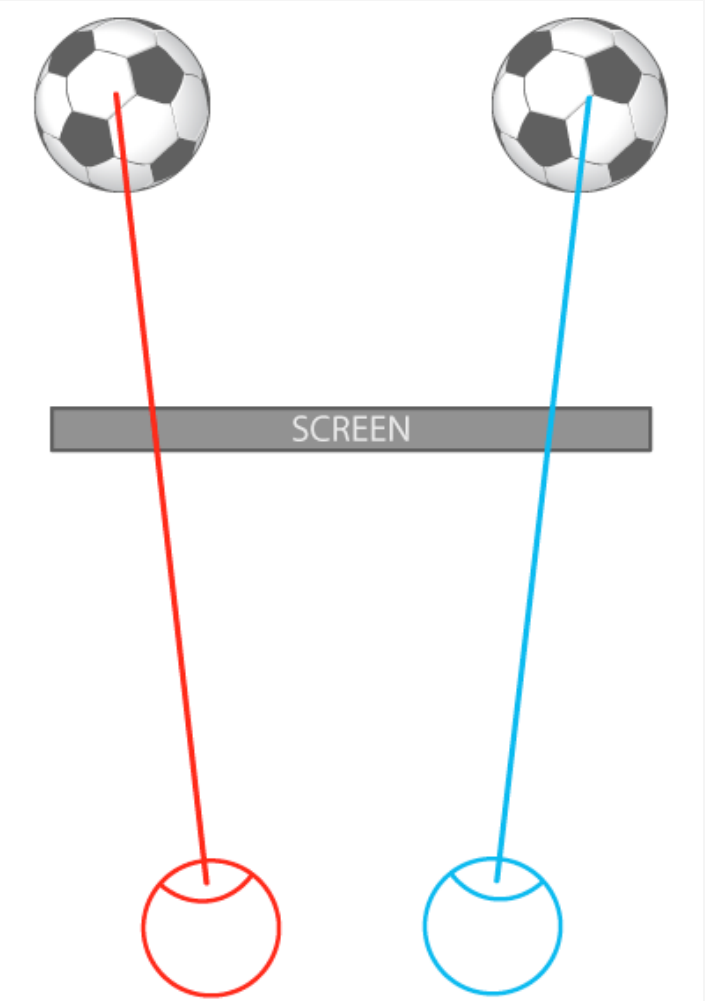
Parallax is a displacement or difference in the apparent position of an object viewed along two different lines of sight

3.2. Interocular and interaxial



3.3 Accomodation, Convergence and Divergence

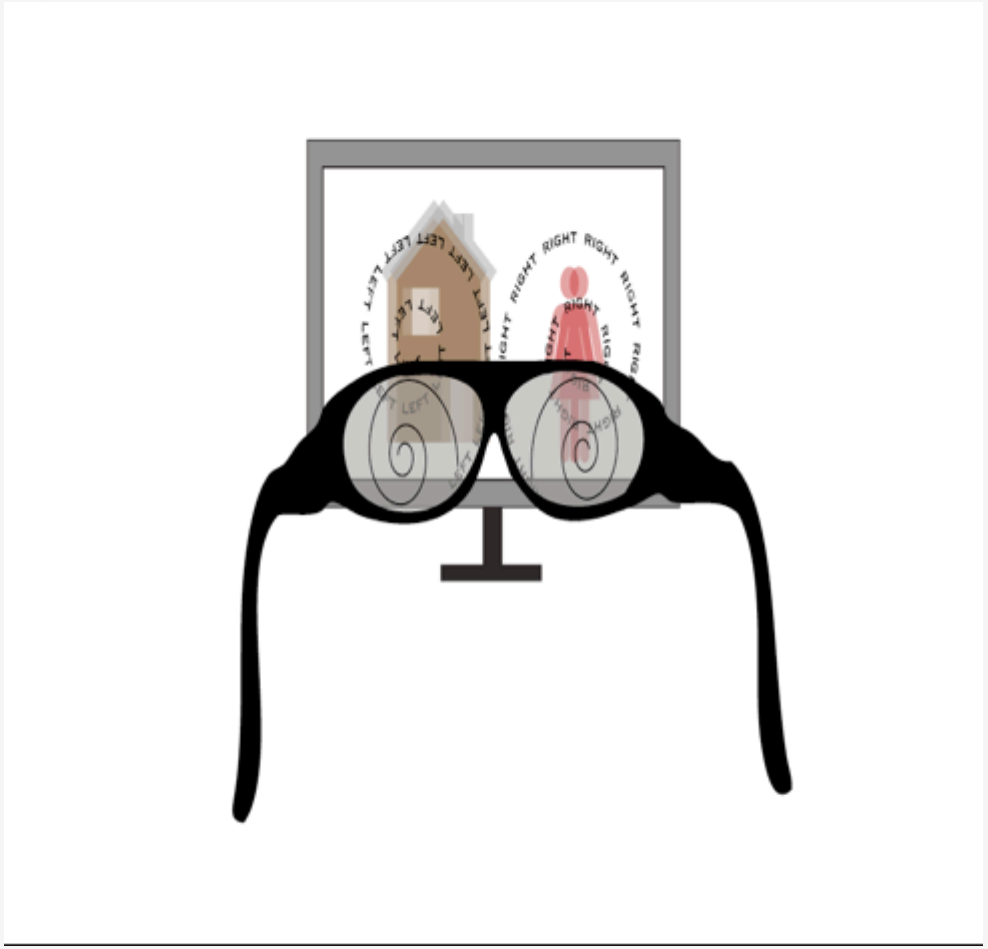




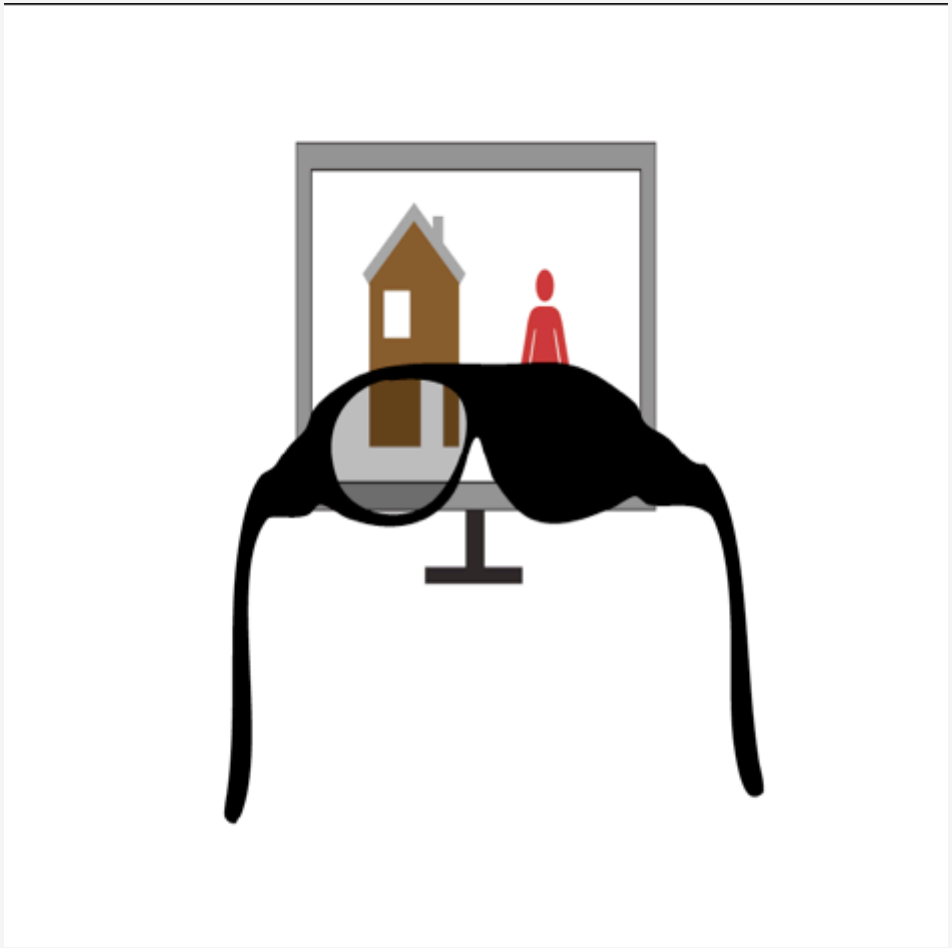
4. 3 D Cinematography

- 2 cameras capture same object from slightly different angles at one fixed viewpoint.
- The left image is shown only to left eye and the right image only to right eye.
- Our brain then fuses these two images to give a perception of depth.

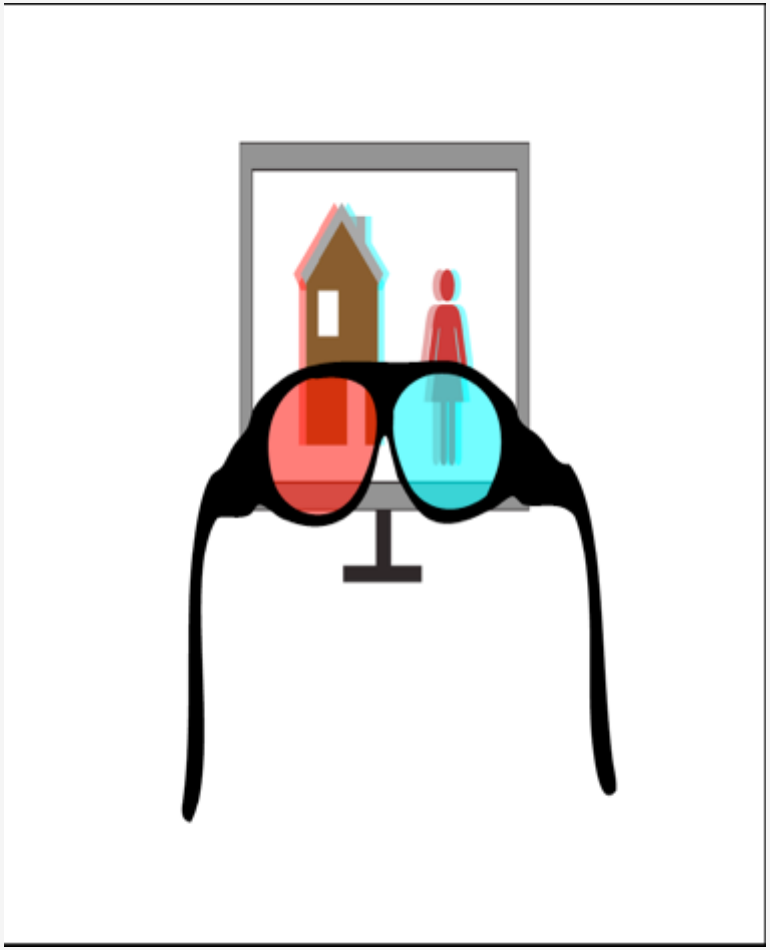
4.1 S3D Glasses (Passive)



4.2 S3D Glasses (Shutter-Active)



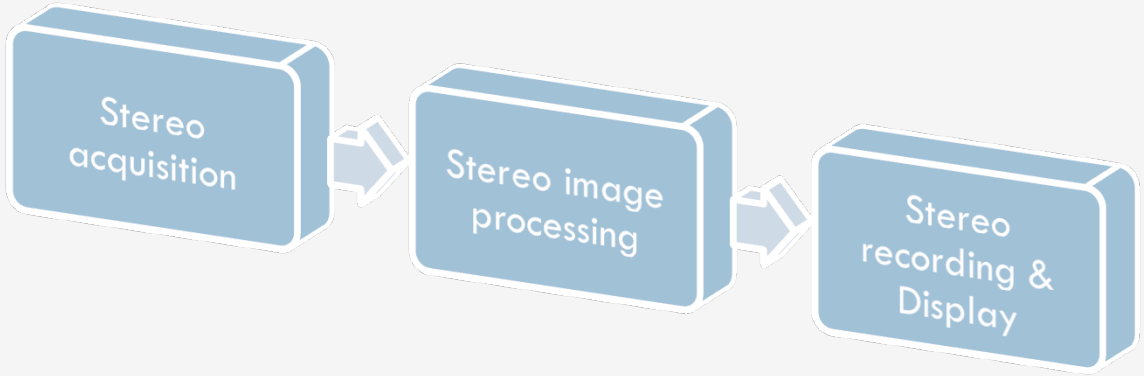
4.3 Anaglyph



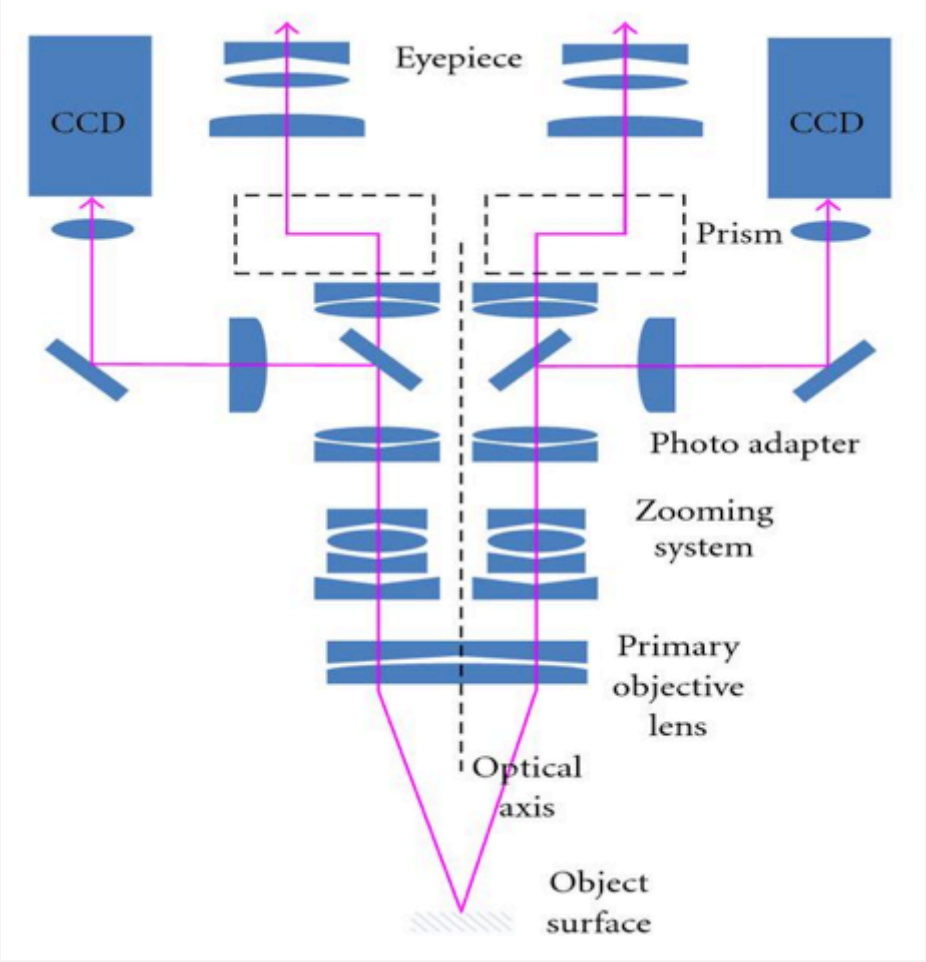
5. 3 D in Microscopy

The existing technique

5.1 Stereomicroscopy for 3D



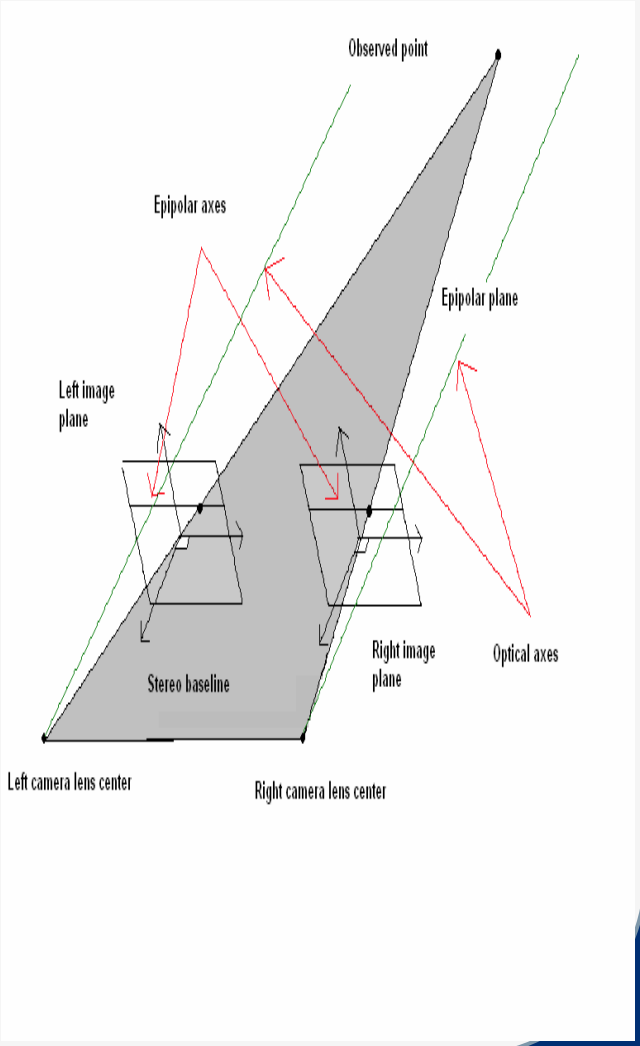
5.1.1. Stereoimage acquisition



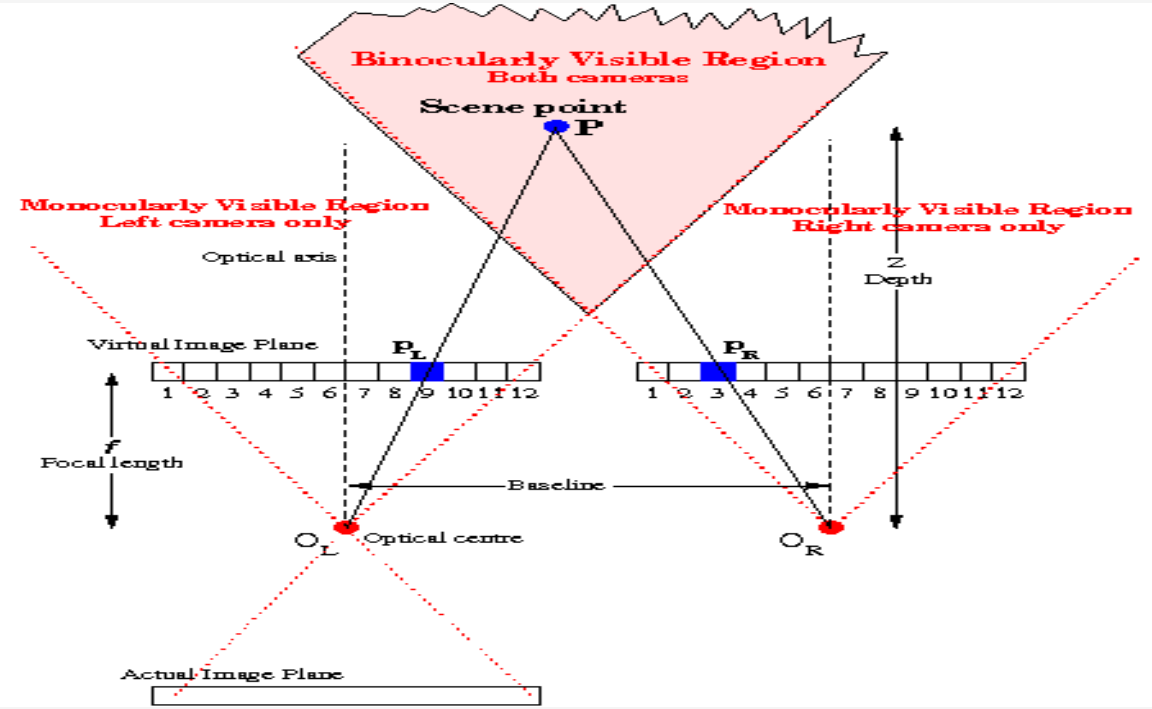
5.1.2. Stereovision

- Baseline
- Epipolar plane
- Epipolar line
- Conjugate pair
- Disparity
- Disparity map

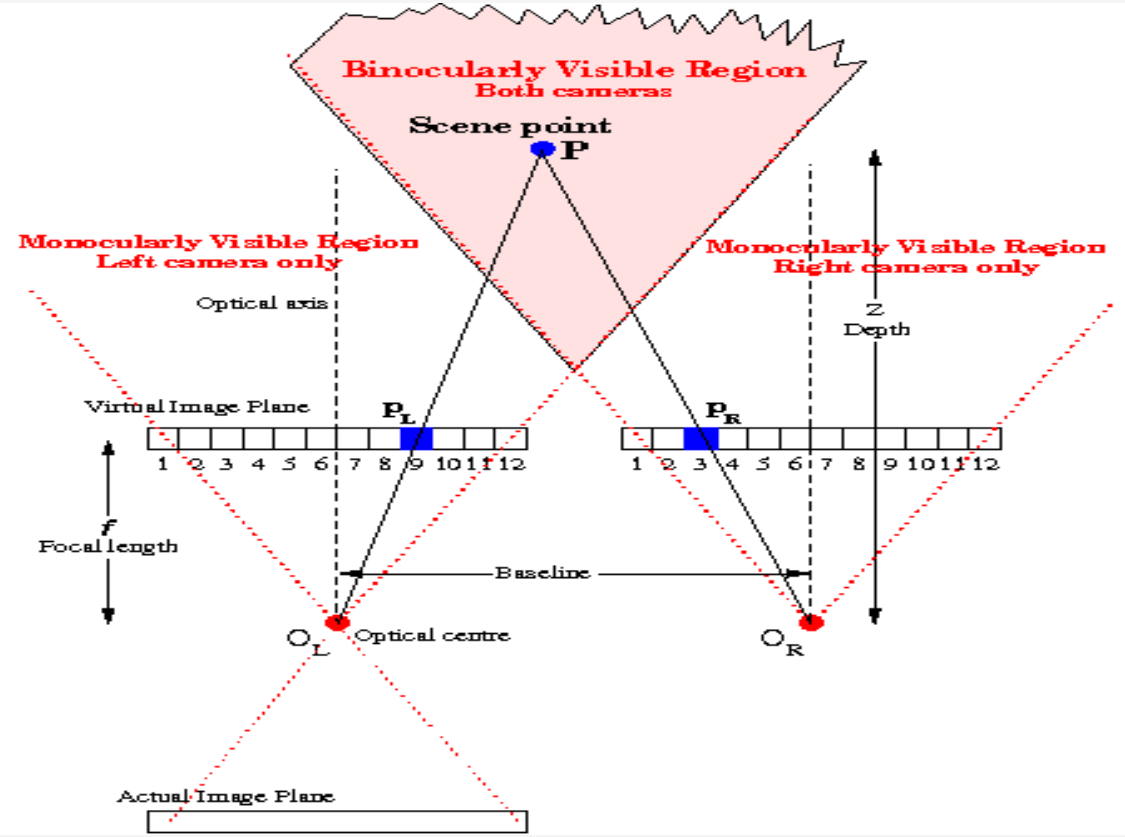
- **Baseline-** Distance between the camera optical centres
- **Epipolar plane-** Plane passing through the optical centres and a point in the scene
- **Epipolar line-**Intersection of the epipolar plane with the image plane



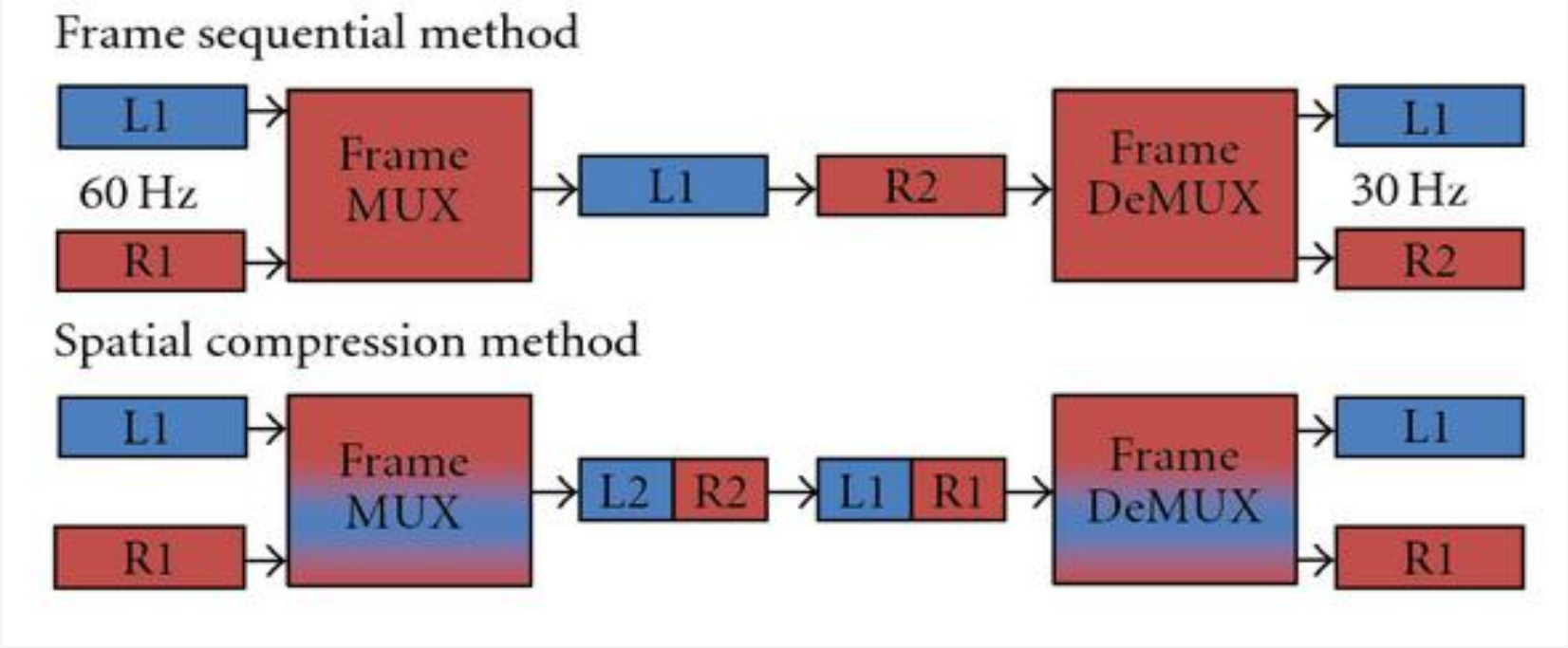
Conjugate pair- Point in the scene that is visible to both cameras (binocularly visible) will be projected to a pair of points in the two images



Disparity-Distance between corresponding points when the two images are superimposed

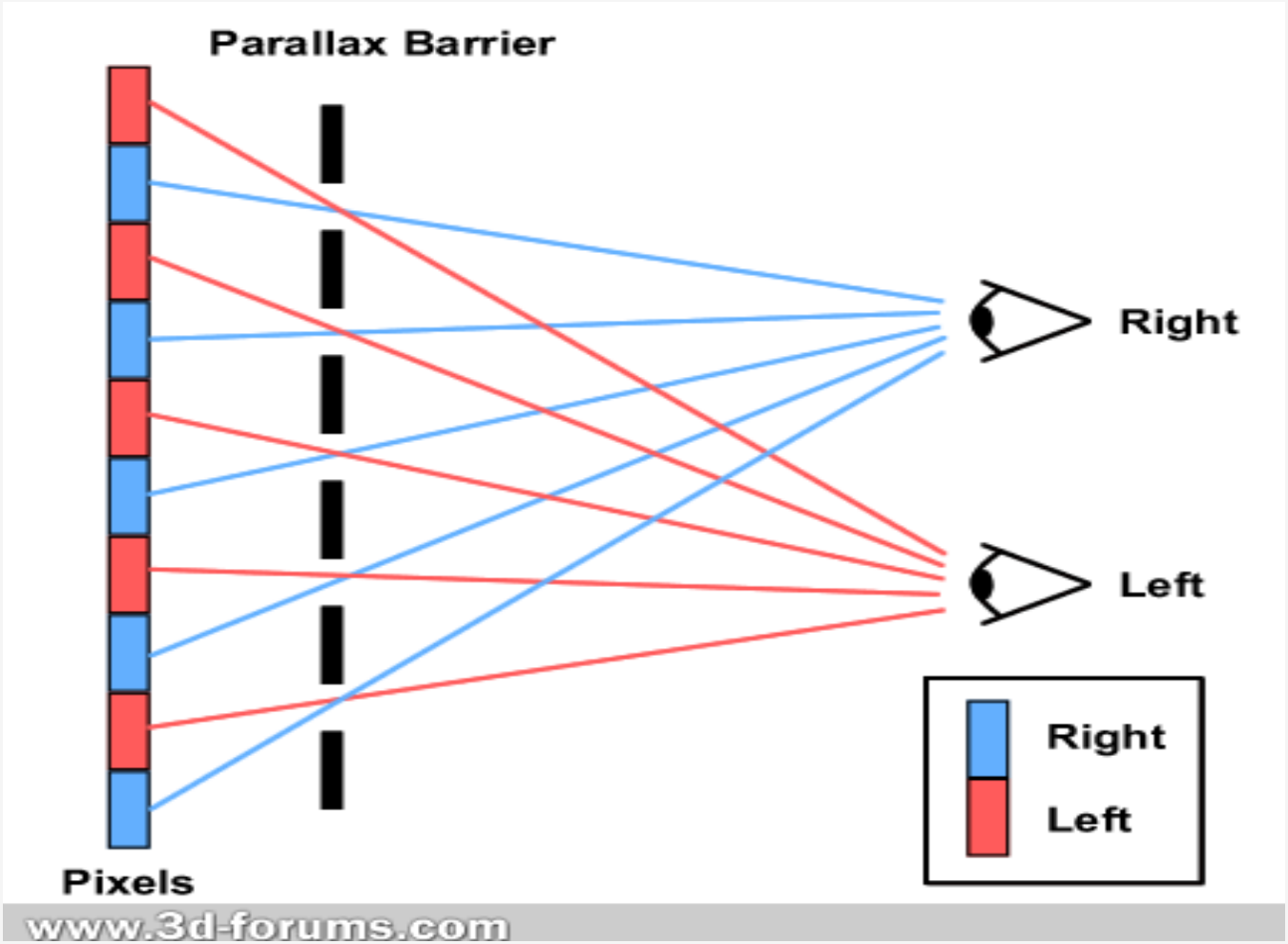


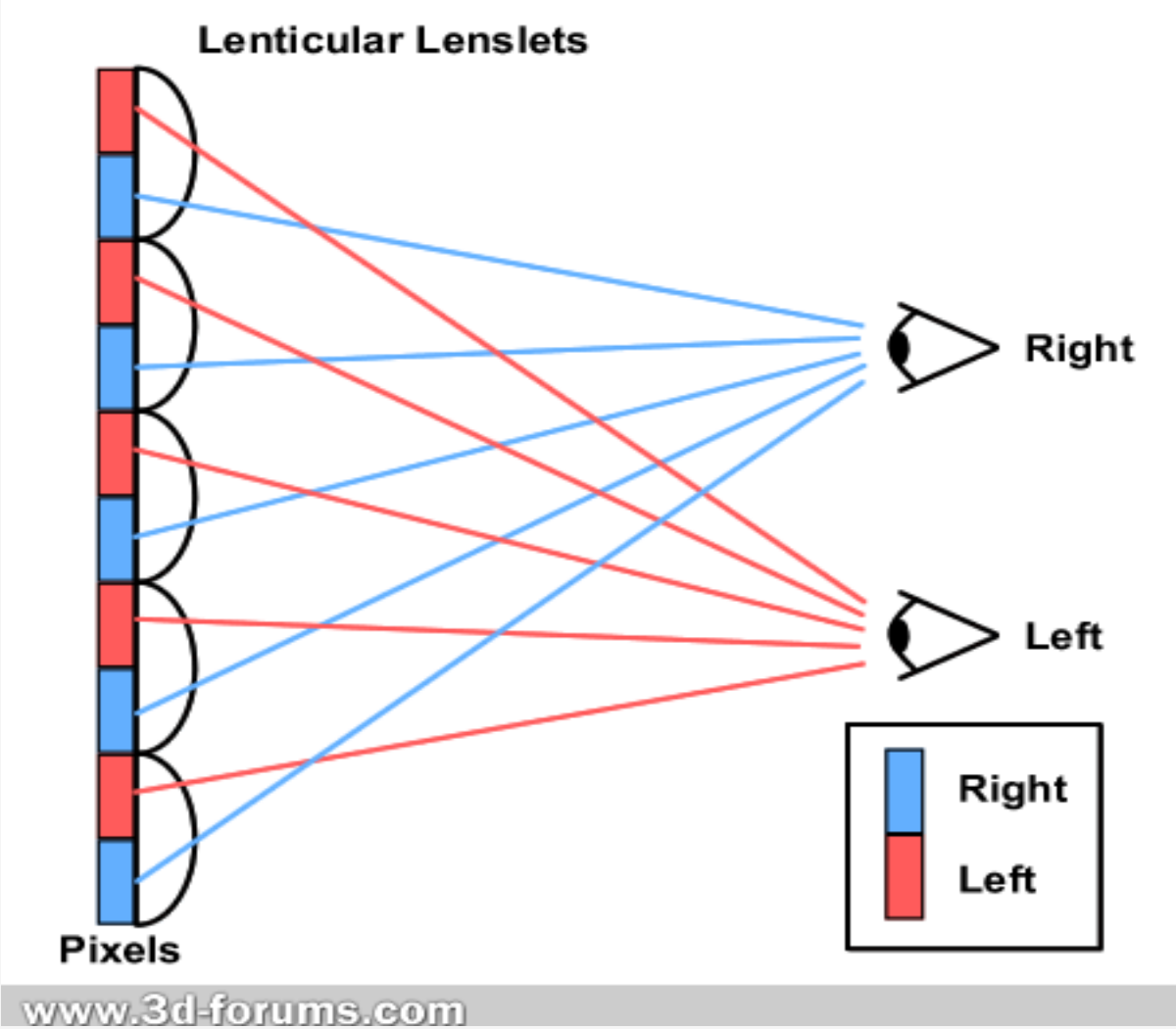
5.1.3. Stereoimage recording

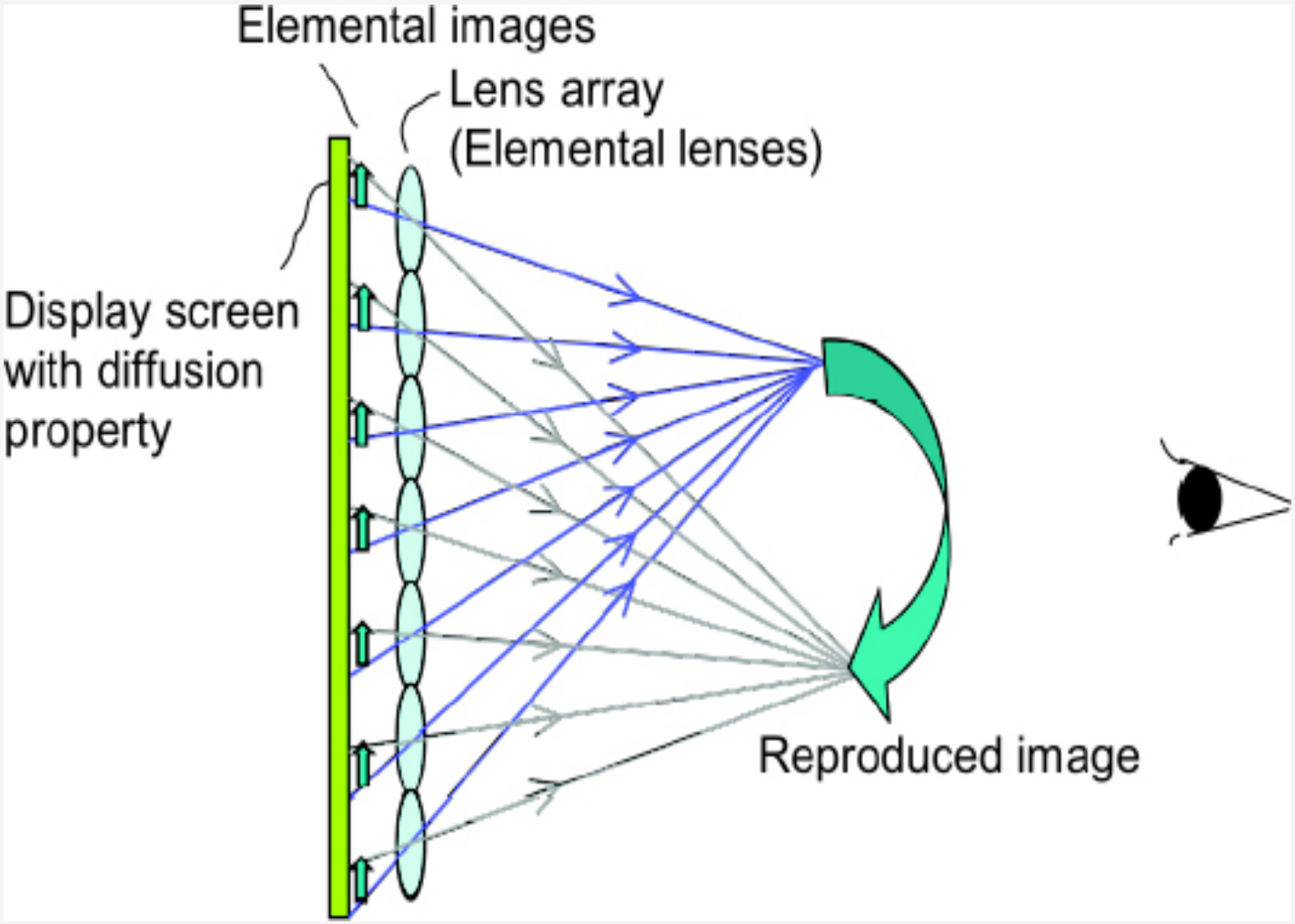


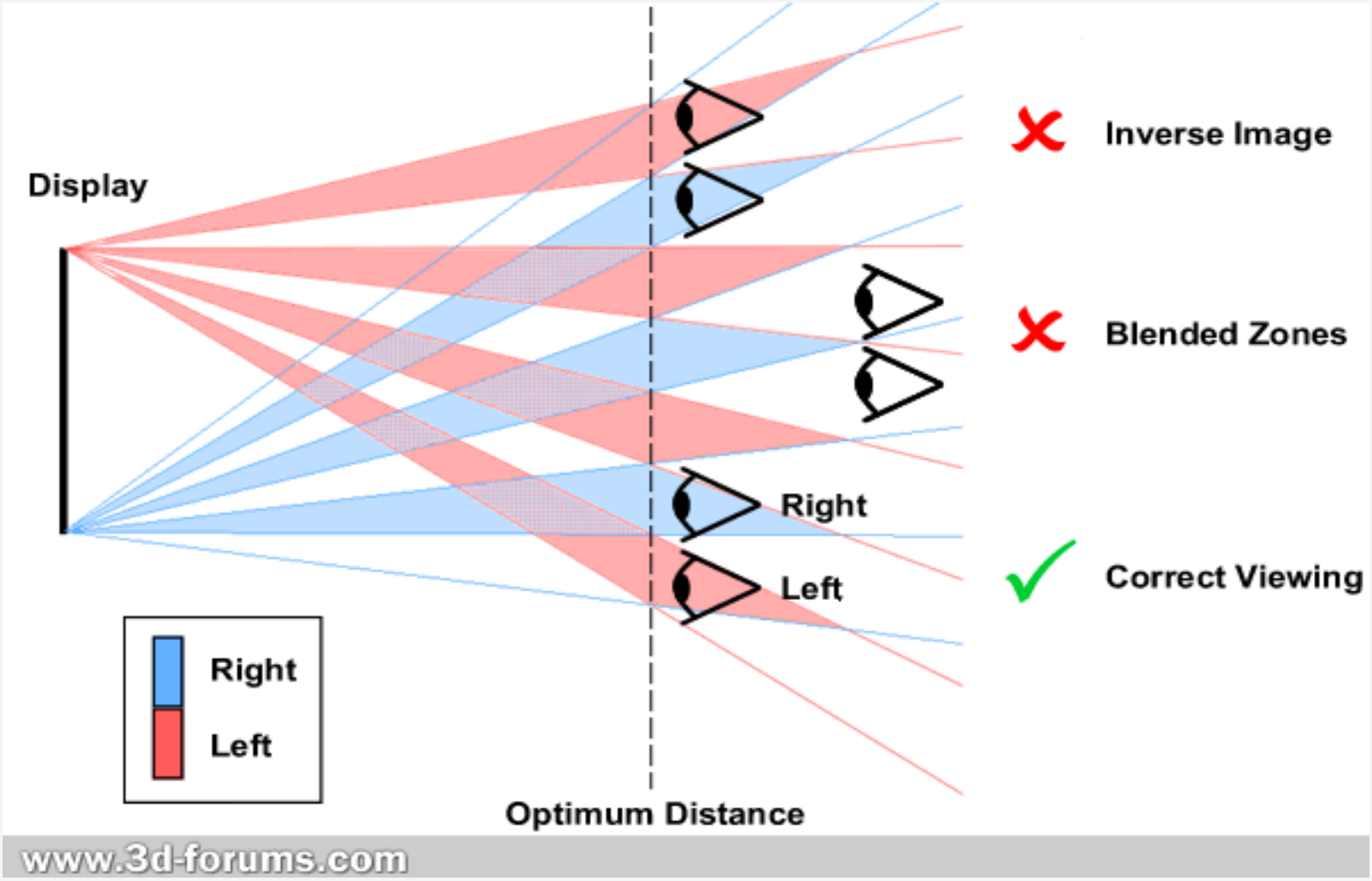
5.14. Stereodisplay

- Binocular stereoscopic(using glasses)
- Autostereoscopic
  - Parallax barrier
  - Lenticular
  - Integral imaging


Parallax Barrier
Right
Left
Right
Left
Pixels
www.3d-forums.com


Lenticular Lenslets
Right
Left
Right
Left
Pixels
www.3d-forums.com


Elemental images
Lens array
(Elemental lenses)
Display screen
with diffusion
property
Reproduced image


Display
Inverse Image
Blended Zones
Right
Left
Correct Viewing
Right
Left
Optimum Distance
www.3d-forums.com

5.2 Future with 3D Microscopy

NEUROSURGERY EDUCATION AND TRAINING SCHOOL

Department of Neurosurgery

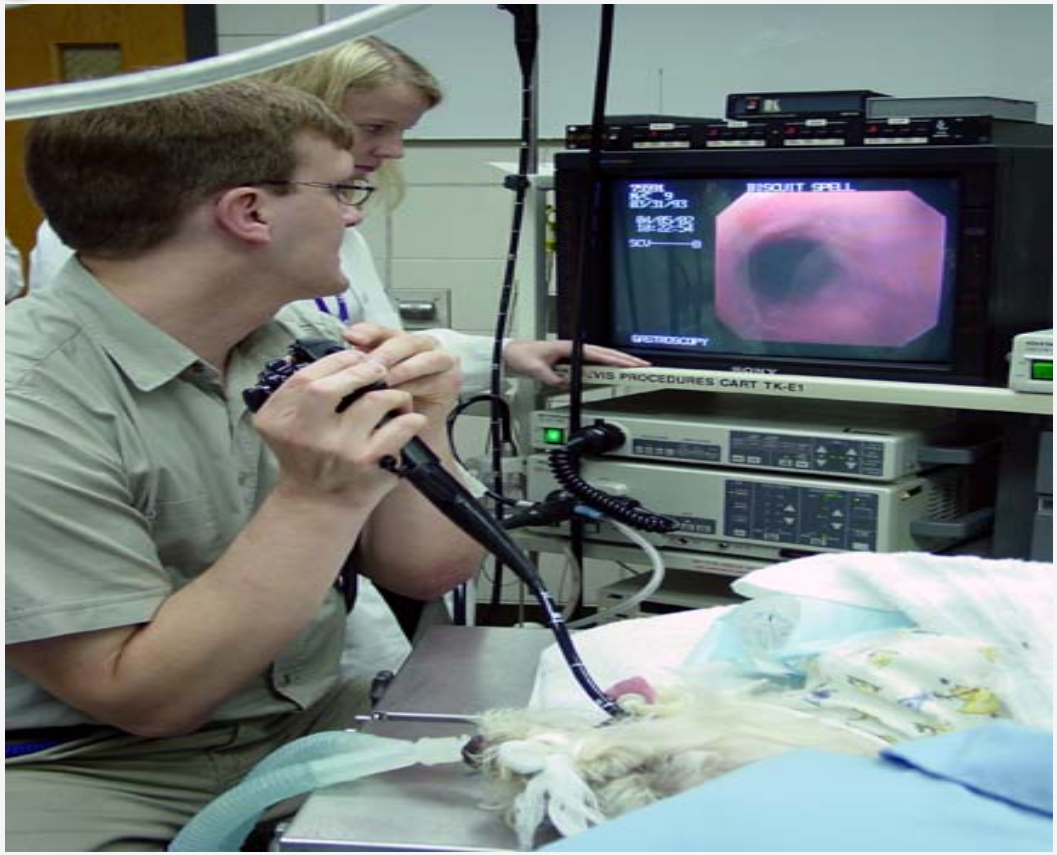
All India Institute of Medical Sciences, New Delhi, India

"The 3D medium has been shown to increase test scores by 35 percent over 2D for learning human anatomy, according to recent studies by Texas Instruments, reinforcing the market for tools with the ability to work with stereoscopic video."

http://www.truevisionsys.com/announcement19.html

6. 3 D in Endoscopy

The existing technique



6. 3 D in Endoscopy

- Image generation types
  - Dual channel
  - Dual chip-on-tip
  - Shutter mechanism
  - Insect-eye technology

6.1. Dual channel endoscopy

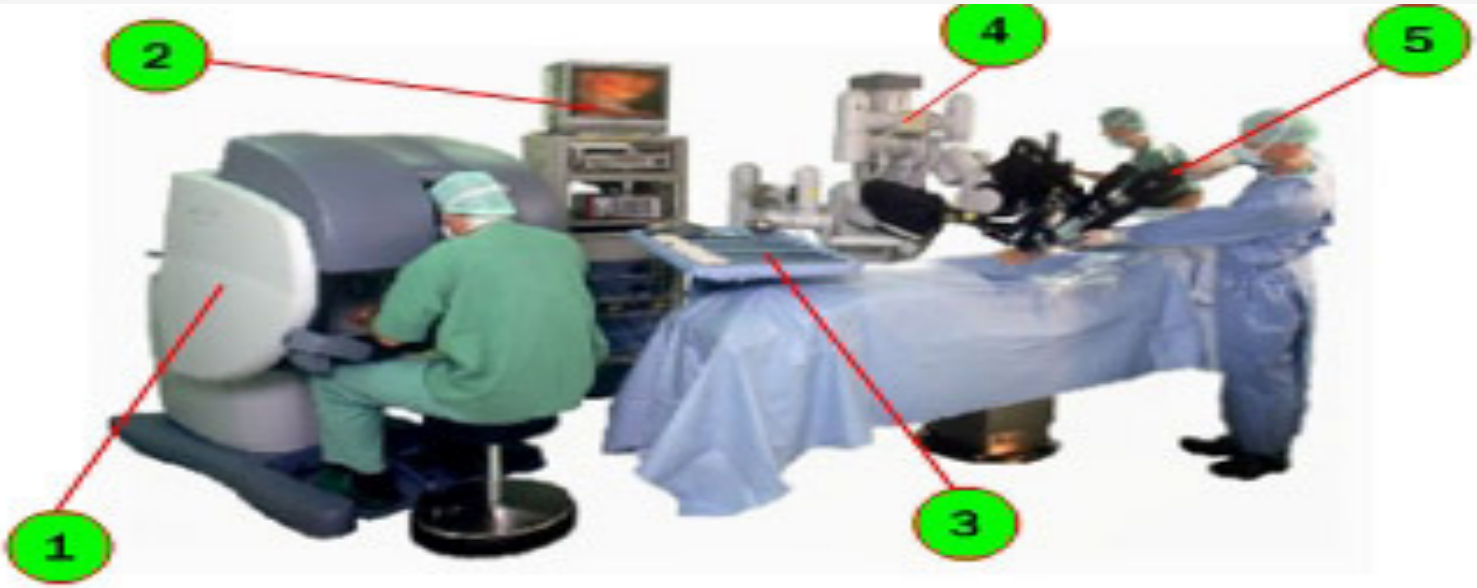


Photo courtesy of Intuative Surgical

1. Surgeon Console
2. Image Processing Equipment
3. Endowrist Instruments
4. Surgical Arm Cart
5. Hi-Resolution 3-D Endoscope

- Da Vinci surgical system- Four arms
- Three of the arms are for tools
- The fourth arm is for an endoscopic camera with two lenses
- The surgeon sits at the console and looks through two eye holes at a 3-D image of the procedure
- The da Vinci System scales, filters and translates the surgeon's hand movements into more precise micro-movements of the instruments, which operate through small incisions in the body.

NEUROSURGERY EDUCATION AND TRAINING SCHOOL

Department of Neurosurgery

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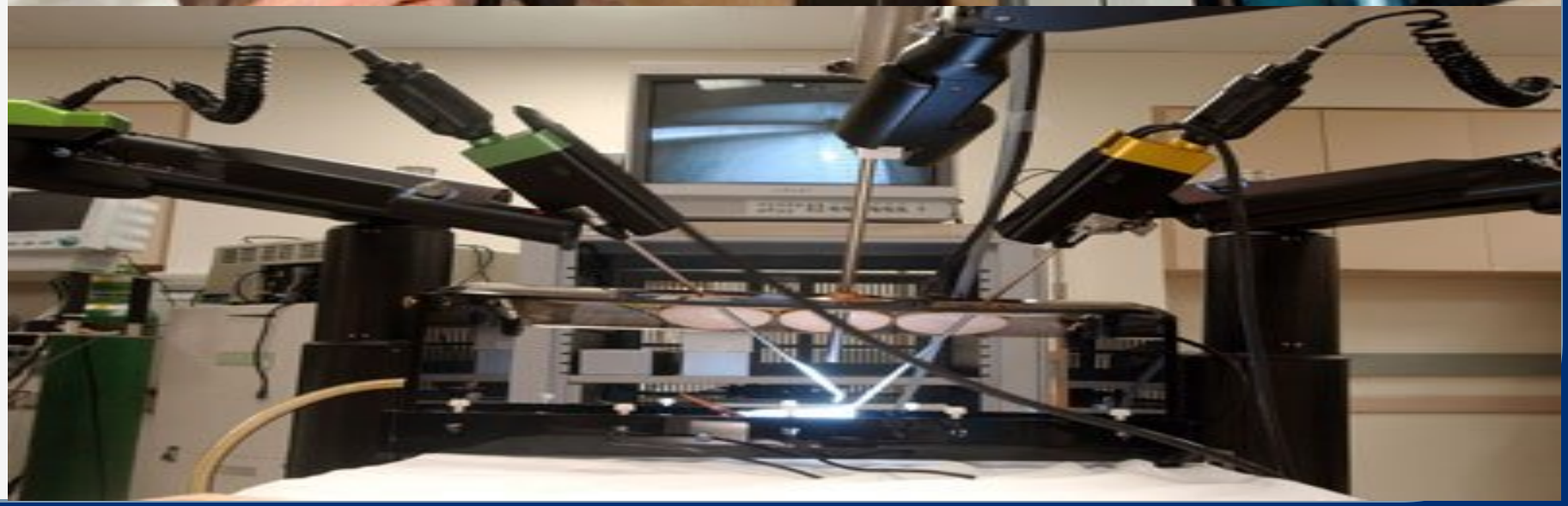


Advantages	Disadvantages
High quality images	1)Images vary not only in angle but also in brightness, color and sharpness 2) Fatigue, dizziness

6.2 Dual chip-on-the-tip

- Two video chips on the end of the scope

Advantages	Disadvantages
Digital images bypasses the optical distortion	Weak 3 D effect due to the disparity issue

6.3 Shutter mechanism

- Camera produces minor angle changes between the frames
- Streaming video is divided into two to produce the stereoscopic effect

Advantages	Disadvantages
Image generated by single optic scope	1) Low disparity 2) Flicker of the video 3) Weak 3 D perception

6.4 Insect-eye technology

- Microscopic array of lenses placed in front of the single video chip like an insect-eye
- The lens array creates small, slightly distorted images which then is made into "left" and "right" images for stereoscopic vision

Advantages	Disadvantages
1)Image from single CCD 2) Volumetric information	1)Lower picture intensity 2) System instability

6.6 Factors required for neurosurgery endoscopy

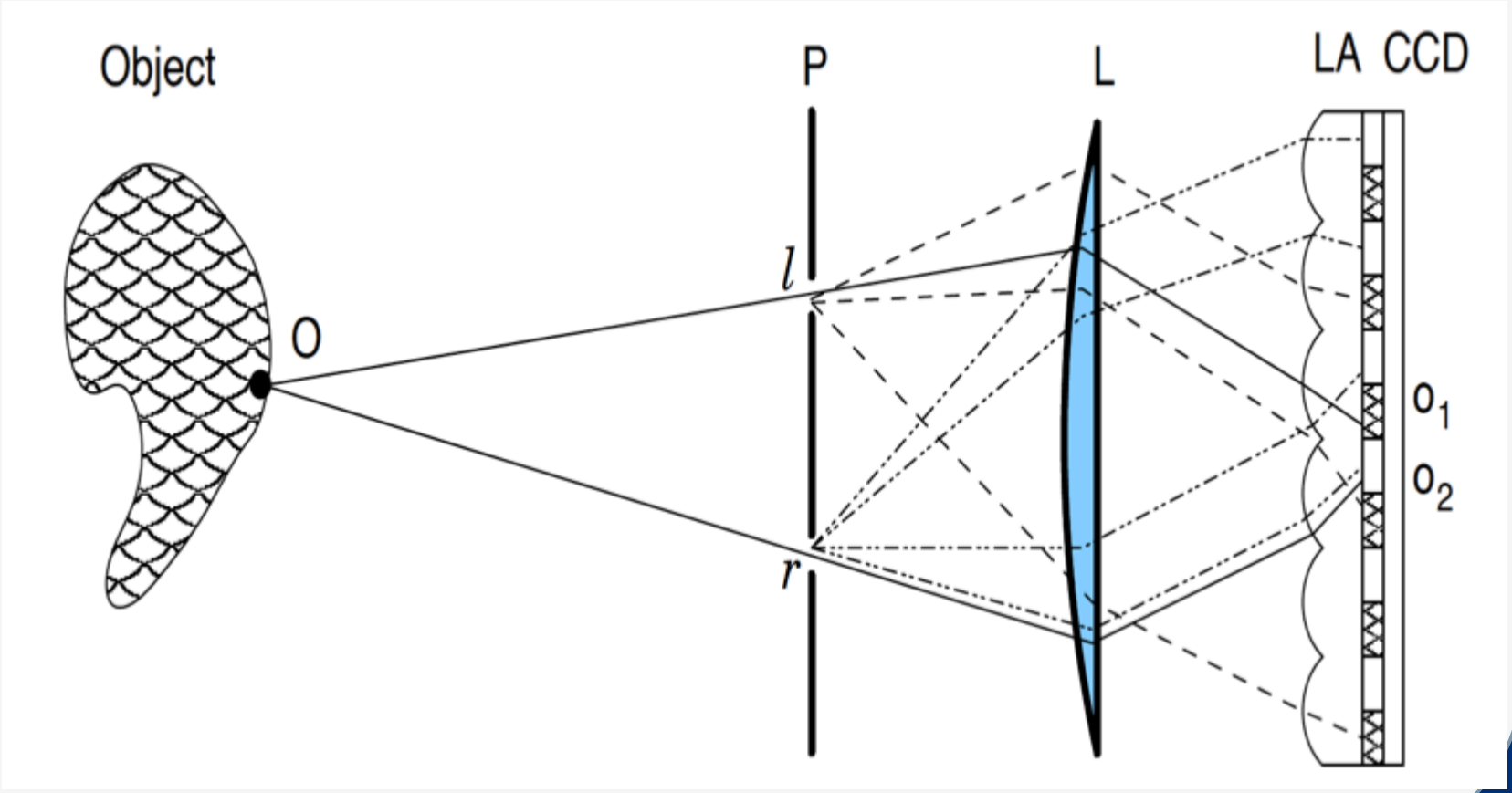
- Illumination A Bright Xenon arc-High depth-of field.
- (DOF) is essential: Objects must be in focus within a range of few millimeters to several centimeters.
- Very wide field-of-view (FOV) from 70◦ to 140◦.

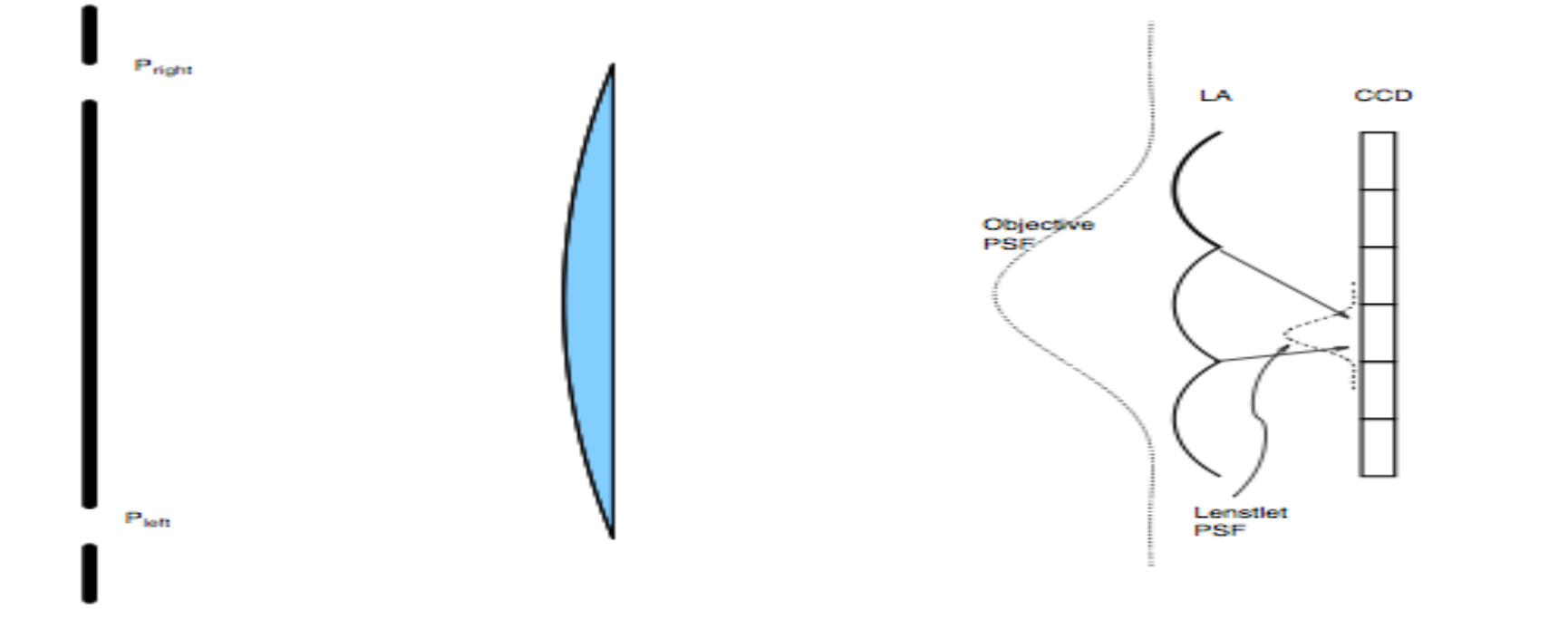
- Smallest possible camera diameter: To minimize the incision for camera insertion and reduce the disturbance to the surgical tools.
- Video images are utilized as a part of a feedback loop: The surgeon uses the information he sees in real- time.
- Anatomic and pathologic markers as well the position of the surgical instruments relative to the tissue.

6.5 3D limitations of earlier 3D endoscopes

- Large diameter
- Lack of angled endoscopes
- Decreased resolution compared with 2-D endoscopes
- Need to wear 3-D glasses, which permit 3-D sensation only at certain viewing angles and result in eye strain

6.7 Insect-eye technology in neurosurgery





Yaron a, M. Shechtermanb and N. Horesh, “Blur spot limitations in distal endoscope sensors “,Visionsense Inc. Orangeburg, NY, Visionsense Ltd. Petah-Tiqva, Israel.

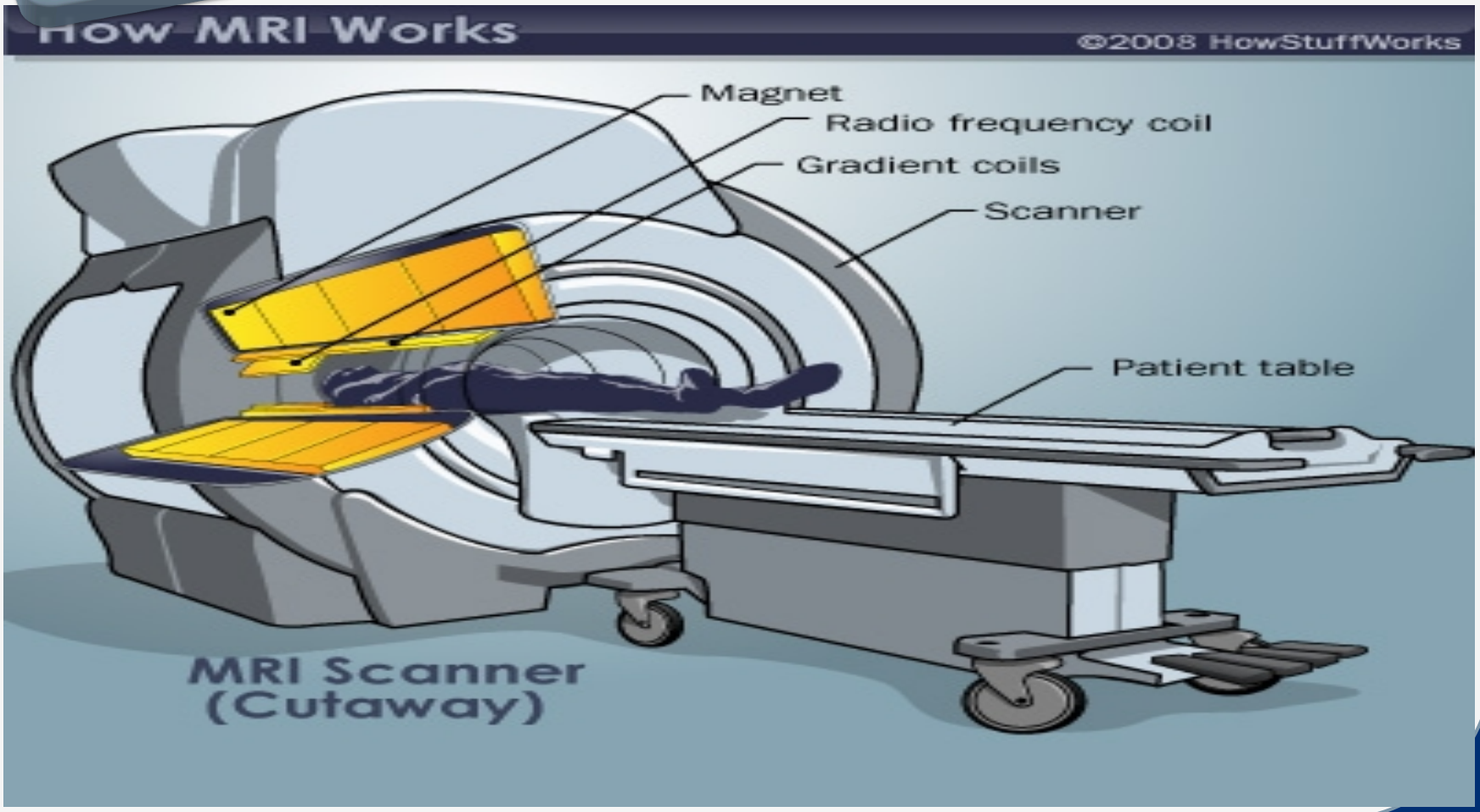
"Adding binocular vision through novel 3D imaging and rendering technology to endoscopic approaches has the potential to reduce mistakes in movement, pro- vide more visual anatomic cues by more clearly illuminating depth relationships, and reduce learning curves for novice surgeons"

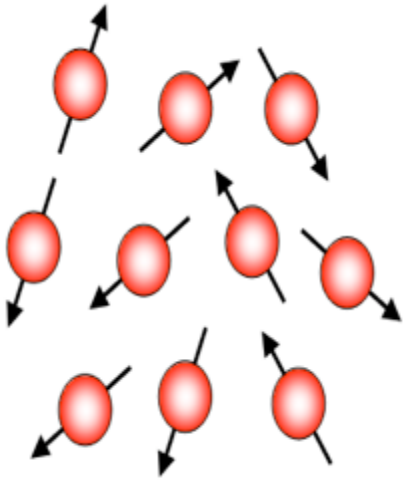
J. F. Fraser1, B. Allen1, V. K. Anand2, T. H. Schwartz1 , **Three-dimensional Neurostereoendoscopy? Subjective and Objective Comparison to 2D**

7. 3 D in neuroimaging

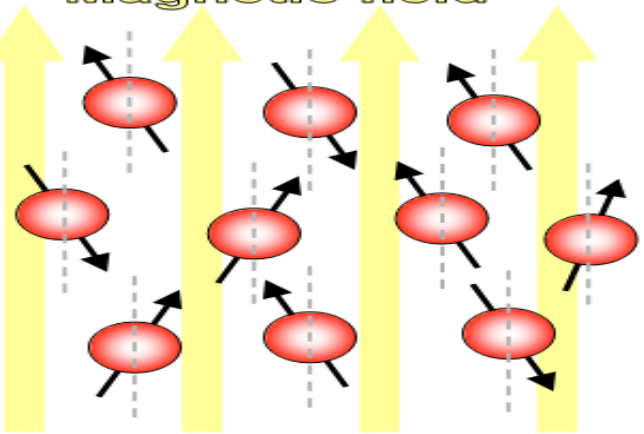
- MRI imaging
- CT imaging

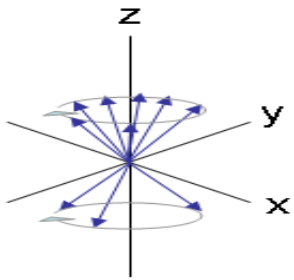
7.1 • MRI Basics

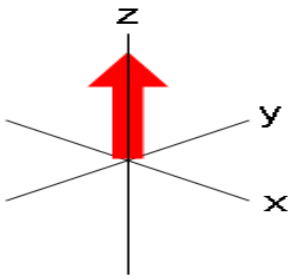




Magnetic field



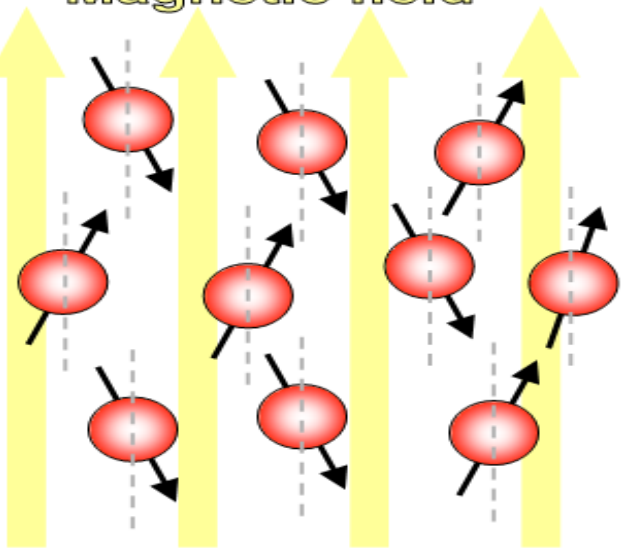


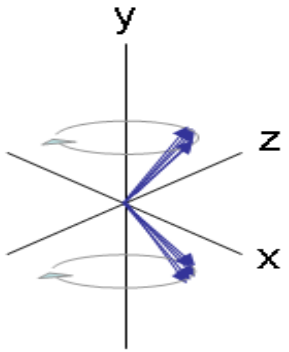


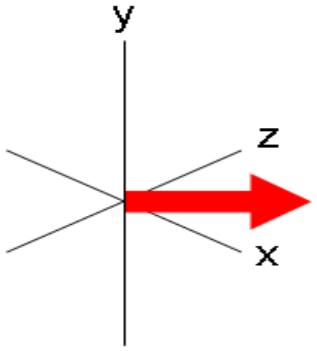
Overall magnetisation of nuclei = Sum of vectors from individual nuclei

RF pulse

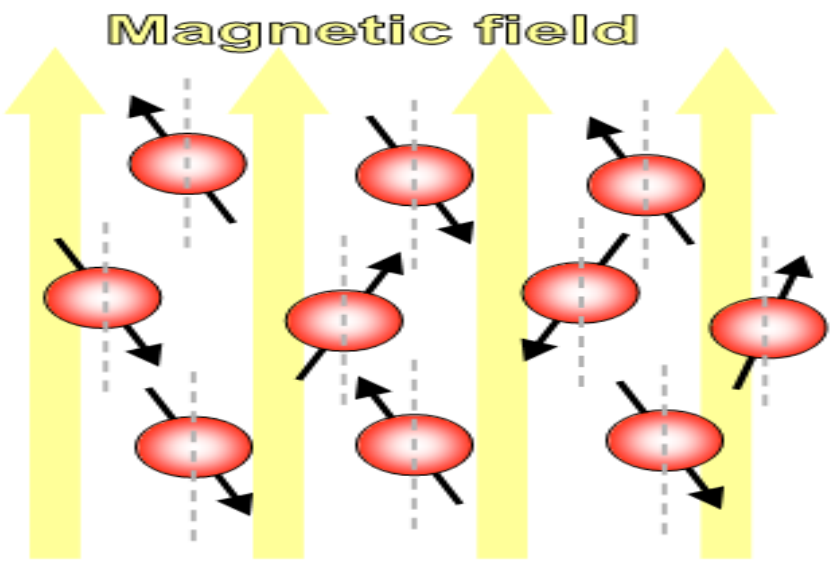
Magnetic field



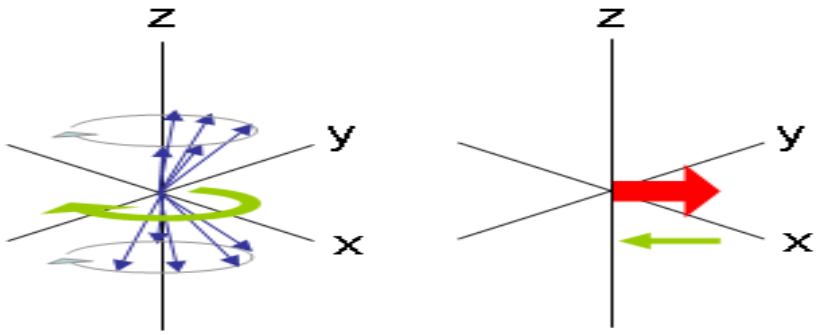




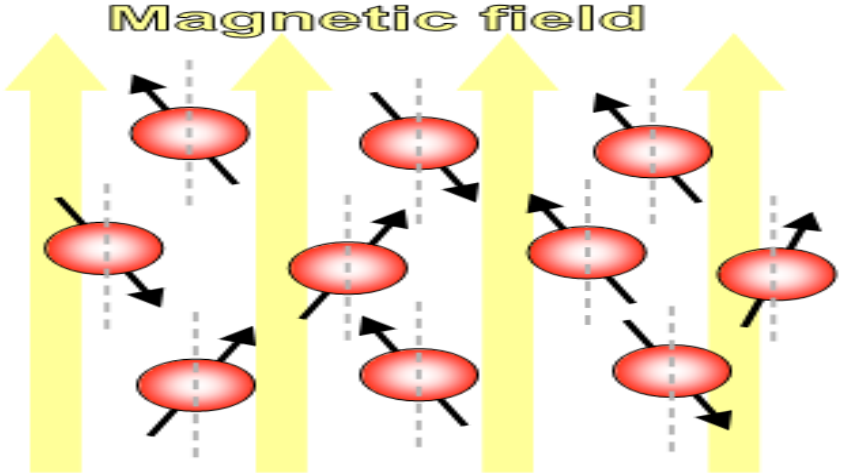
Overall magnetisation of nuclei = Sum of vectors from individual nuclei



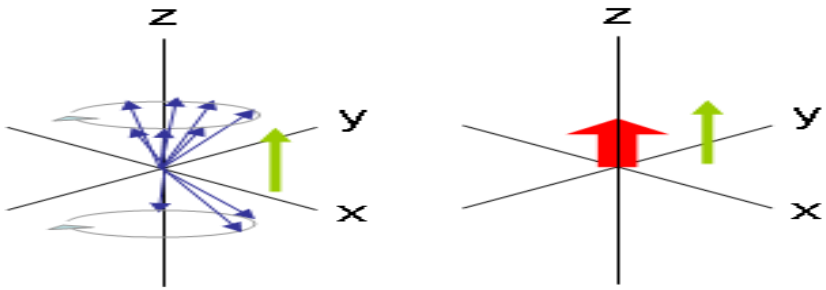
T_2 Relaxation



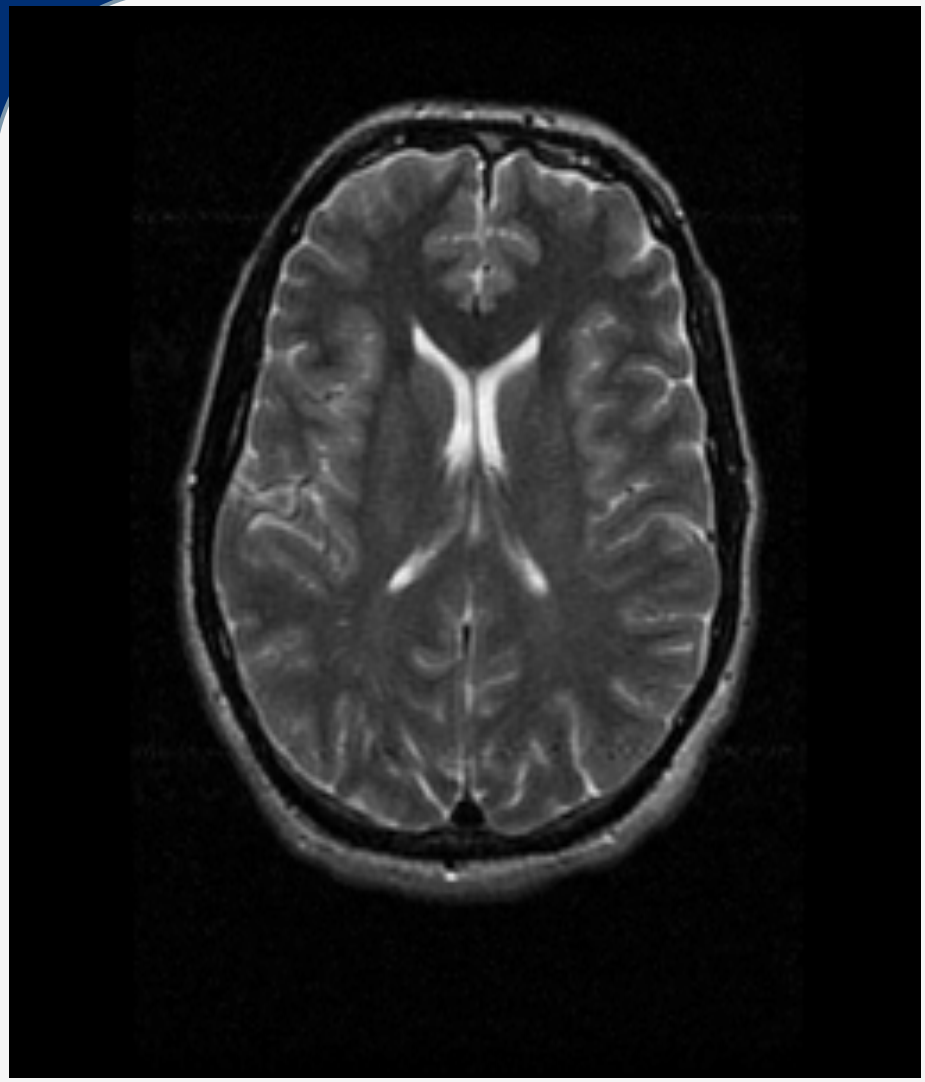
Overall magnetisation of nuclei = Sum of vectors from individual nuclei

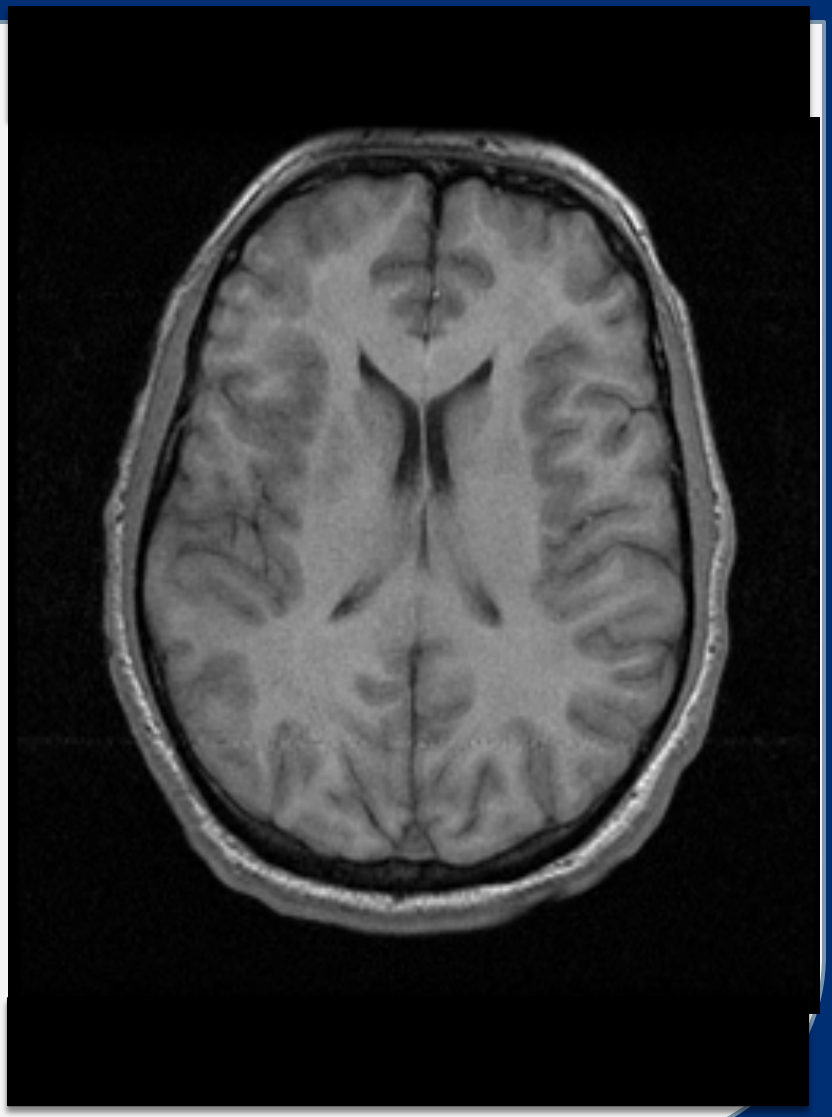


T_1 Relaxation



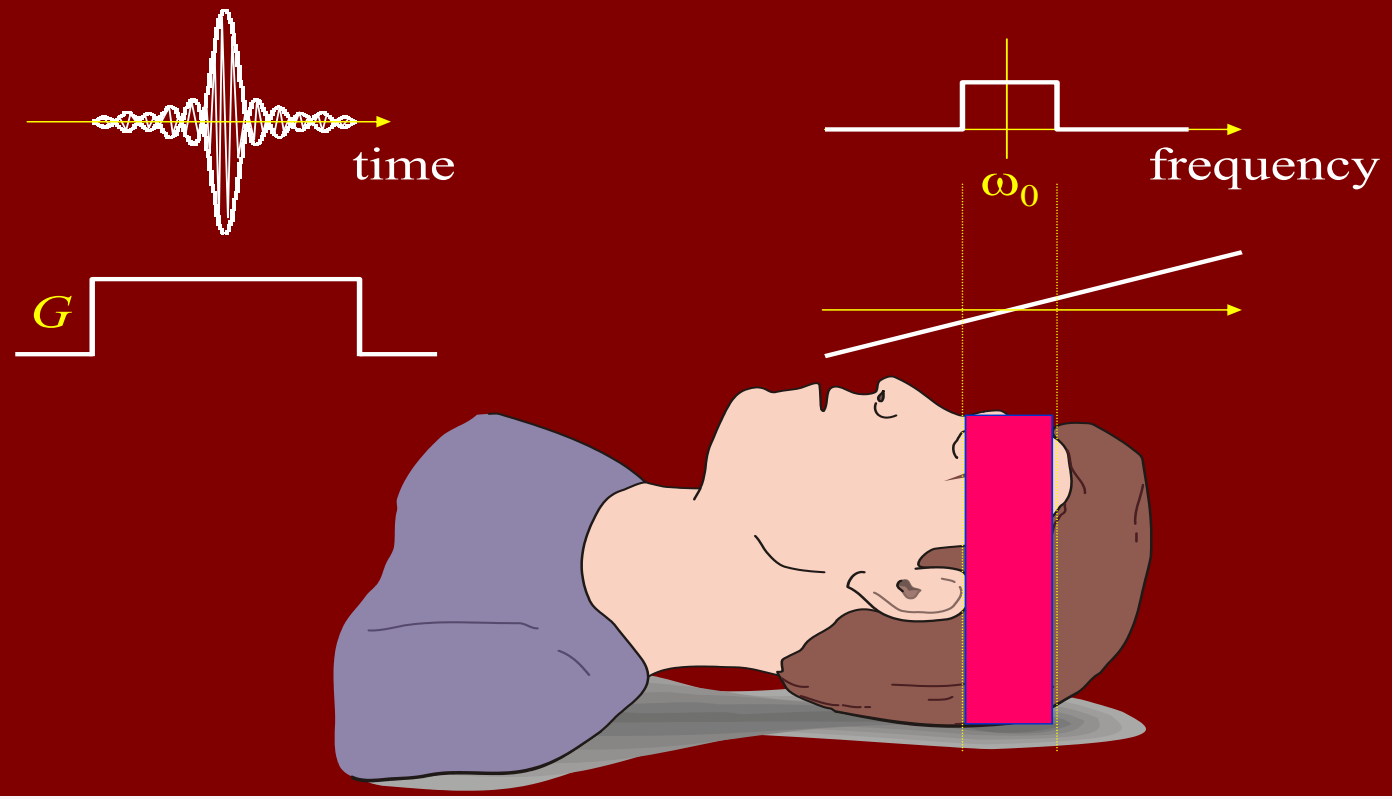
Overall magnetisation of nuclei = Sum of vectors from individual nuclei

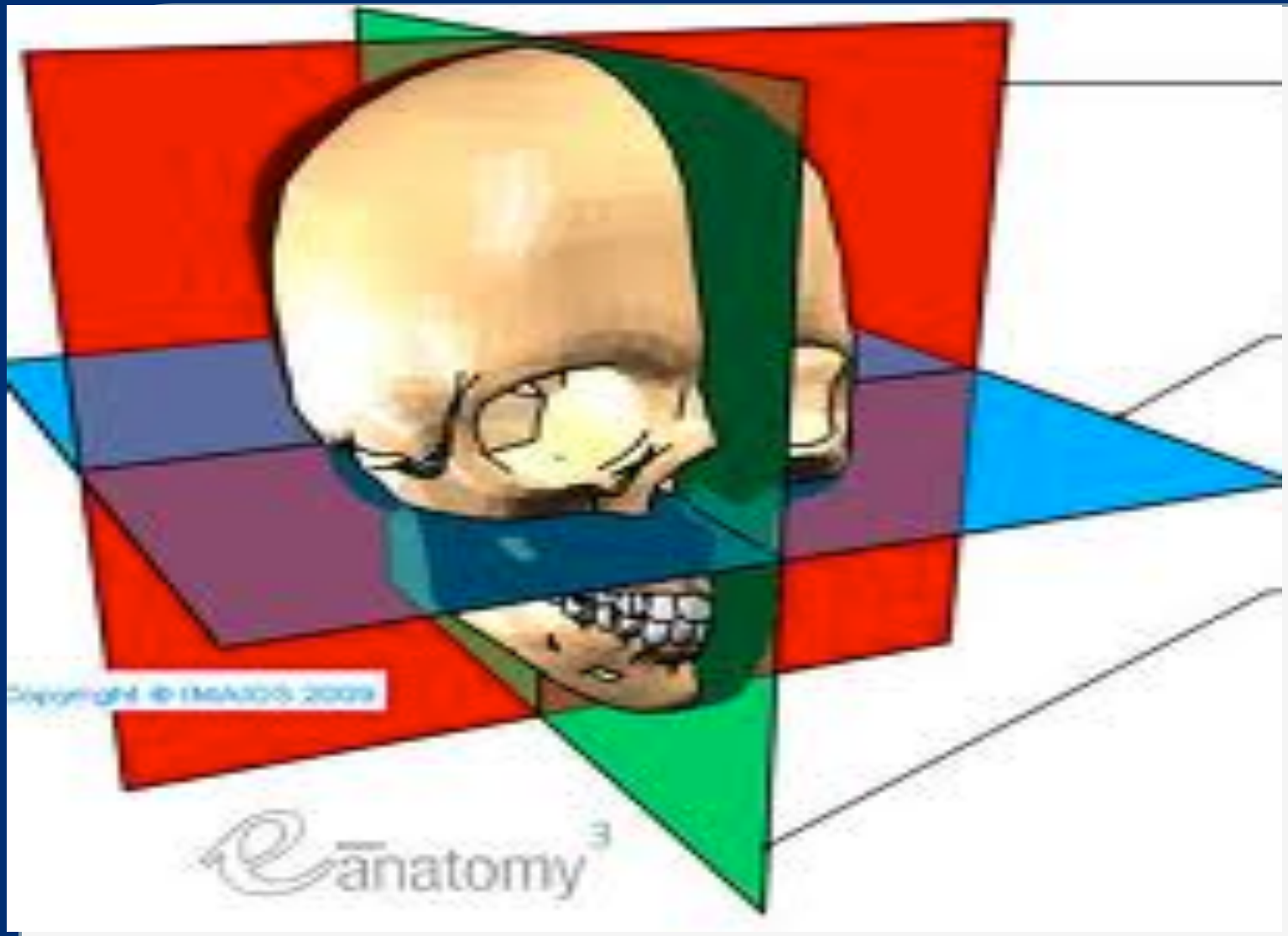


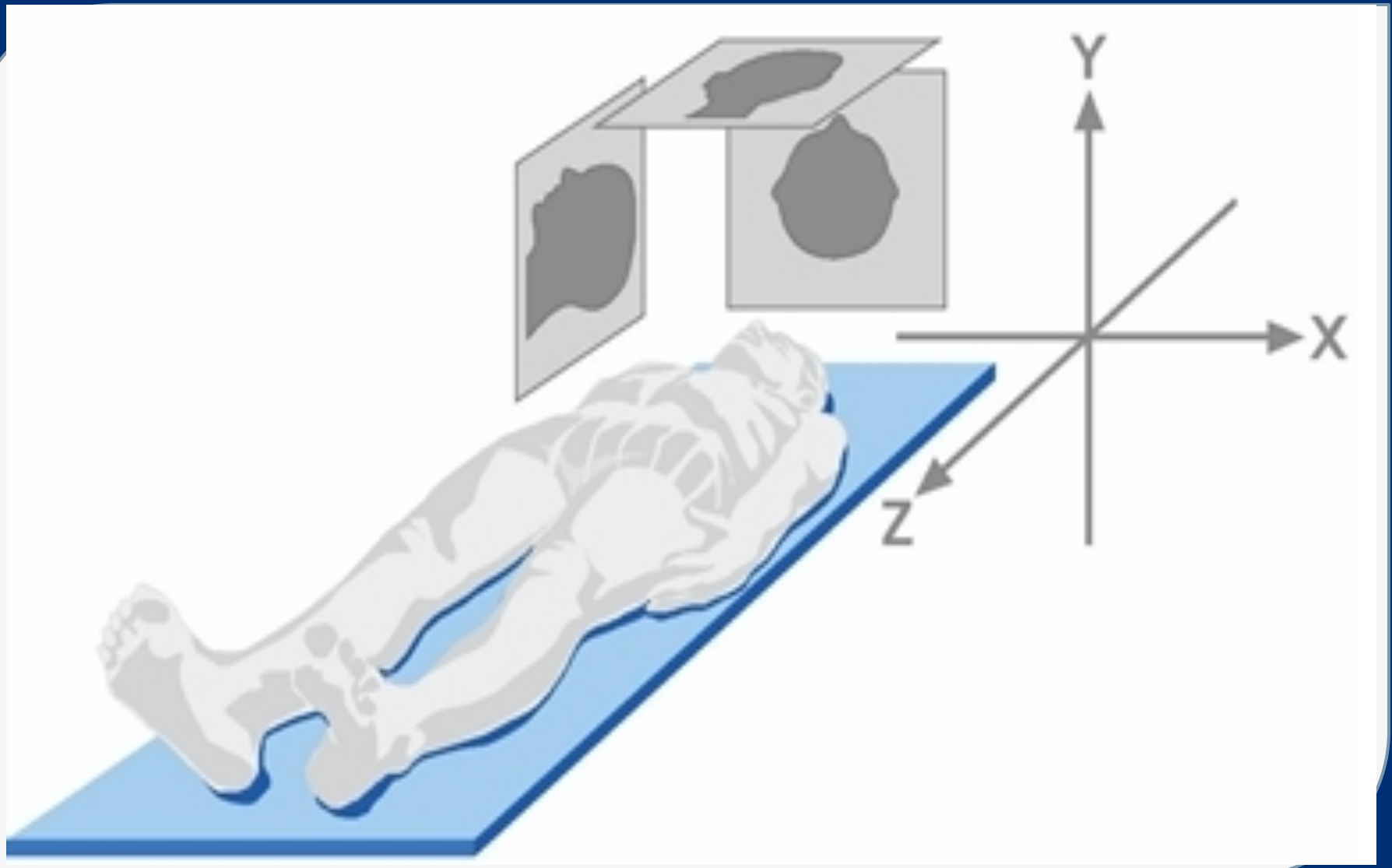


- Superconducting magnet provides large magnetic field
- RF coil provides the RF pulse
- Gradient coils are used for:
  - Slice selection
  - Phase encoding
  - Frequency encoding
- The change in the the magnetic flux produces voltage and it is also measured by RF coil

Slice Selection




Coronal
Axial
Sagittal
anatomy


Y
X
Z

Phase Encoding

- This results in all the protons precessing in the same frequency but in different phases.
- The protons in the same row, perpendicular to the gradient direction, will all have the same phase

Frequency Encoding

- This modifies the Larmor frequencies in the horizontal direction throughout the time it is applied.
- It thus creates proton columns, which all have an identical Larmor frequency.

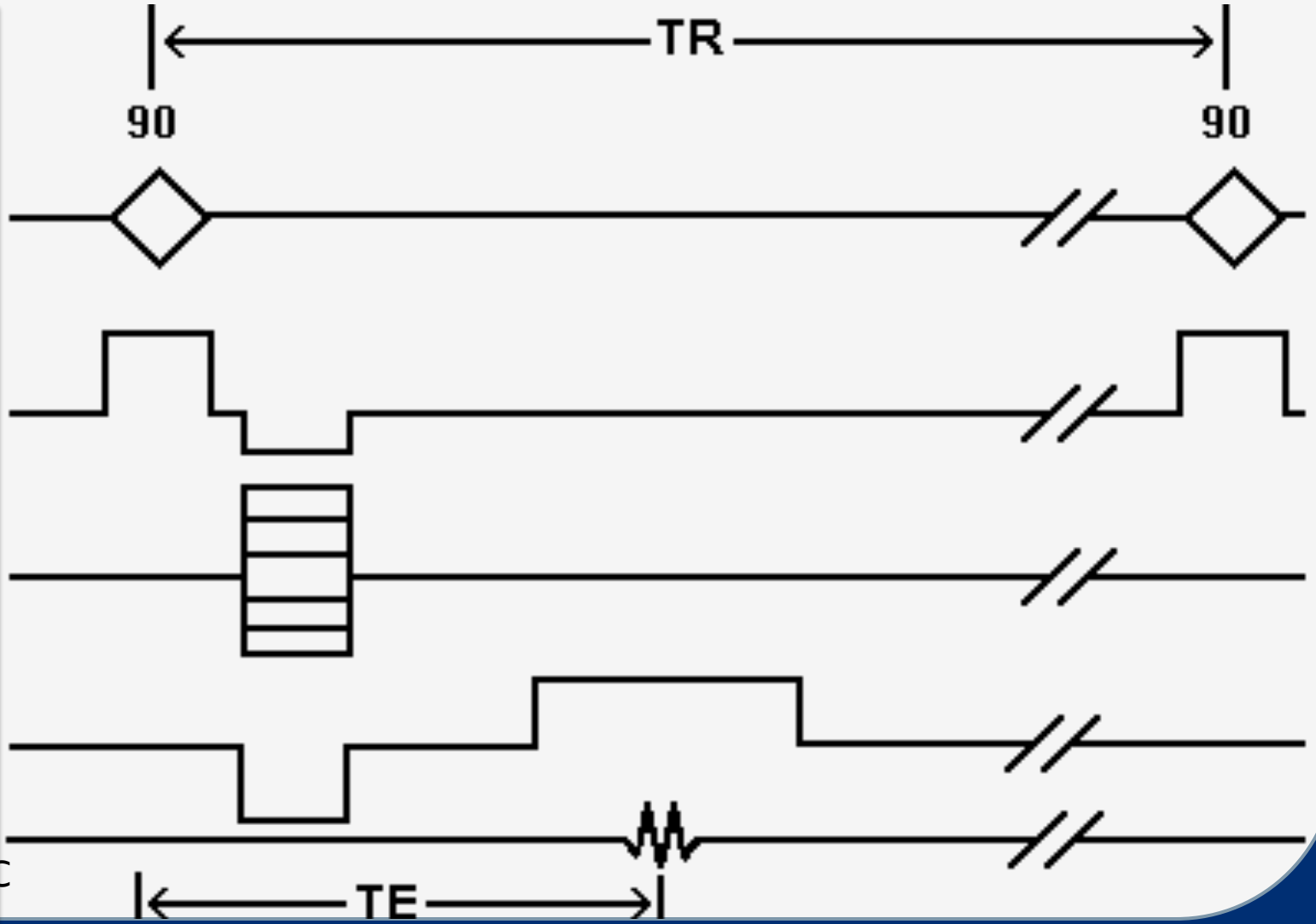
Radio Frequency pulse

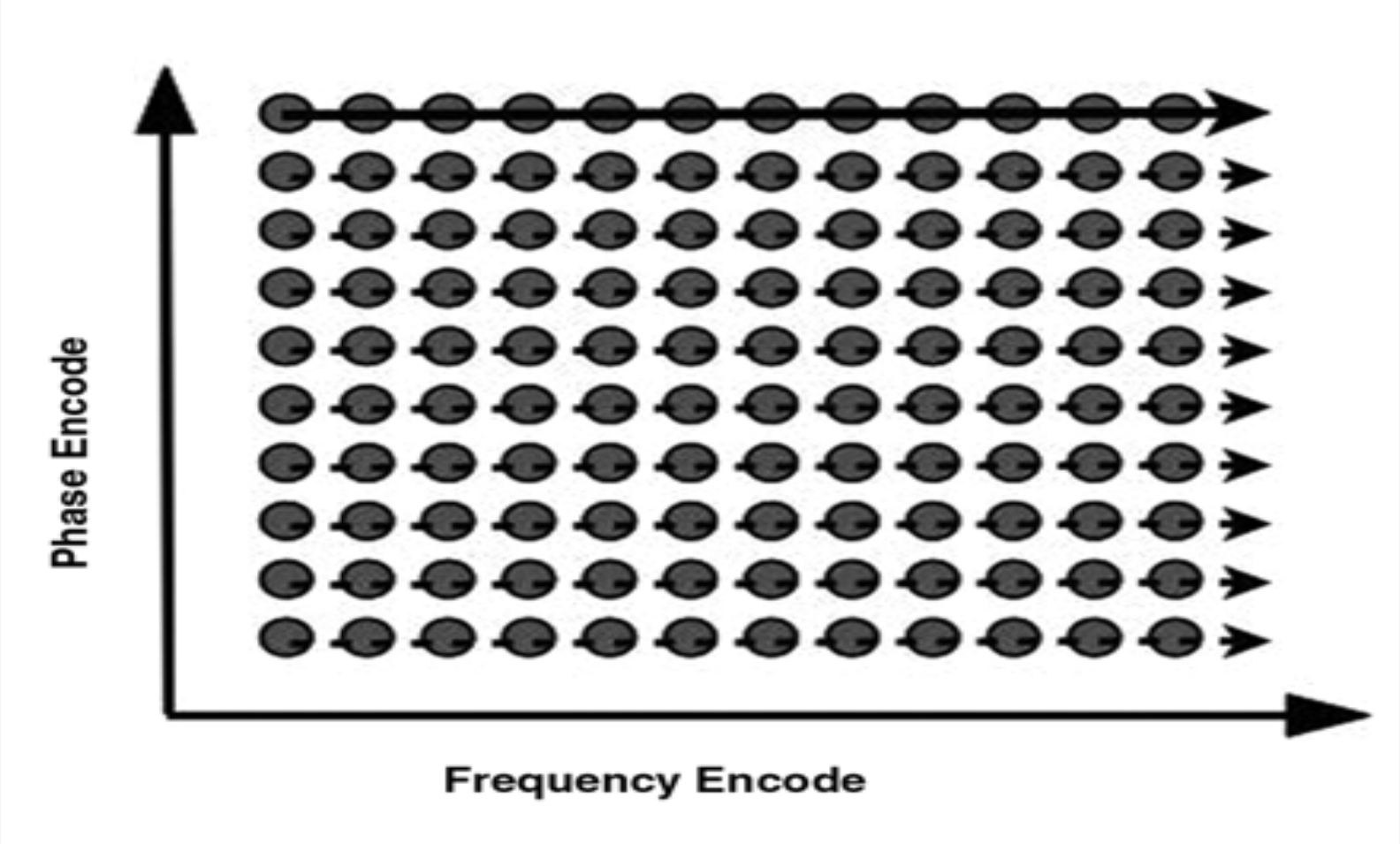
Slice selection (G_{sliice})

Phase encoding (G_{phase})

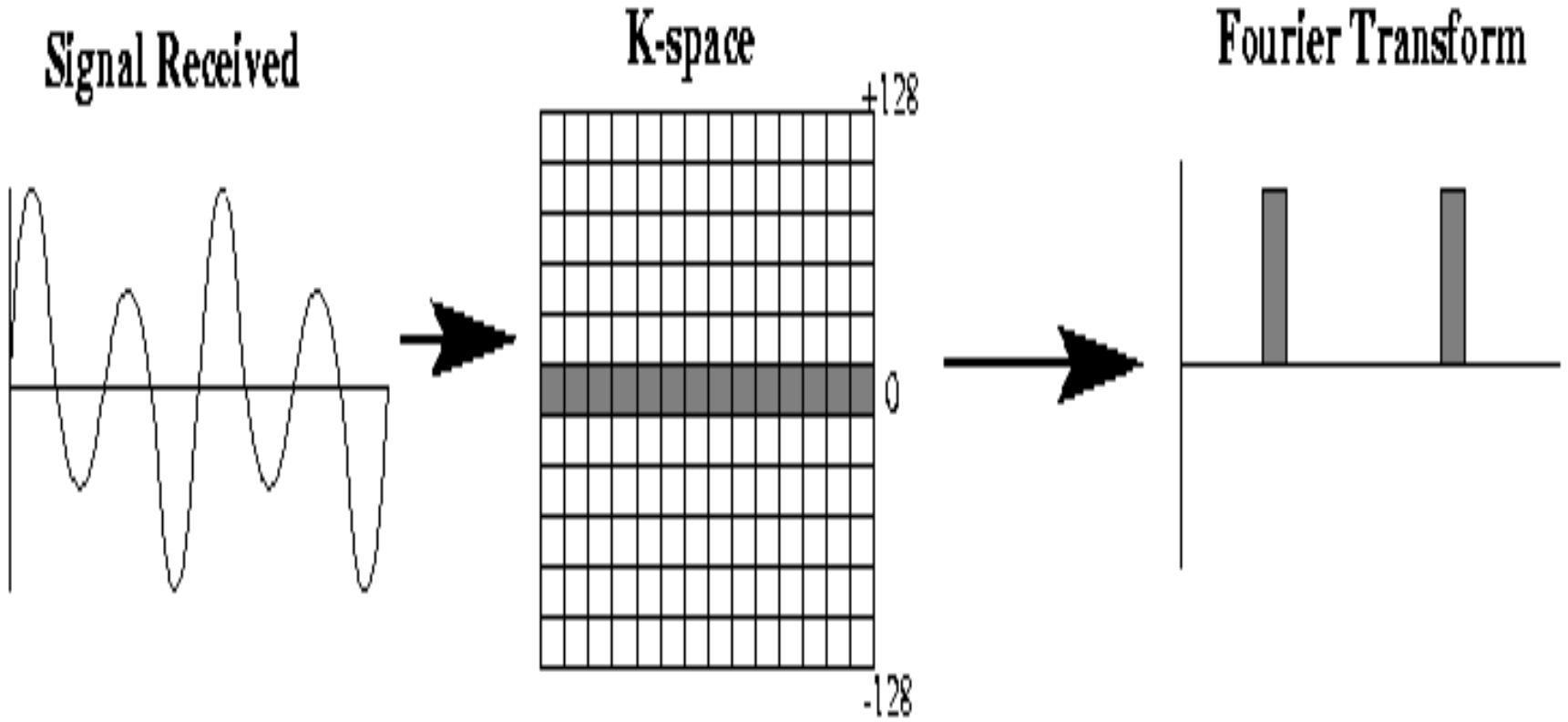
Frequency encoding (G_{freq})

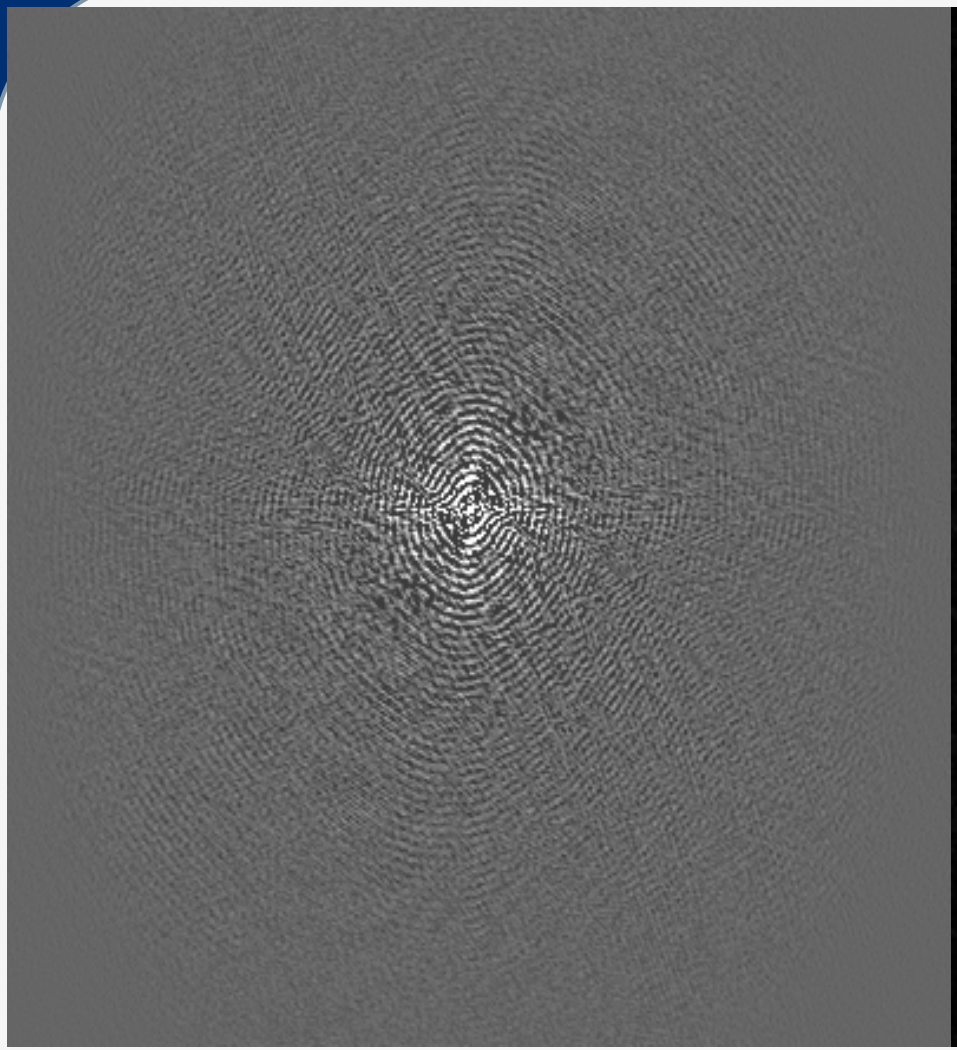
Echo to ADC

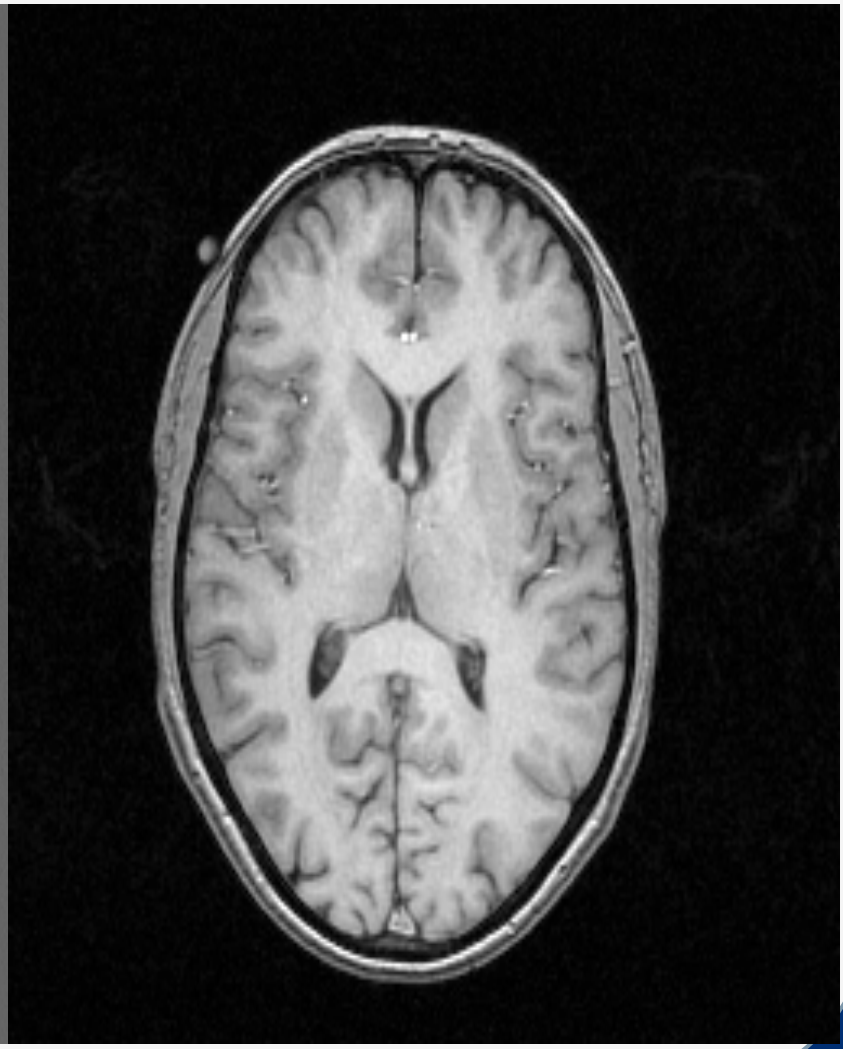




Samples in k-space

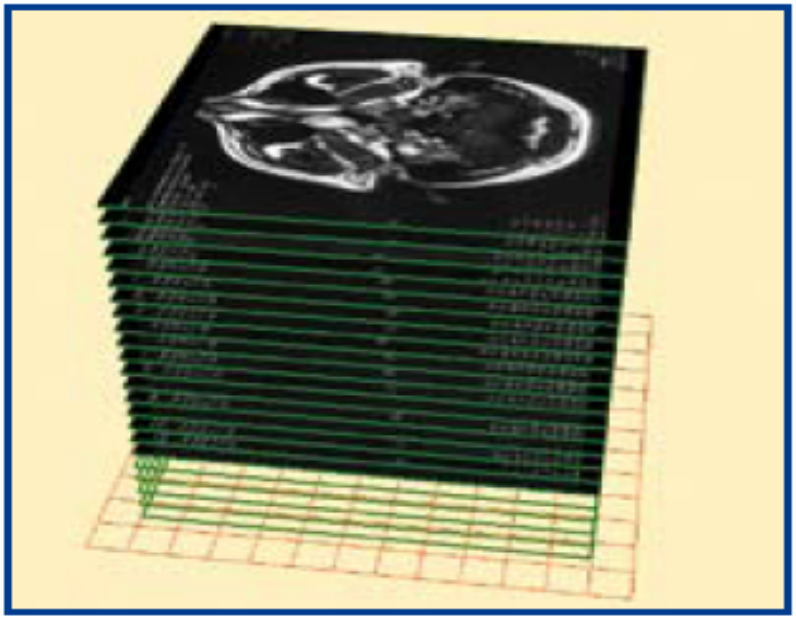

Signal Received
K-space
Fourier Transform
+128
0
-128



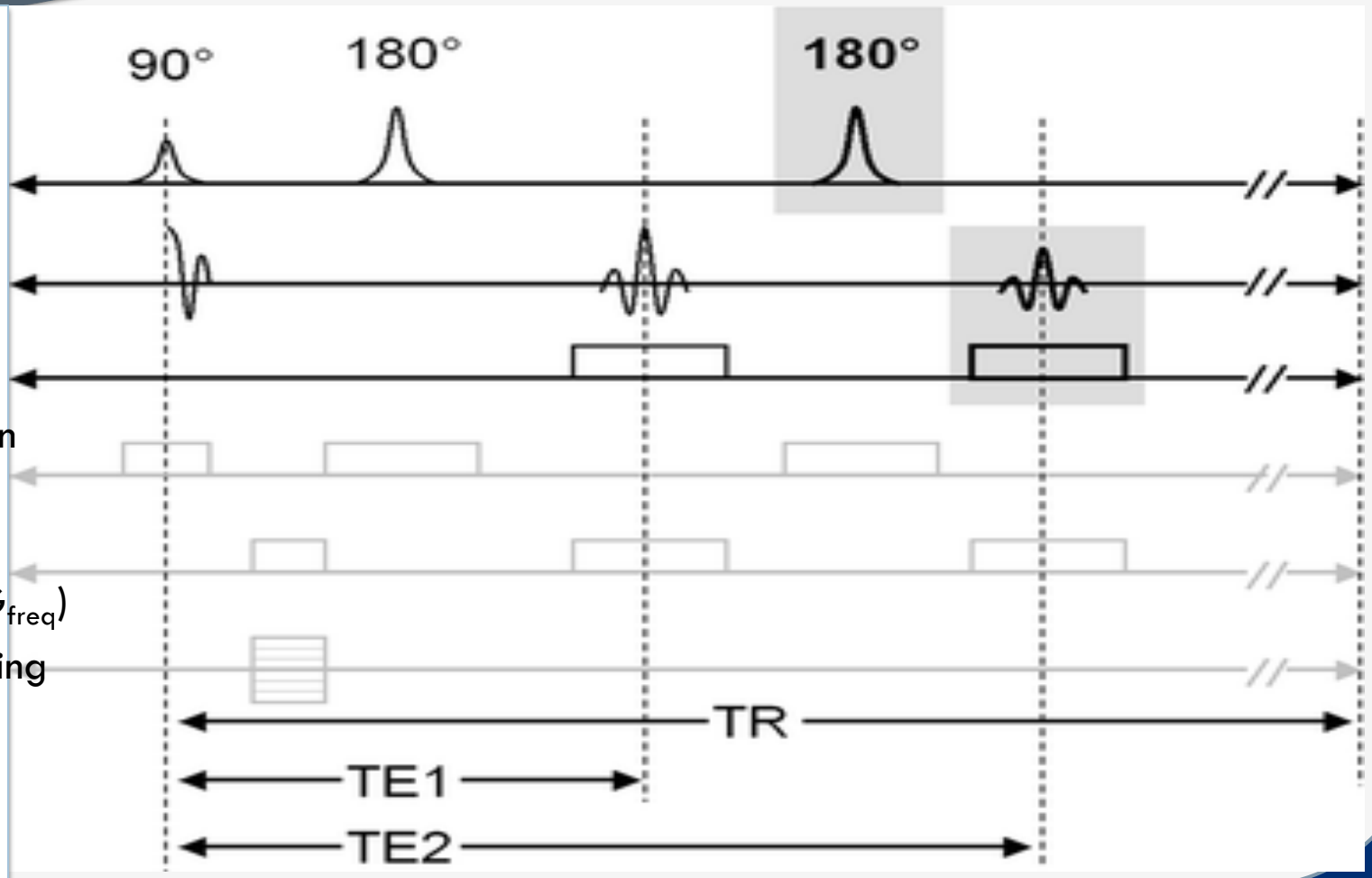


7.2 • 3 D MRI

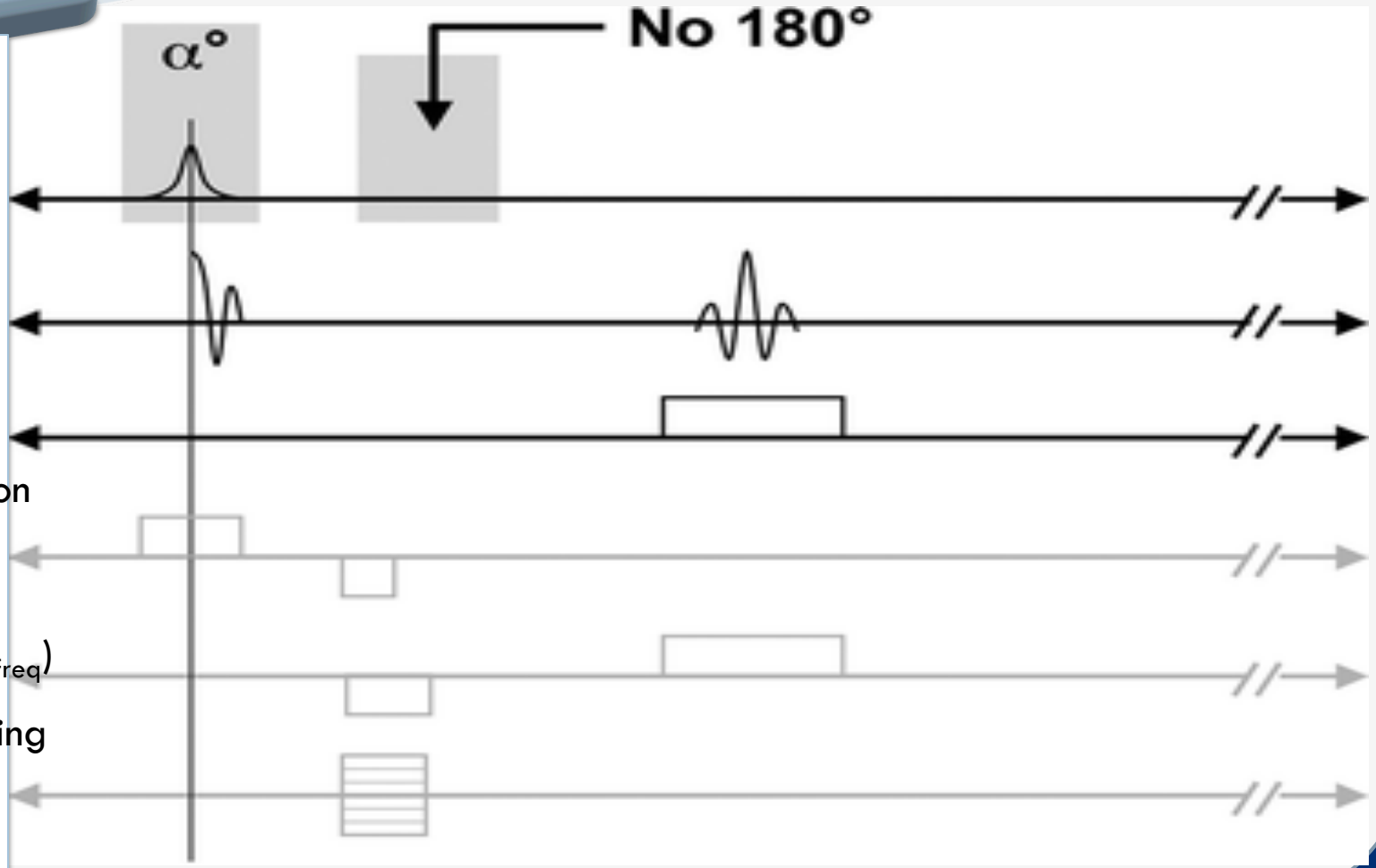
- Multi slice imaging- where different frequencies are used



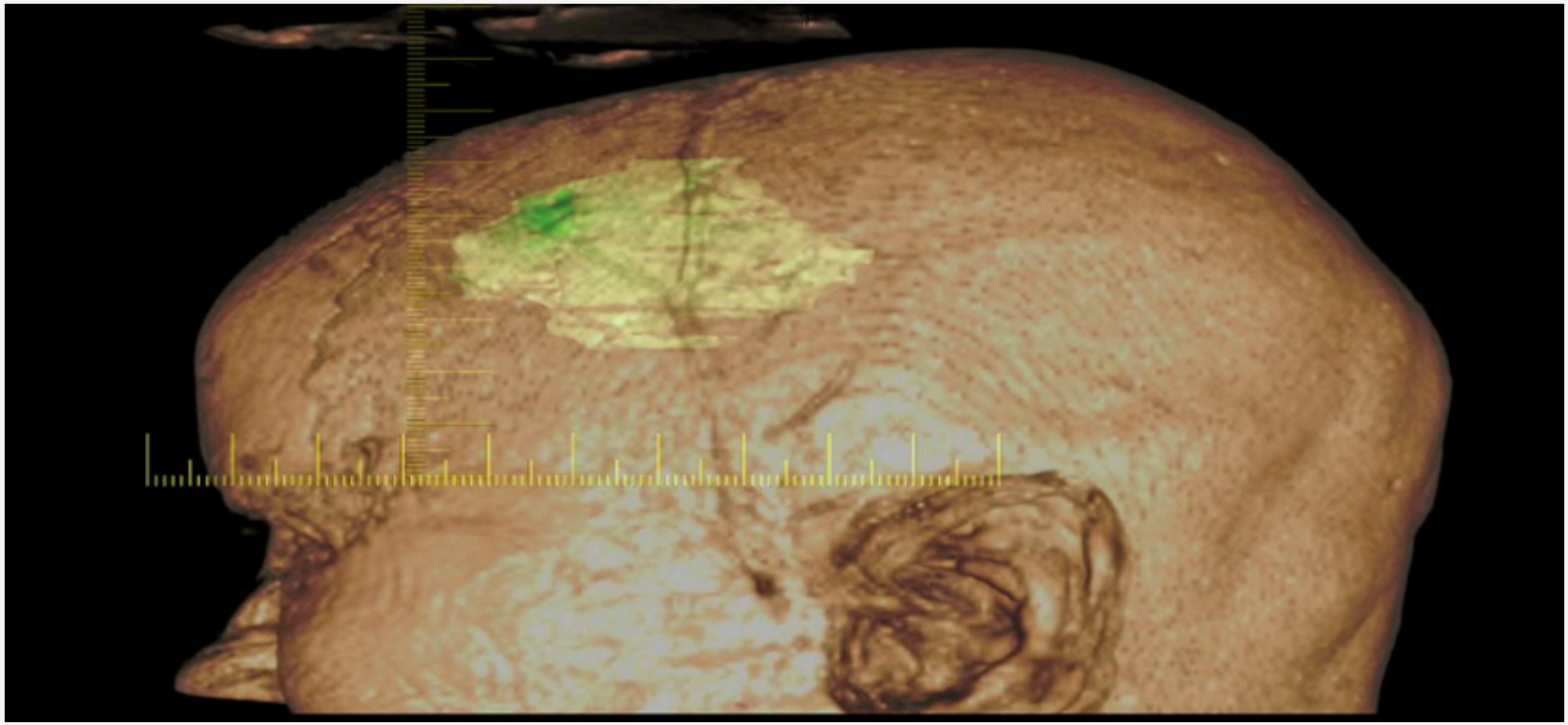
7.2.1 Spin-echo sequence



7.2.2 Gradient-echo sequence



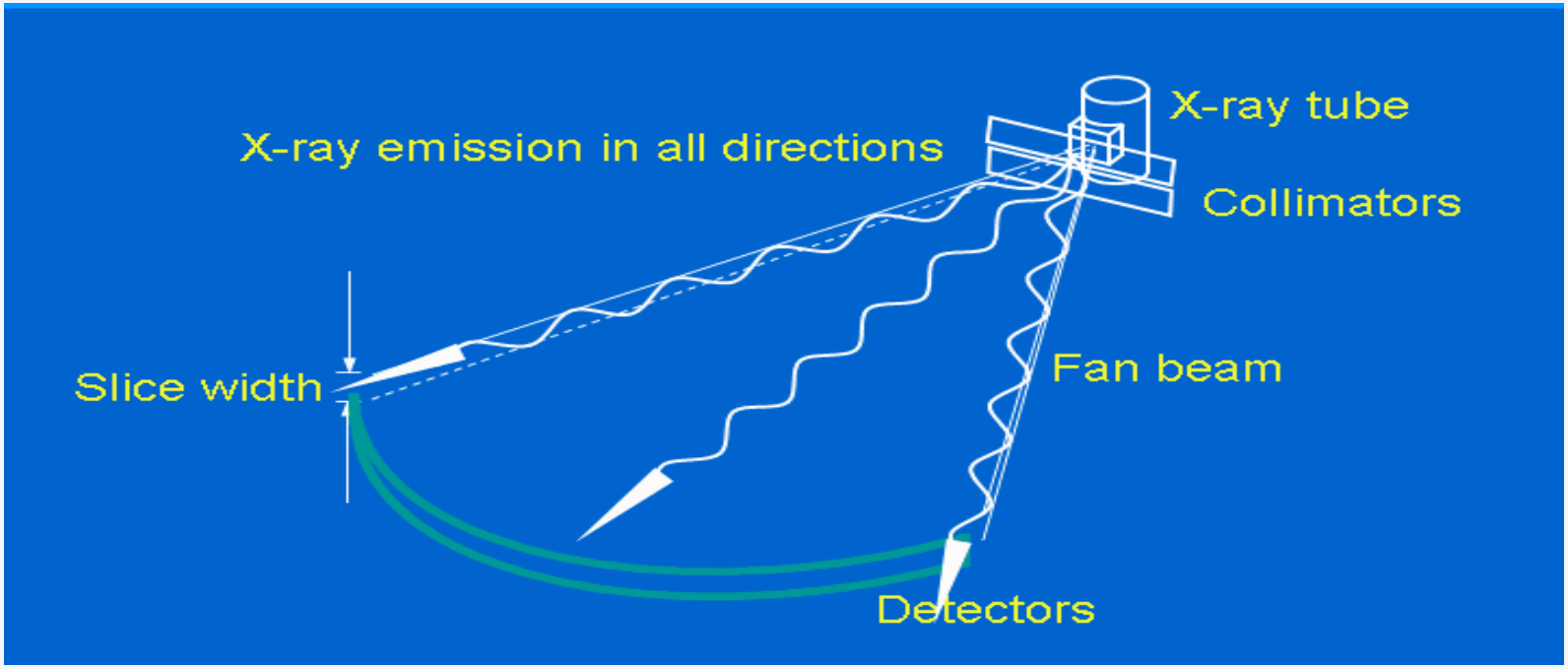
7.3 3 D Model for neurosurgery



- Helps in planning the surgery
- Image Guidance

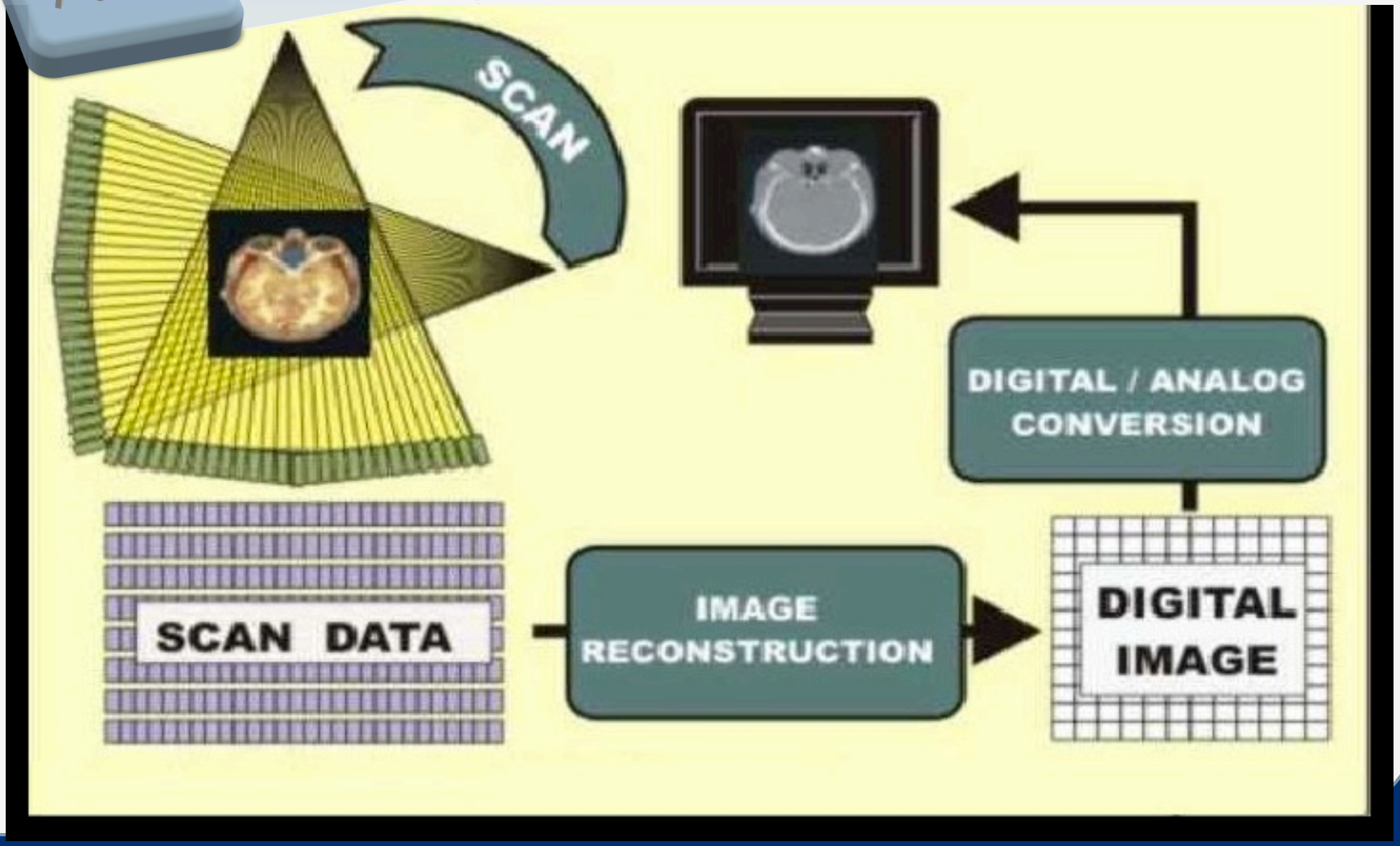
7.4 CT Basics

Source of ionizing radiation → Object of interest → Recording apparatus



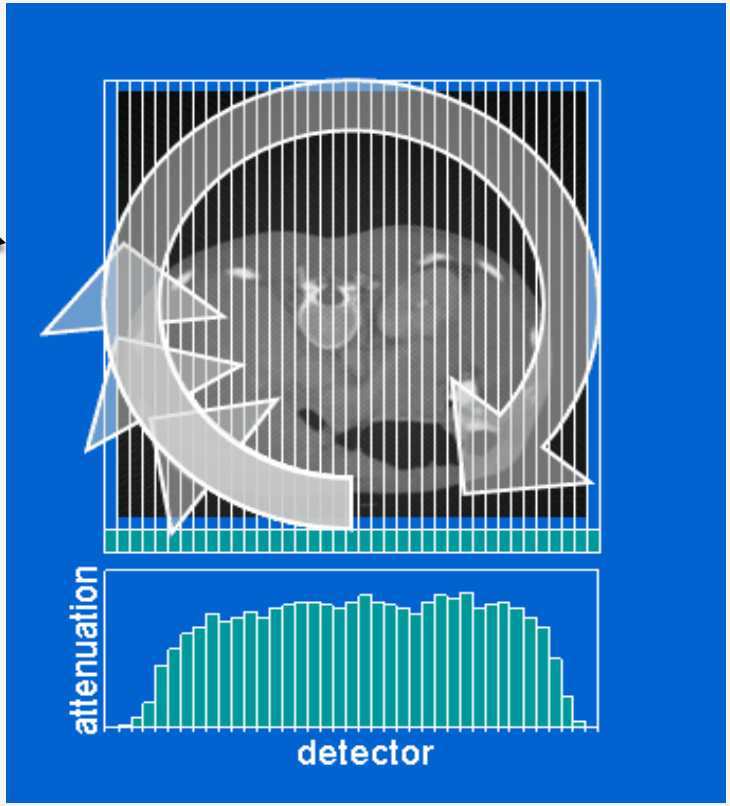
- $I = I_o e^{-\mu x}$
- I=transmitted intensity of X-ray
- I_o=incident beam of X-ray on the surface
- x=thickness of the object
- e=Euler's constant(2.718)
- μ= linear attenuation coefficient

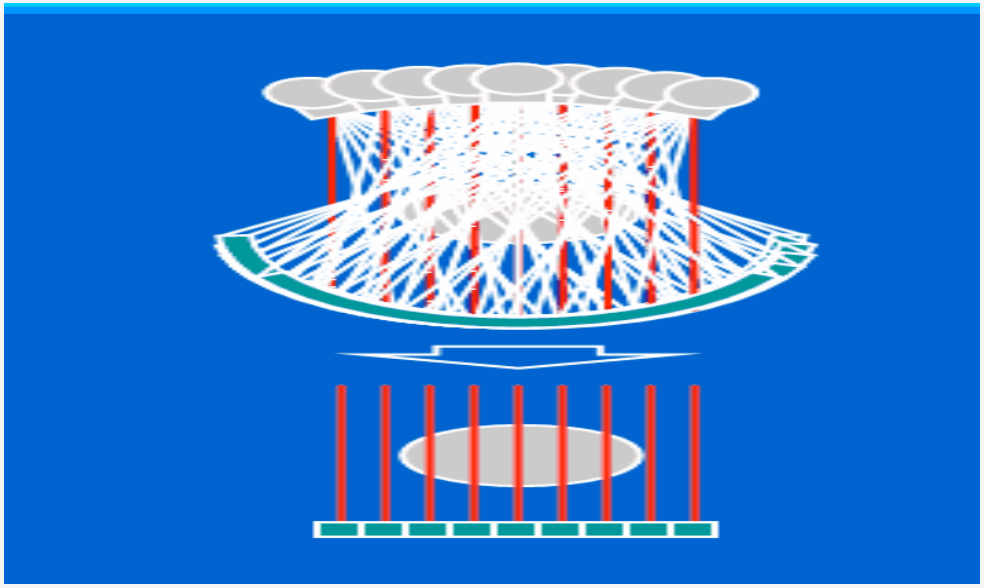
7.4.1 - 3 step process of CT

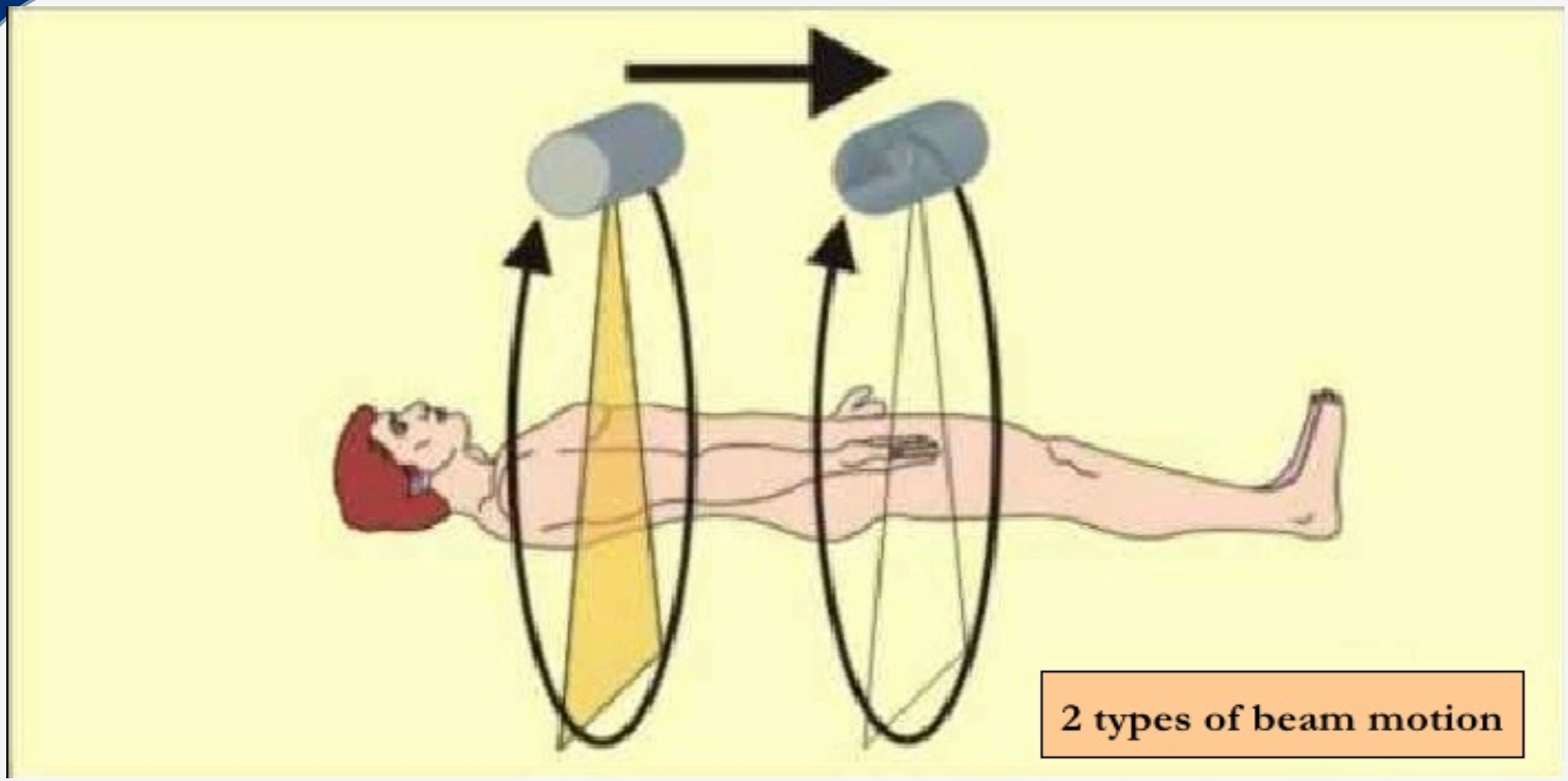


7.4.2 • Scanning

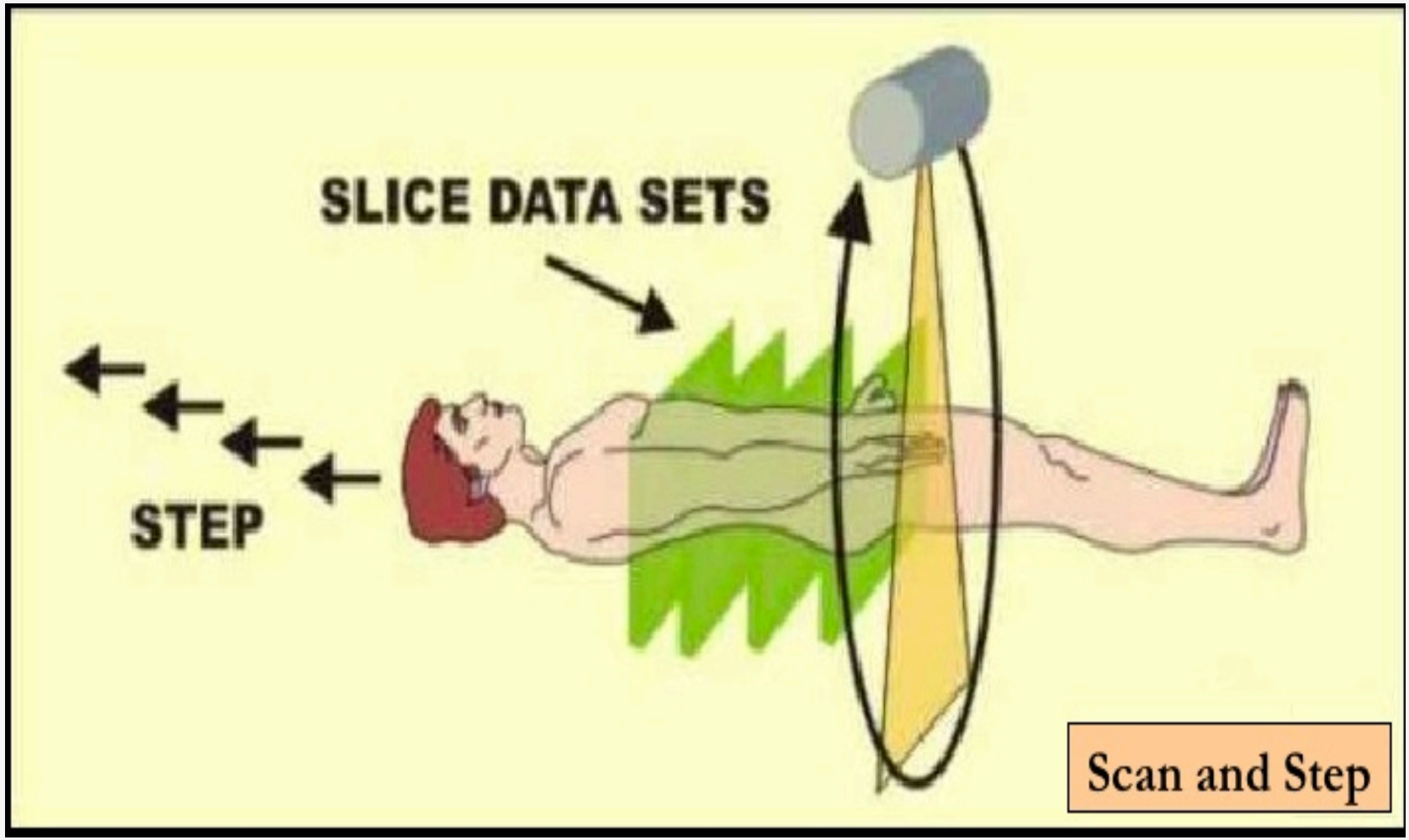
- 2 D image-Projections at angles all around the patient
- Different generation

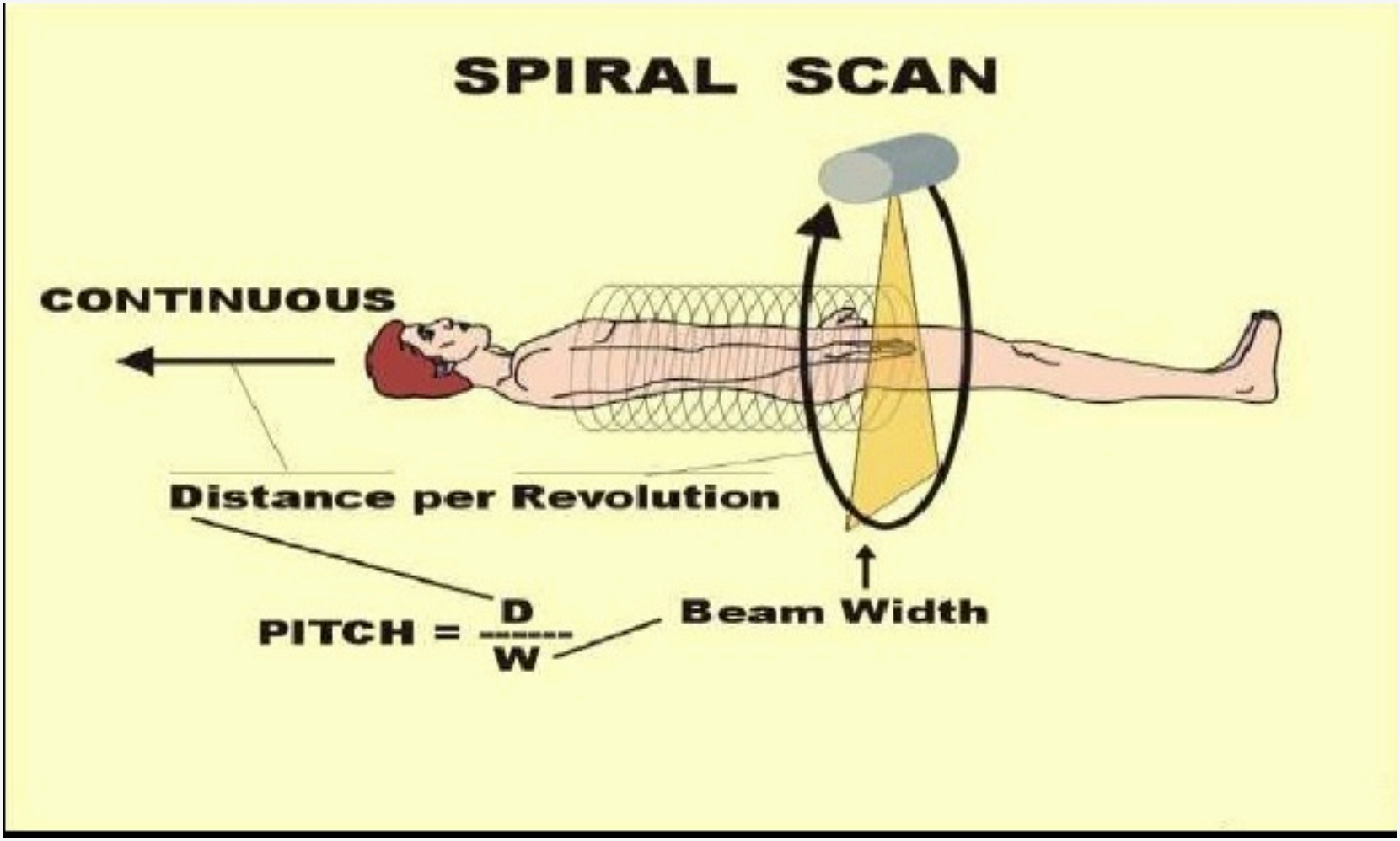




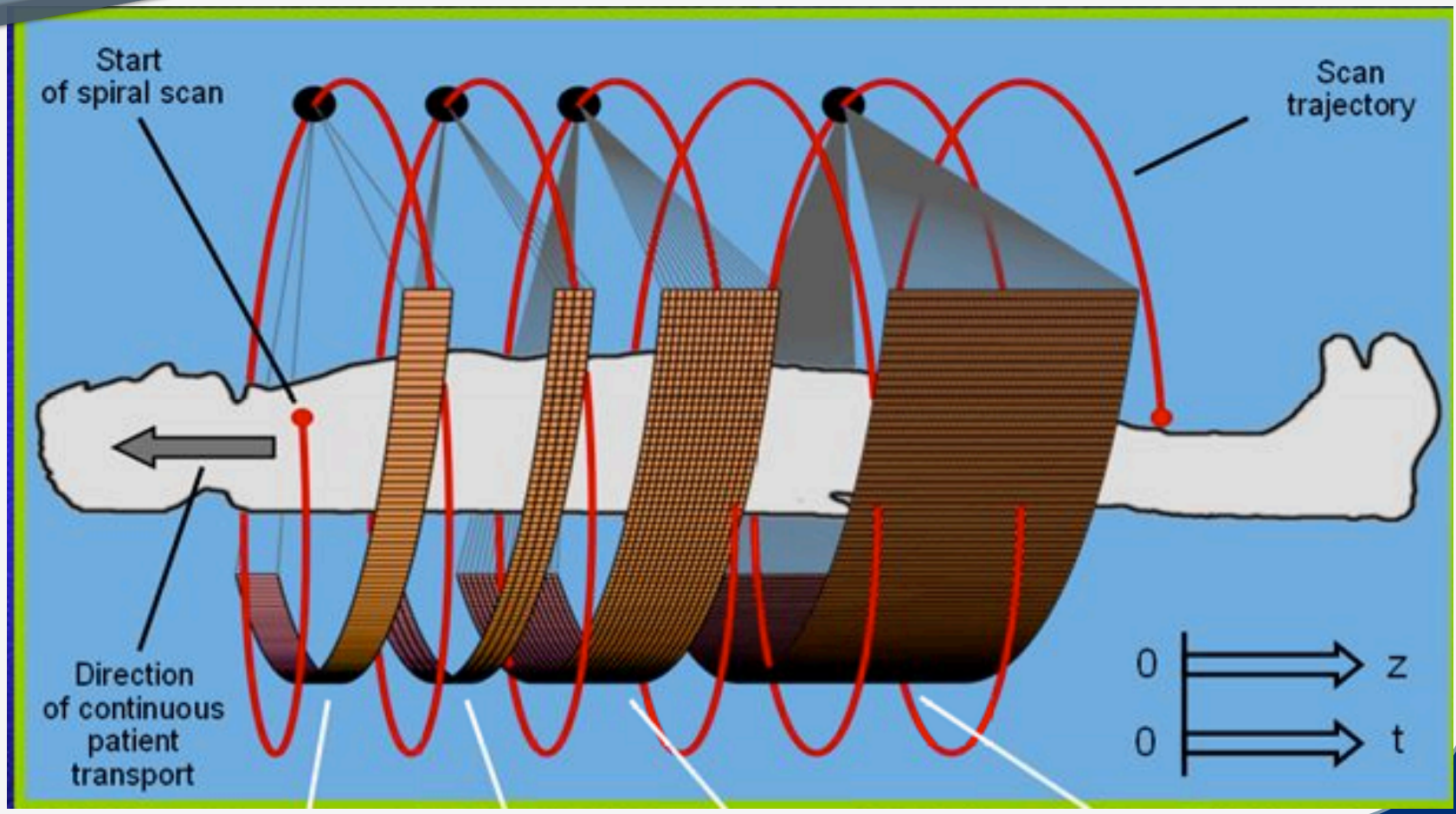


- 1)Around the body
- 2) Along the length of the body

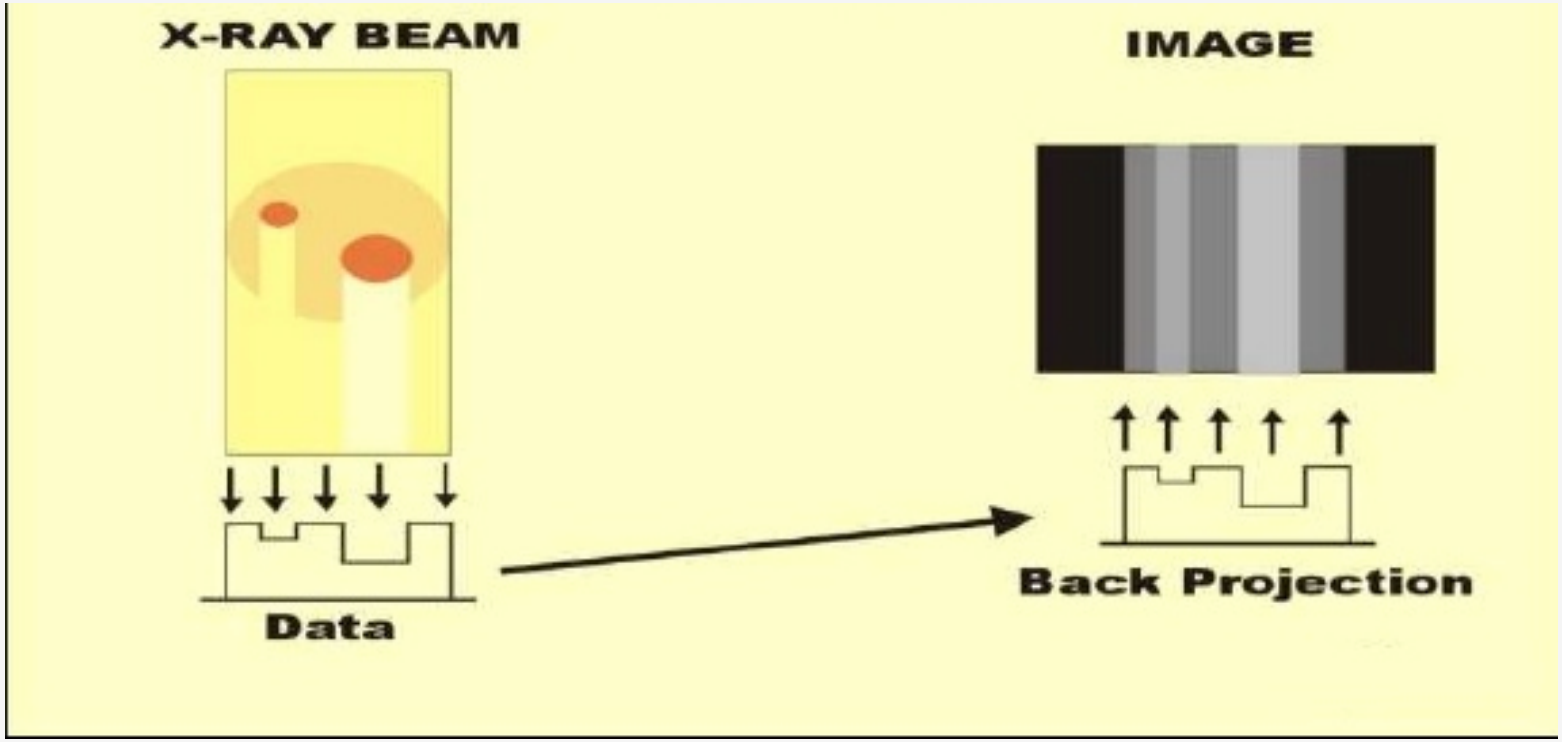

SLICE DATA SETS
STEP
Scan and Step


SPIRAL SCAN
CONTINUOUS
Distance per Revolution
PITCH = D / W
Beam Width

7.4.3 Multislice spiral CT (for 3-D CT)



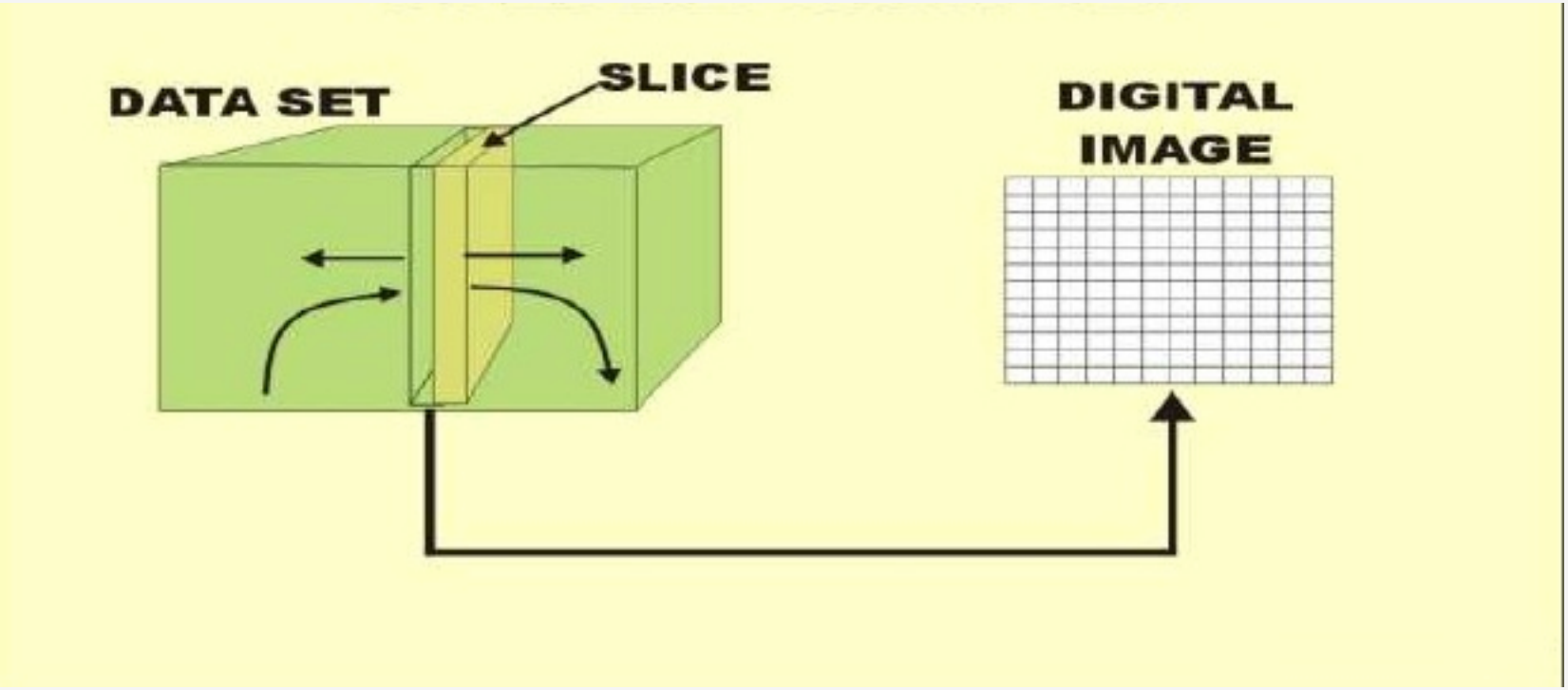
7.4.4 Reconstruction



- X-ray linear attenutation coefficient is first calculated by reconstruction process and then used to calculate the CT number (Hounsfield units) ie. an image pixel
- Water is the reference and its CT number is zero

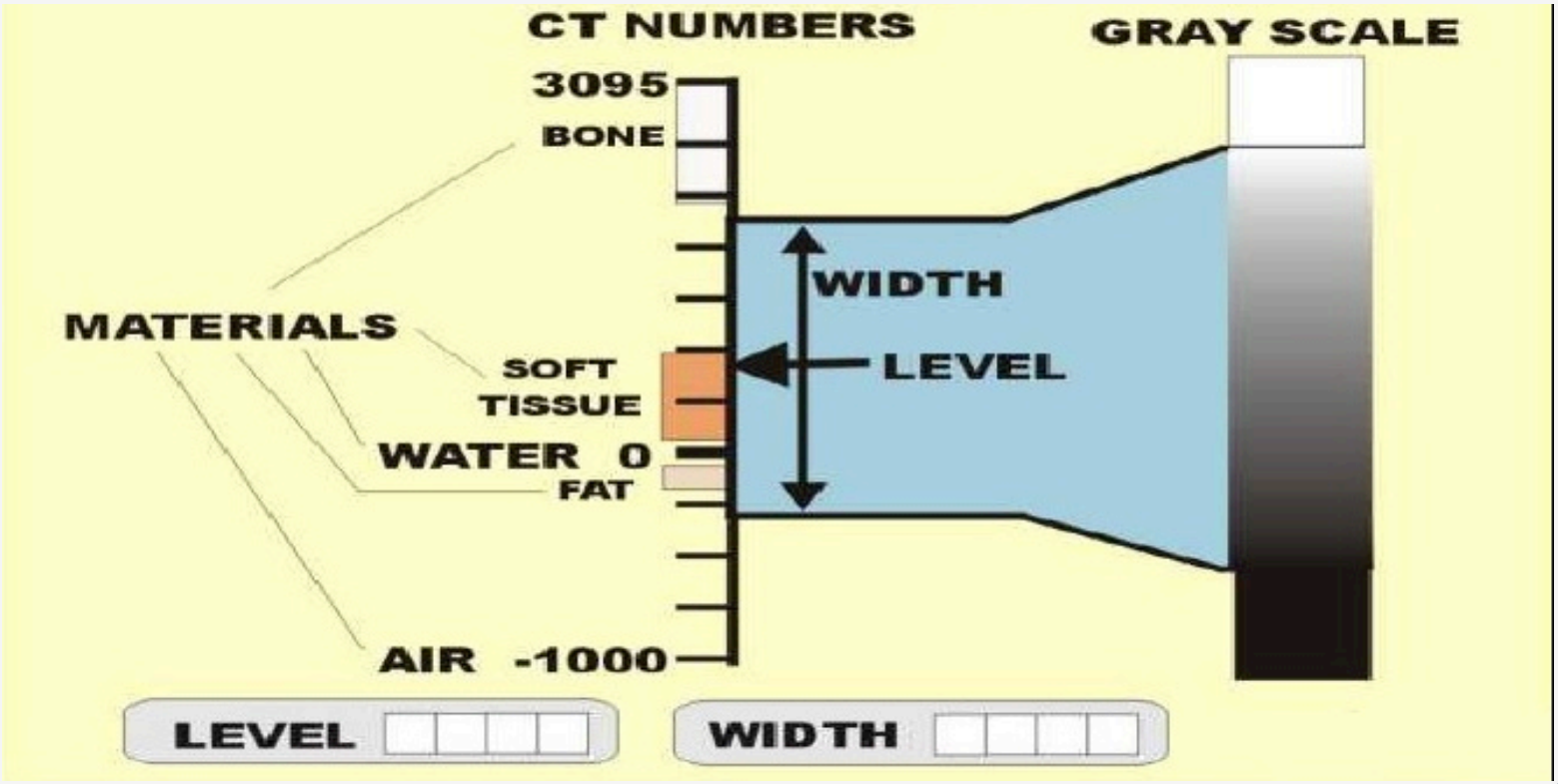
$$\text{CT number} = \frac{\mu_{tissue} - \mu_{water}}{\mu_{water}} \times 1000$$

- Volume data set can be used to reconstruct 3-D images

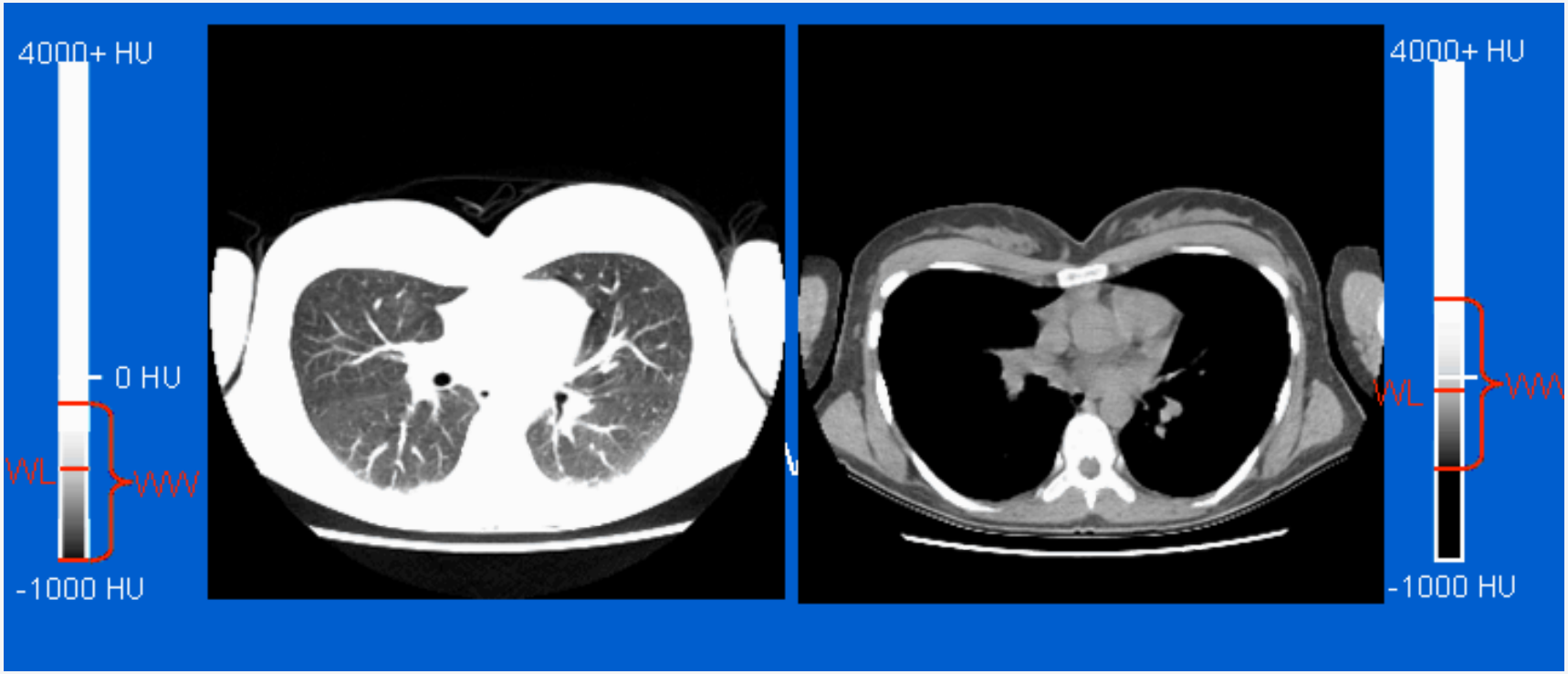


7.4.5 • Display

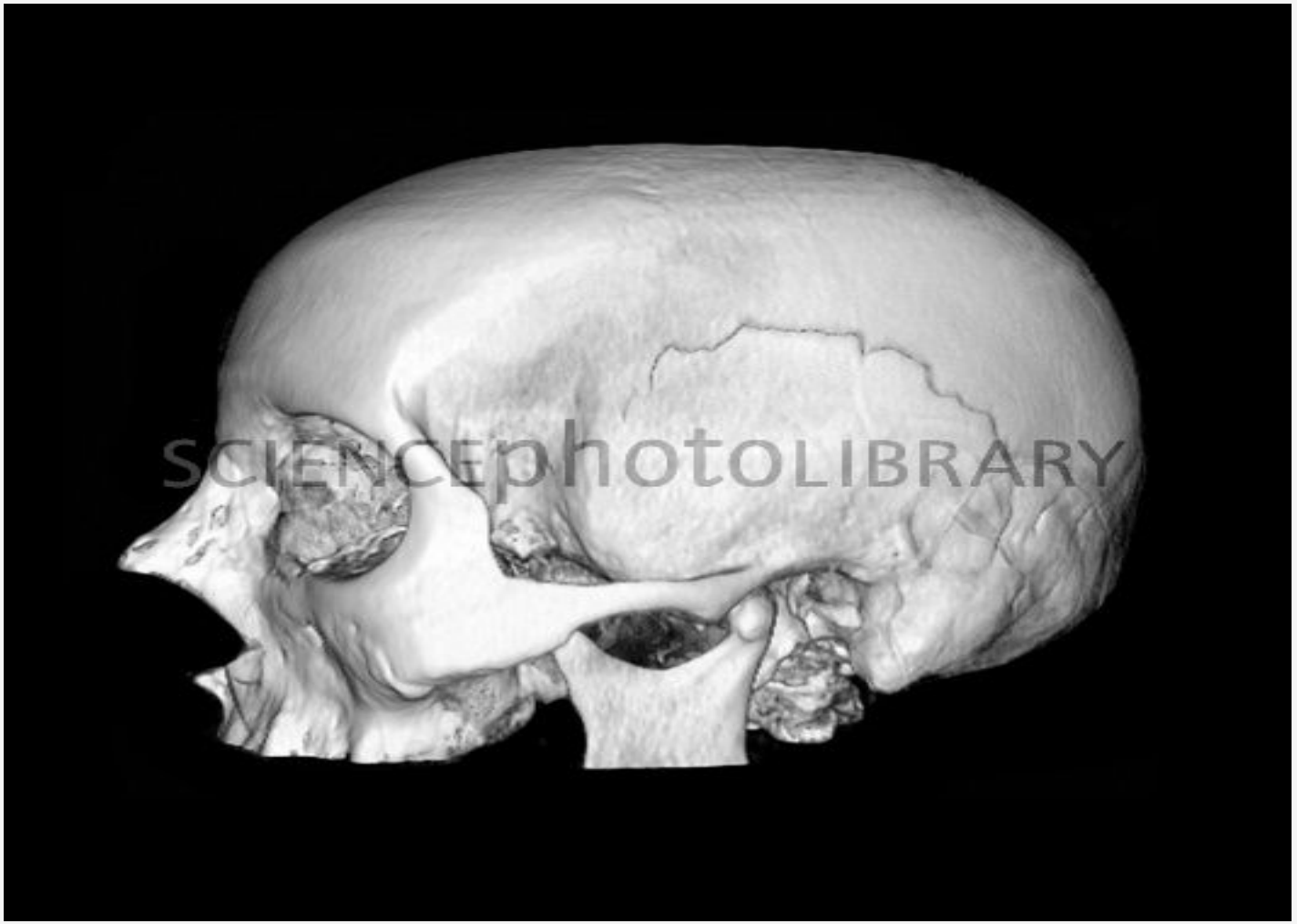
- Display is defined using Window Level (WL) and Window Width(WW)



- Same image data at different WL and WW



3 D CT image



7.5 3 D CT in neorosurgery

Spiral CT angiography yield enough topographical information for the accurate planning of stereotactic surgery for brain lesions.

7.6 3 D CT vs 3 D MRI

	CT	MRI
Application	Suited for bone injuries, Lung and Chest imaging, cancer detection.	Suited for Soft tissue evaluation, e.g. ligament and tendon injury, spinal cord injury, brain tumors
3D	With capability of MDCT, isotropic imaging is possible. After helical scan with Multiplanar Reformation function, an operator can construct any plane.	MRI machines can produce images in any plane. Plus, 3D isotropic imaging can also produce Multiplanar Reformation.
Image	Good details about bony structures but less tissue contrast	Good tissue contrast for soft tissues

THANK YOU