Remote Sensing

APPLICATION OF PHYSICS

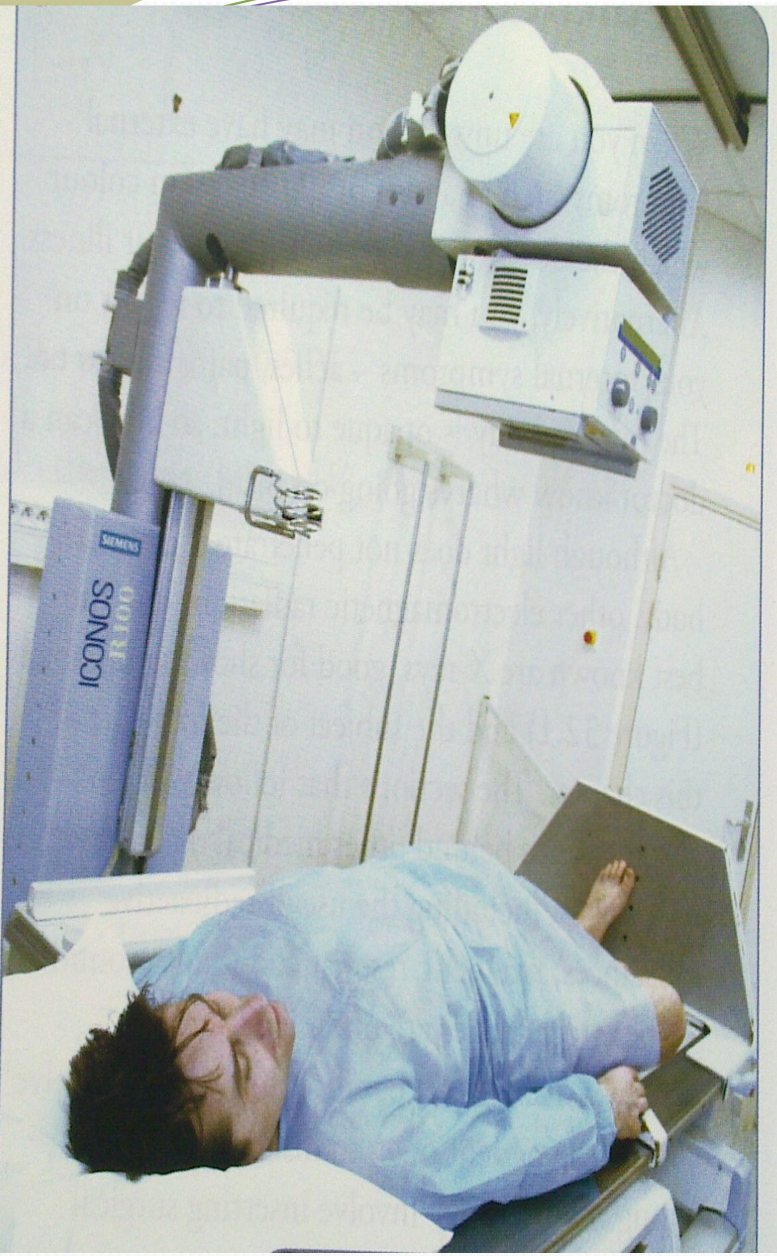
A-Level

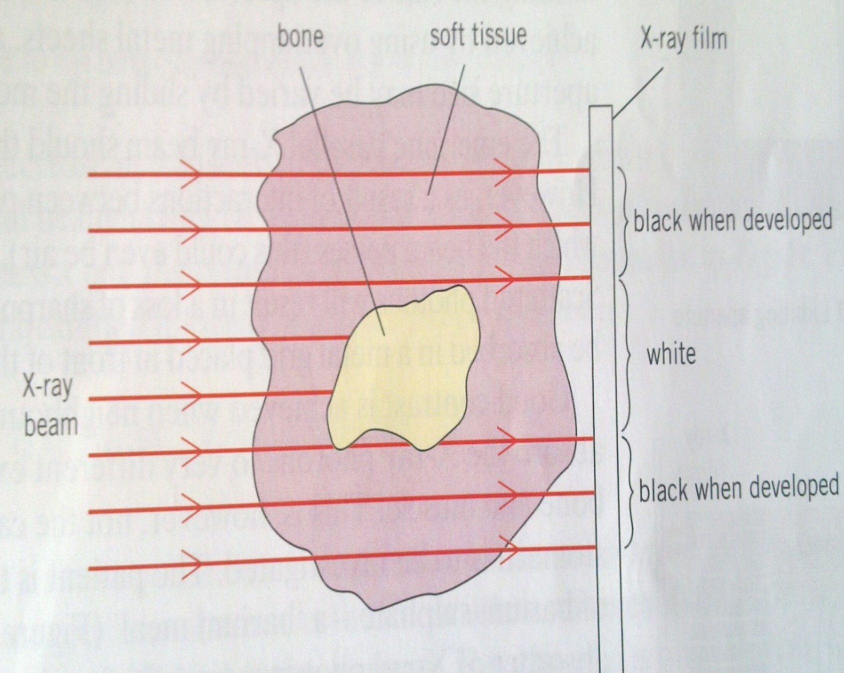
NON-INVASIVE Technique

- Invasive Technique involves direct contact
- For example, Surgery that involves risk of infection and trauma of pain

- Non-invasive Technique does not involve direct contact for investigation
- Do not involve cutting the patient open to discover what is wrong inside the body.
- For example,use of X-rays, radioactive substances,magnetic resonance, ultrasound etc.

X-Rays

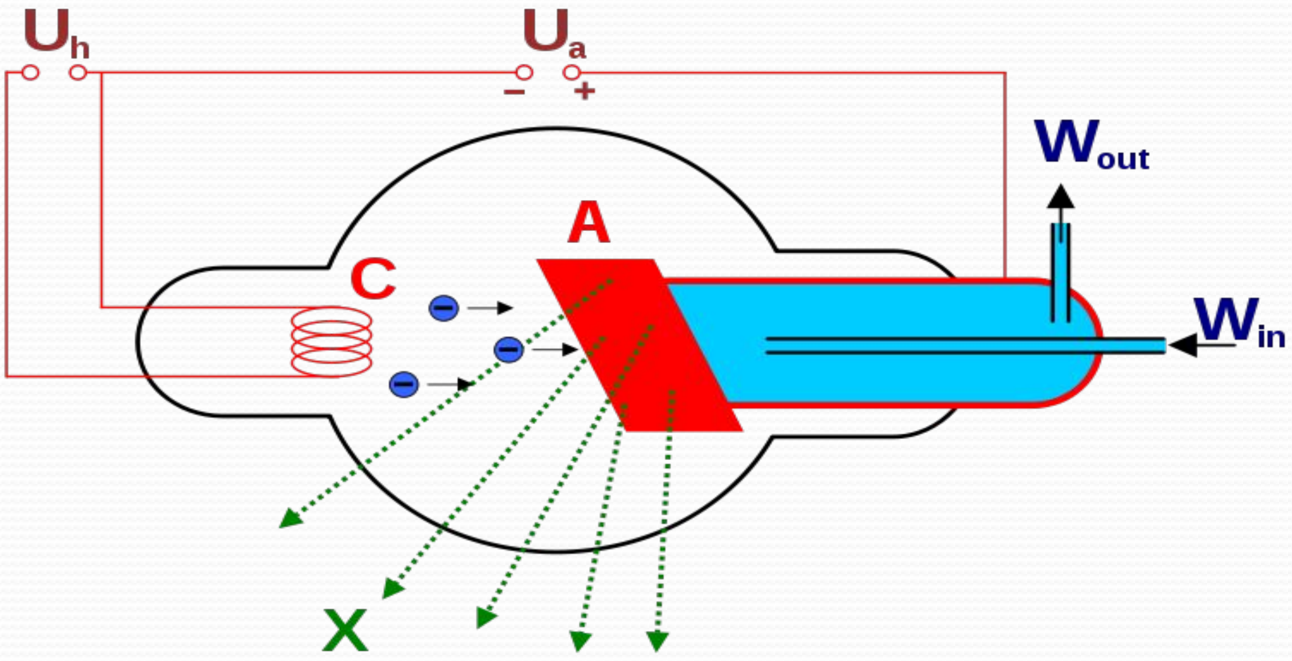

SIEMENS
ICONOS R100


bone
soft tissue
X-ray film
black when developed
white
black when developed
X-ray beam

Production of X-rays(1)

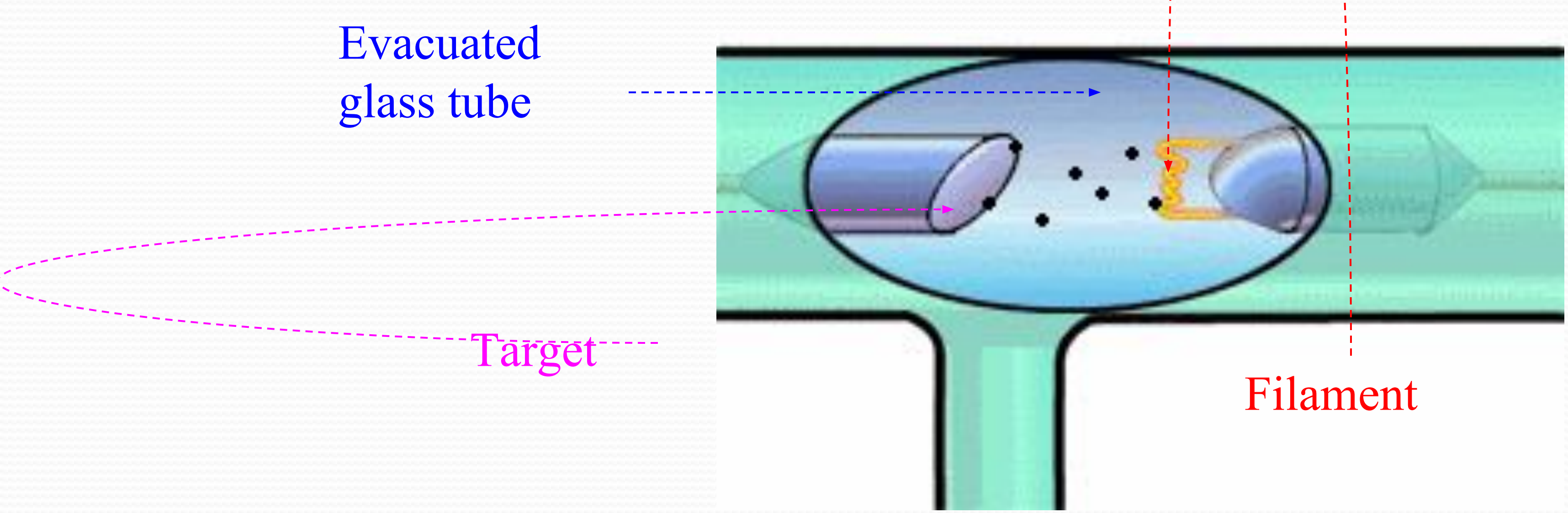
The X-ray tube **requires:**

- electron source
- electron acceleration potential
- target for X-ray production



Production of X-rays (2)

- X-rays are produced when rapidly moving electrons that have been accelerated through a potential difference of order 1 kV to 1 MV strikes a metal target.



Production of X-rays(3)

- Electrons from a hot element are accelerated onto a target anode.
- When the electrons are suddenly decelerated on impact, some of the kinetic energy is converted into EM energy, as X-rays.
- Less than 1 % of the energy supplied is converted into X-radiation during this process. The rest is converted into the internal energy of the target.

Control of X-rays

- Intensity of X-ray - Power per unit area
  is controlled by the no. of electrons reaching @metal target,i.e.,tube current.Tube current,in turn, is controlled by heater current.
- Hardness of X-ray – having higher photon energy…
  is controlled by the accelerating Voltage.

Intensity Vs.Accelerating Voltage

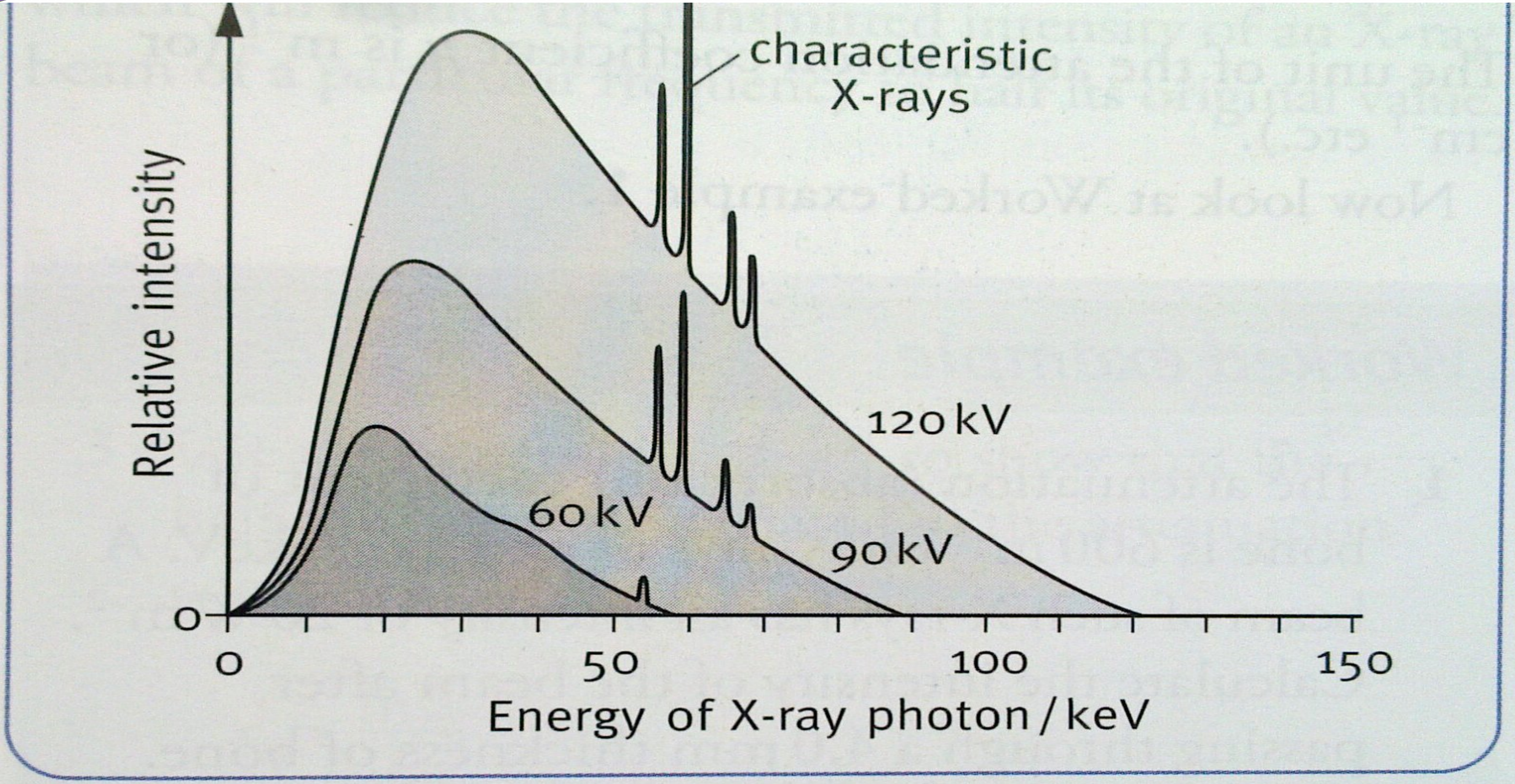


Figure 32.5 X-ray spectra for a tungsten target with accelerating voltages of 60 kV, 90 kV and 120 kV. The continuous curve shows the braking radiation while the sharp spikes are the characteristic X-rays.

X-ray Spectra

- The graph shows the following features.
  - A continuous background of X-radiation in which the intensity varies smoothly with wavelength. The background intensity reaches a maximum value as the wavelength increases, then the intensity falls at greater wavelengths.
  - Minimum wavelength(cut-off w/l) which depends on the tube voltage. The higher the voltage the smaller the value of the minimum wavelength.
  - Sharp peaks of intensity occur at wavelengths unaffected by change of tube voltage. And are the characteristics of metal targets

Minimum wavelength in the X-ray Spectra

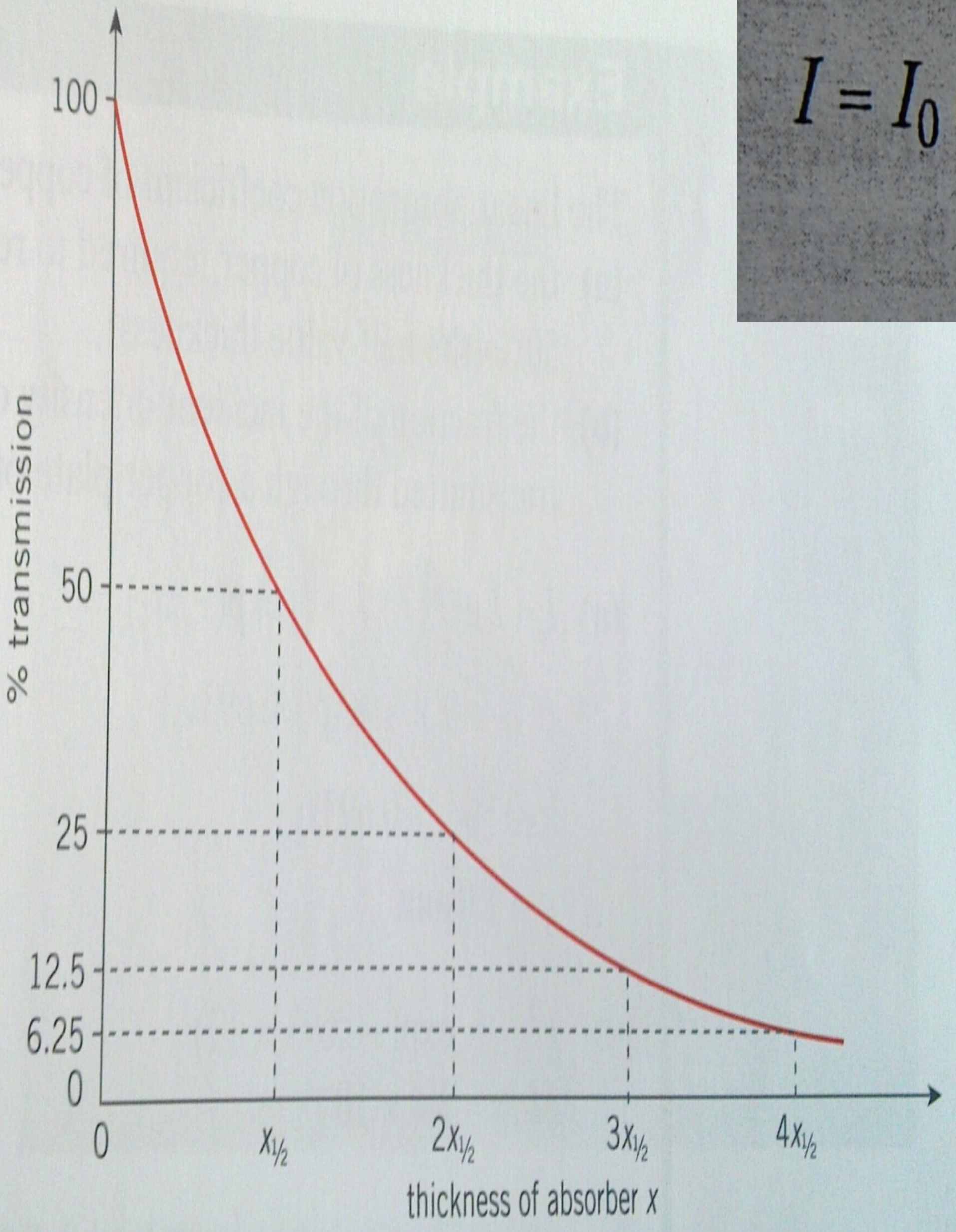
- When an electron hits the target its entire kinetic energy is converted into a photon.
- The work done on each electron when it is accelerated onto the anode is eV.
- Hence $hf = eV$ and the maximum frequency

$$f_{\max} = \frac{eV}{h}$$

Therefore,

$$\lambda_{\min} = \frac{hc}{eV}$$

Attenuation of X-rays



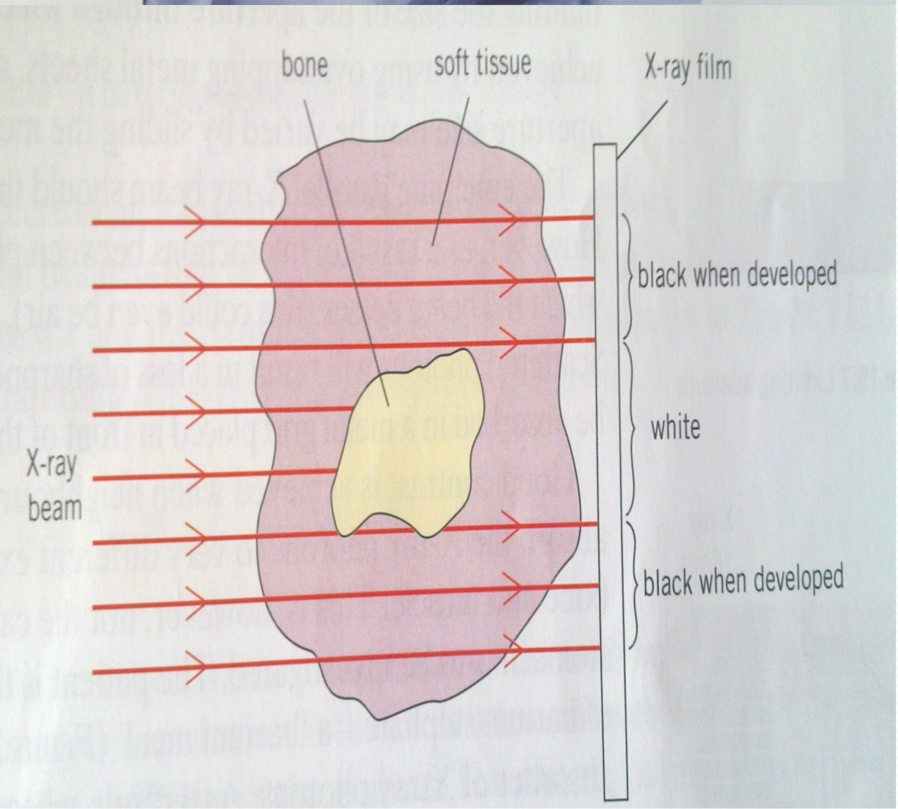
$$I = I_0 e^{-\mu x} \quad \text{or} \quad I = I_0 \exp(-\mu x)$$

$$\ln 2 = \mu x_{\frac{1}{2}}$$

substance	μ/cm^{-1}
copper	7
water	0.3
bone	3
fat	0.9

X-ray Image: What is this?

- Really NOT an image produced by a lens
- It is a *2D* "*SHADOW*" of the bone and surrounding tissues.
- X-ray beam penetrates soft tissues(skin,fat,muscles etc.) with little loss of intensity- so photographic film/plate shows dark areas-corresponding to the soft tissues
- Bone causes significant absorption of X-rays - so photographic film will be lighter in color in area corresponding to bones



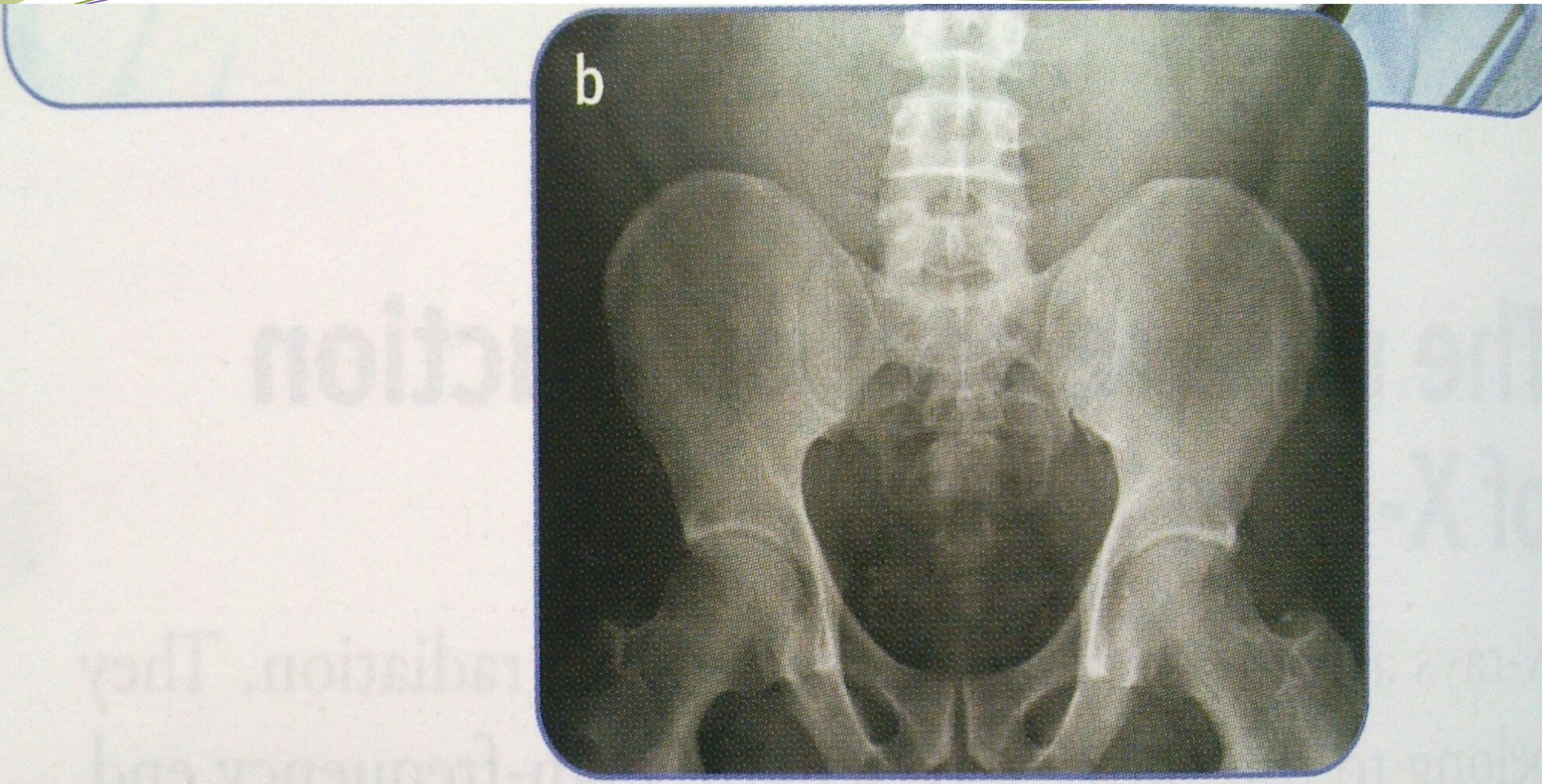


Figure 32.3 **a** A general-purpose X-ray system. **b** A typical X-ray image produced by such a machine, showing the region around the pelvis.

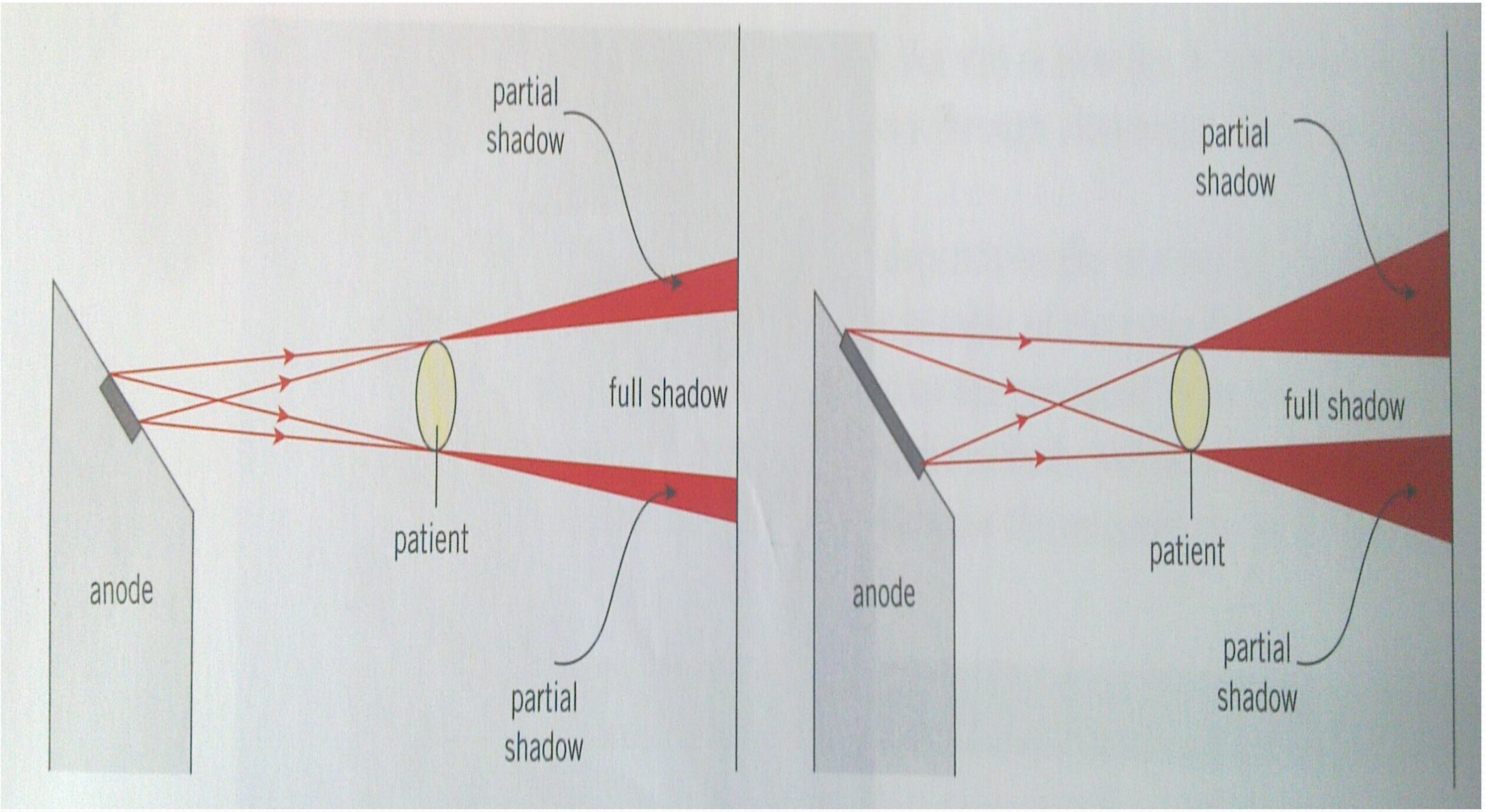
Quality of Shadow Image

- Depends on Sharpness and Contrast
- ***Sharpness*** implies how easy or difficult the edges of structures can be determined.
- **A sharp image** is that image where the bones and other organs are clearly outlined.
- **Contrast** refers to the clear difference in blackening between,say,the bone and the surrounding tissues.
- An X-ray image having a wide range of degrees of blackening is said to have **good Contrast**.

Improving Sharpness (1)

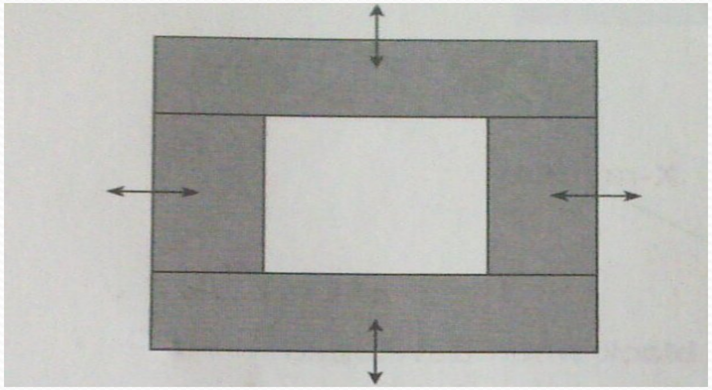
Sharpness requires a parallel X-ray beam.

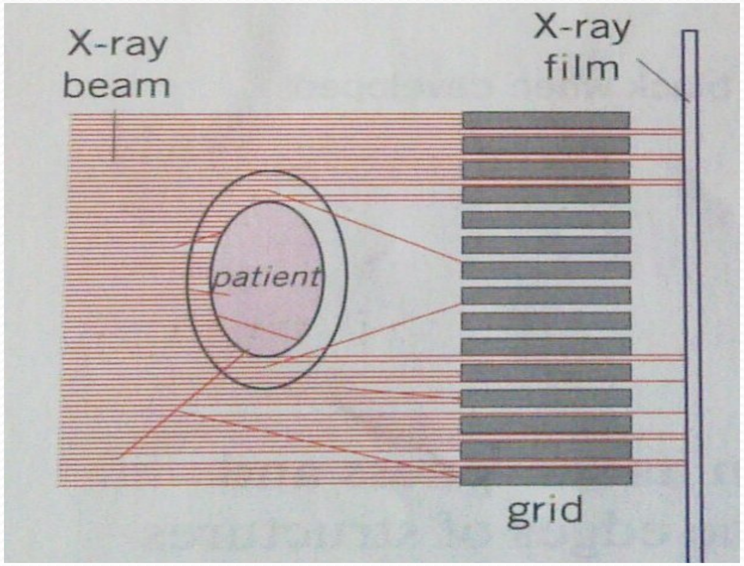
- Reducing the area of the target anode in the X-ray tube



Improving Sharpness(2)

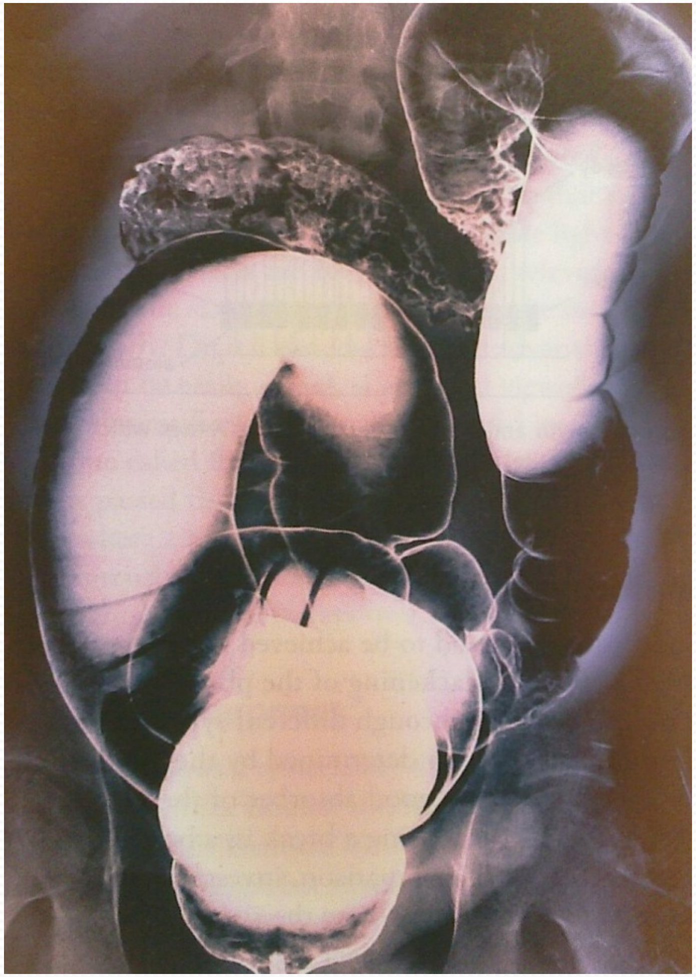
- Limiting the size of aperture, produced by overlapping metals, through which X-ray beam passes
- Reducing the scattering of X-rays using a lead-grid in front of X-ray film.





Improving Contrast

- Based on different level of absorption of X-ray by different tissues/organs
- Desirable to show up different tissues that absorb X-rays equally
- "Contrast medium" –good absorber of X-rays,such as *Iodine,Barrium* may be used.
- "Barium meal"-***Barrium*** *Sulphate* swallowed by patient-good absorber of X-rays, results in clear outline of stomach



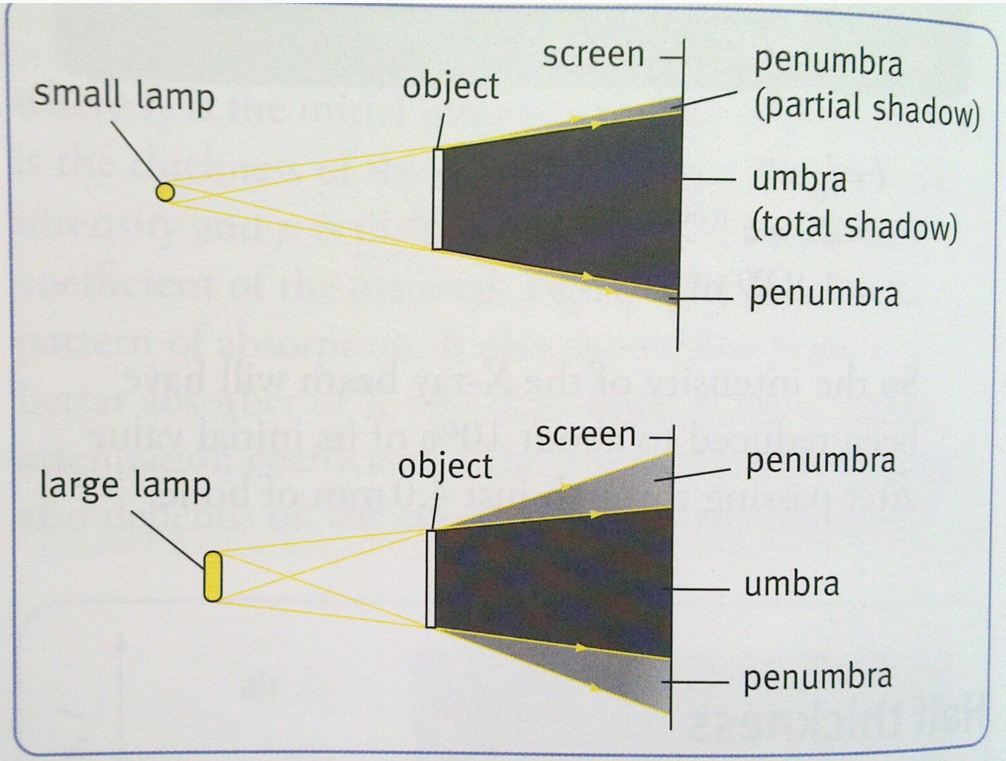


Figure 32.9 The small lamp casts a smaller penumbra and this improves the sharpness of the shadow.

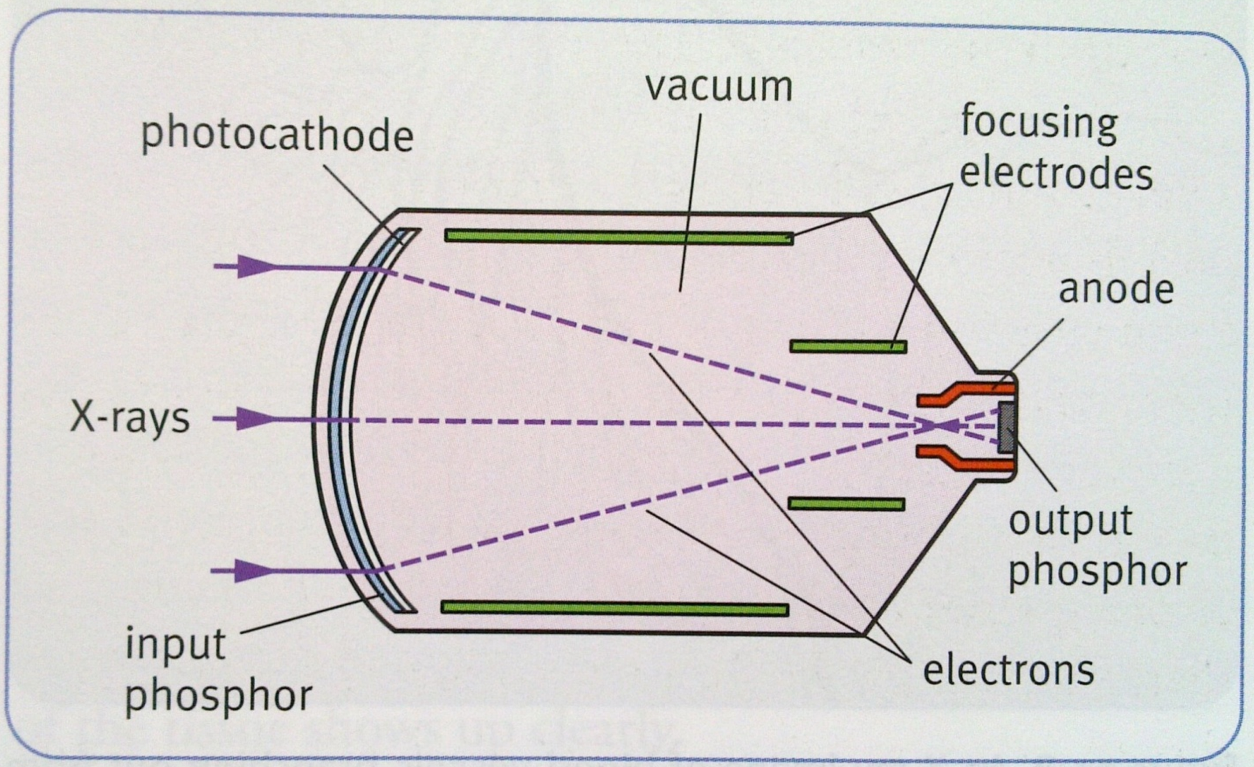


Figure 32.7 An X-ray image intensifier.

Collimating X-ray beam

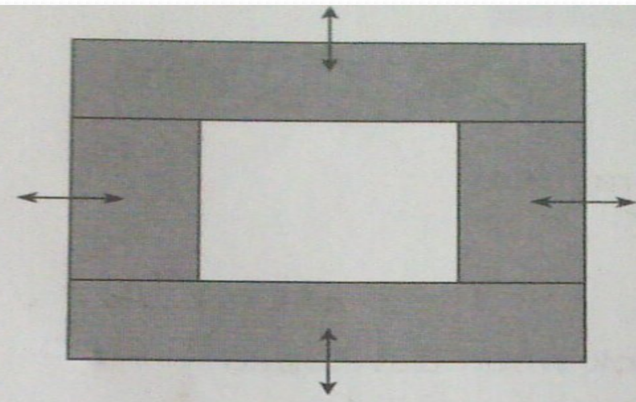
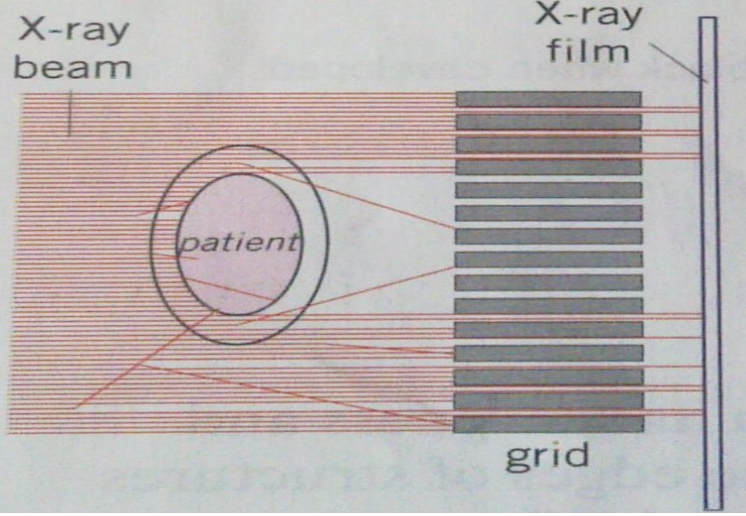
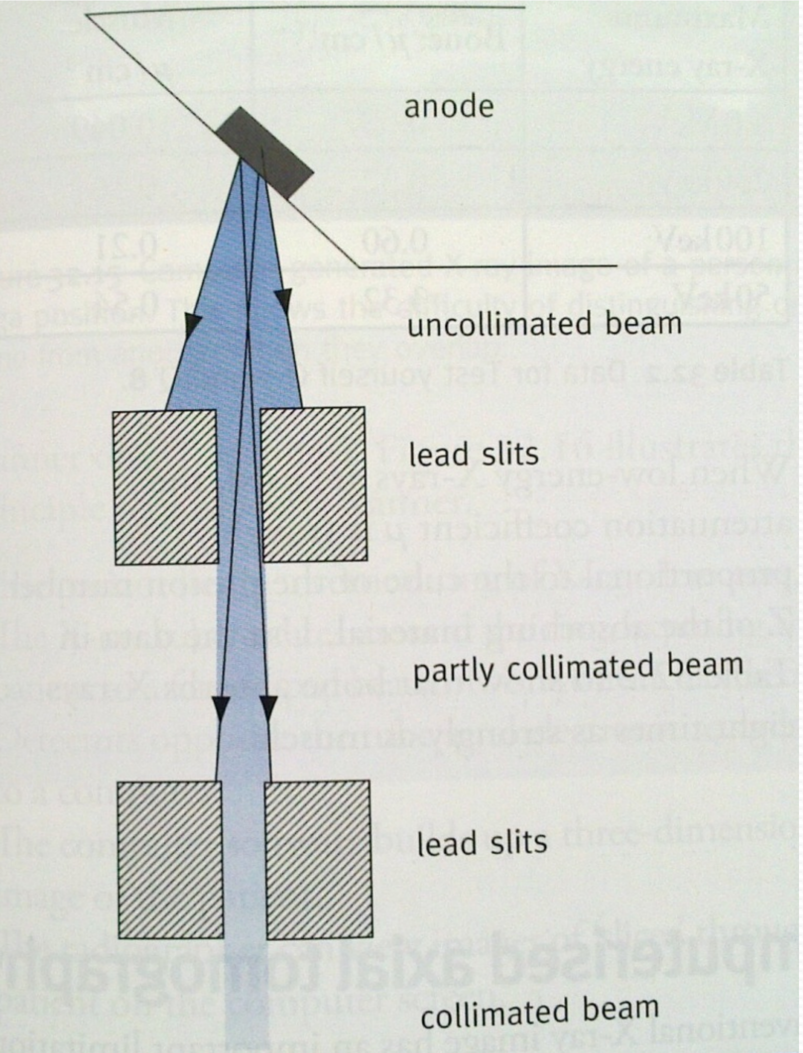


Figure 15.7 Limiting aperture size





Computerized Tomography(CT Scanning)

This technique is called Computer axial Tomography

Because…

- It relies on a computer to control the scanning motion and to gather and manipulate the data to produce images.
- X-ray tube rotates around an axis
- It produces images of slices through the patient

  - 'tomo' means '*slice*' in Greek.

Computerized Tomography

Why?

- Conventional X-ray image does NOT give any real impression of depth.
- Whether an organ is near to the skin or deep within the body is NOT apparent.
- It is difficult to distinguish the bones of the front and back of ribcage in the right figure.

Computerized Tomography

What is it?

This is a technique by which a 3-D image or 'slice' of the body may be obtained

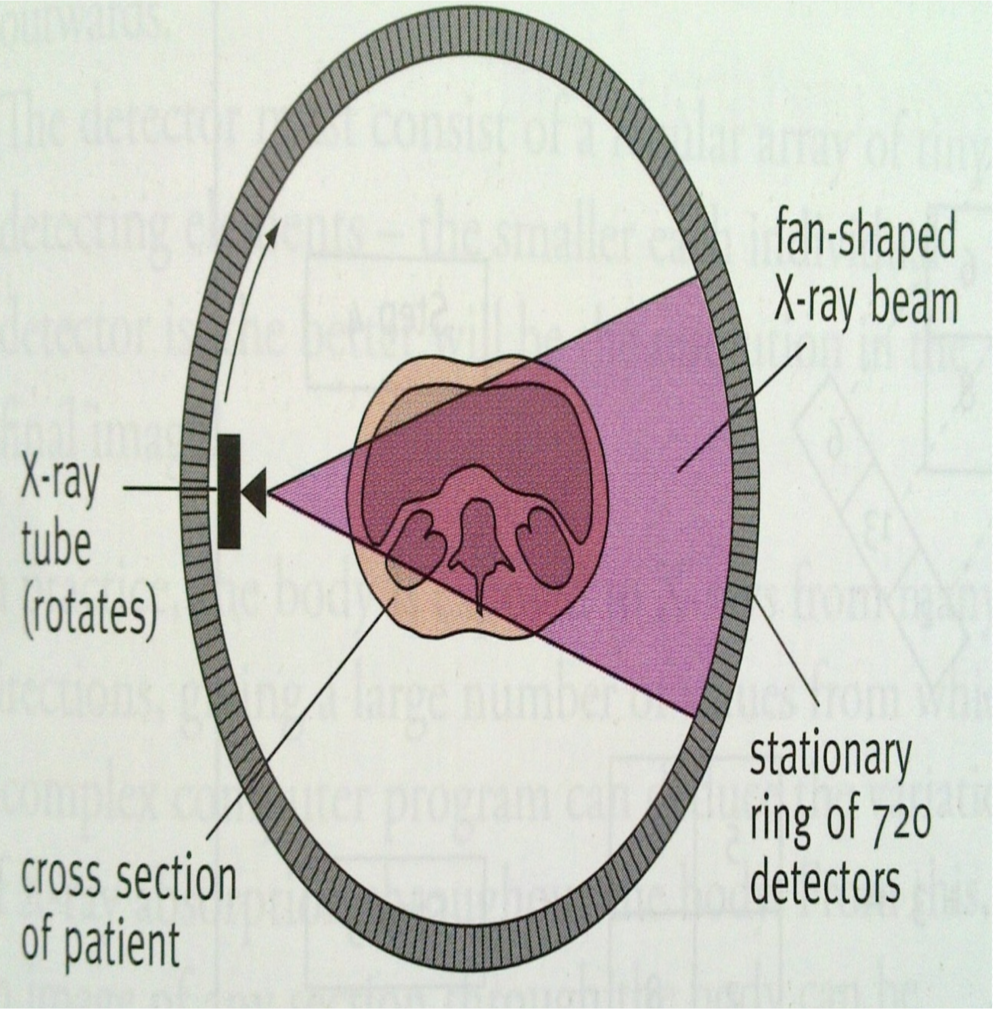
In this technique

- A series of X-ray images are obtained from different angles through one section or slice of the object to be examined.
- Data for each individual X-ray image & the angle of viewing is fed into a high-power computer.
- Images of successive slices can be combined to give a 3-D image.
- The 3-D image can be rotated and viewed from any angle.

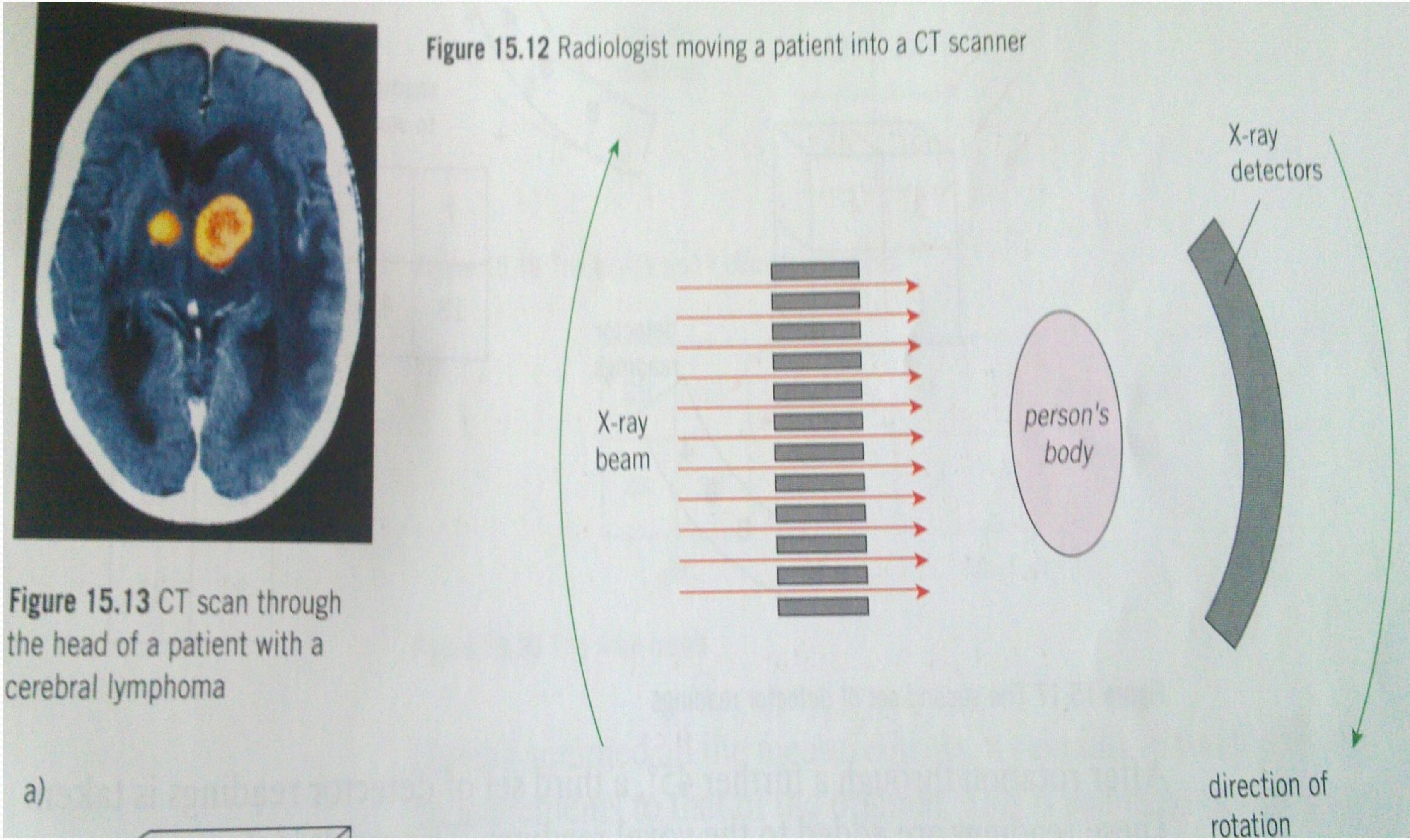
Principle of CAT Scanning

How is CAT achieved?

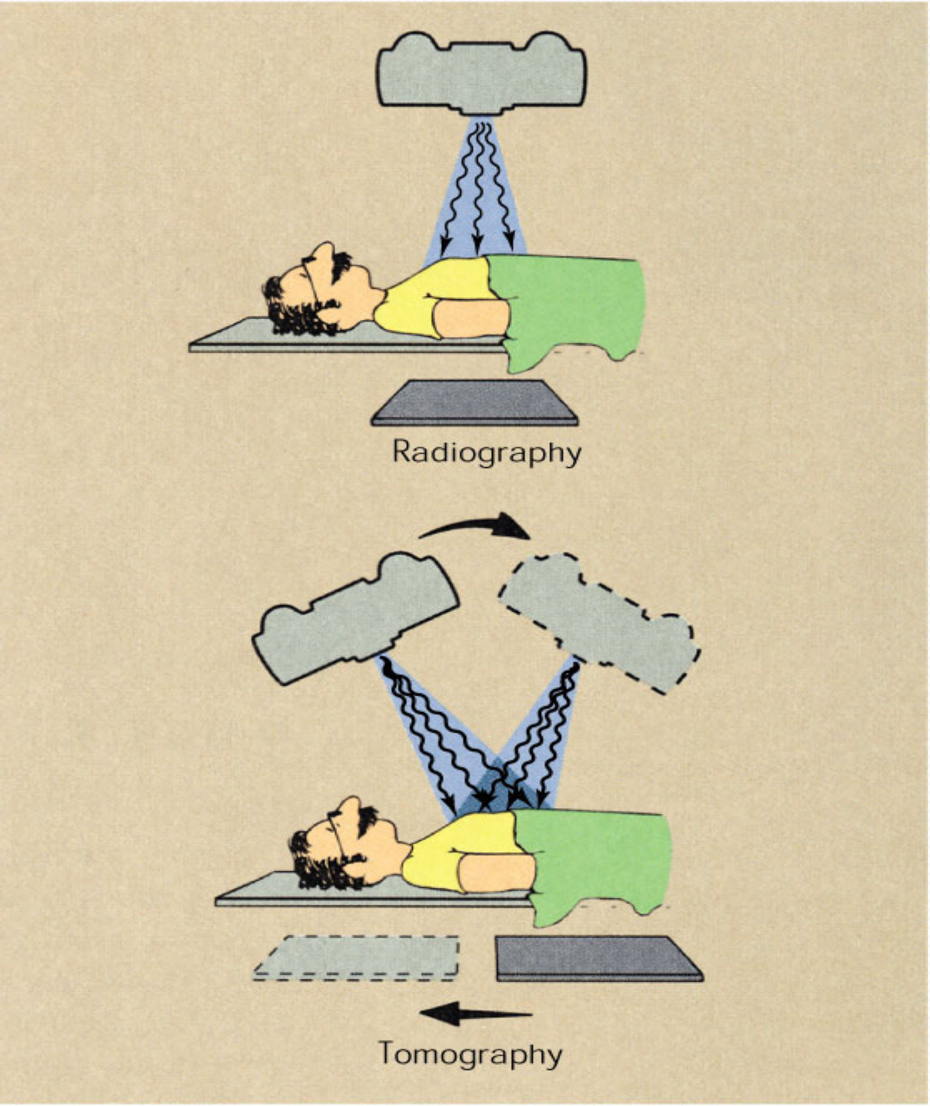
- Patient lies in a vertical ring of X-ray detectors
- The X-ray tube rotates around the ring,exposing the patient to fan-shaped beam of X-rays from all directions.
- Detectors opposite the tube send electronic records to a computer
- The computer software builds up a 3-D image of the patient
- Radiaographer can view images of ‘slices’ through the patient on the computer screen

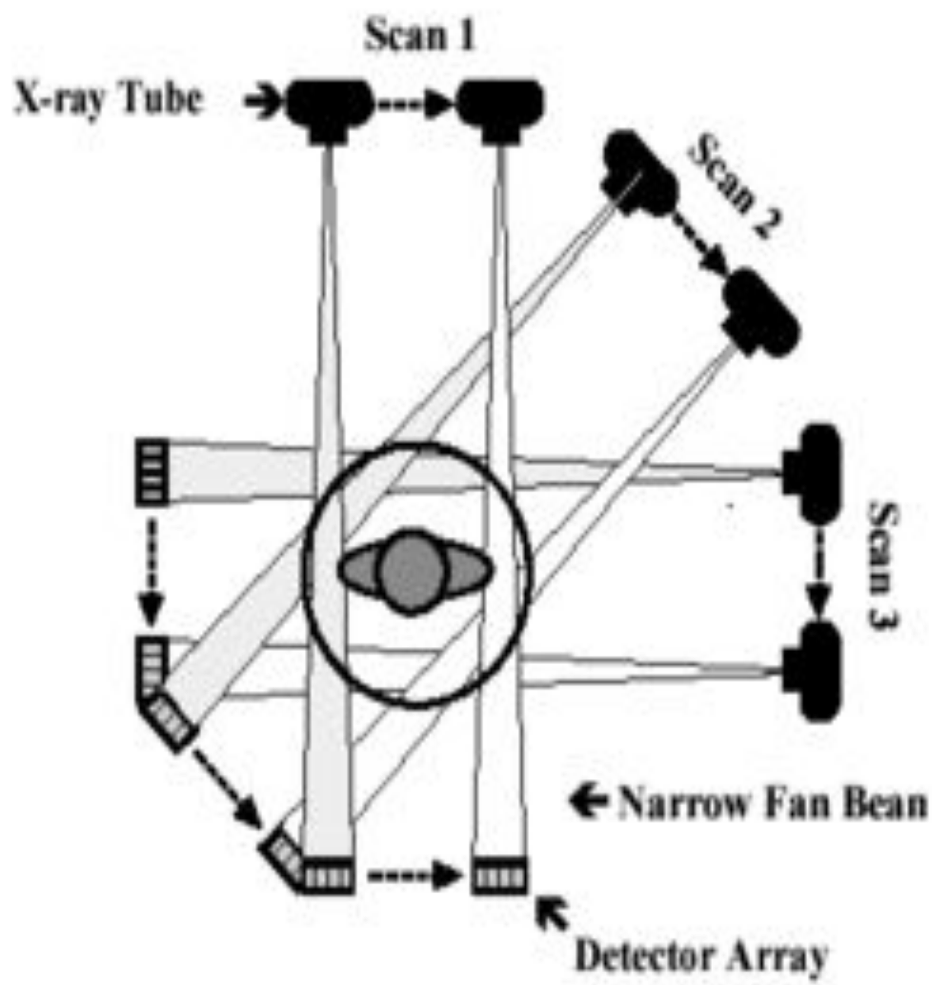


CAT : Equipment Arrangement



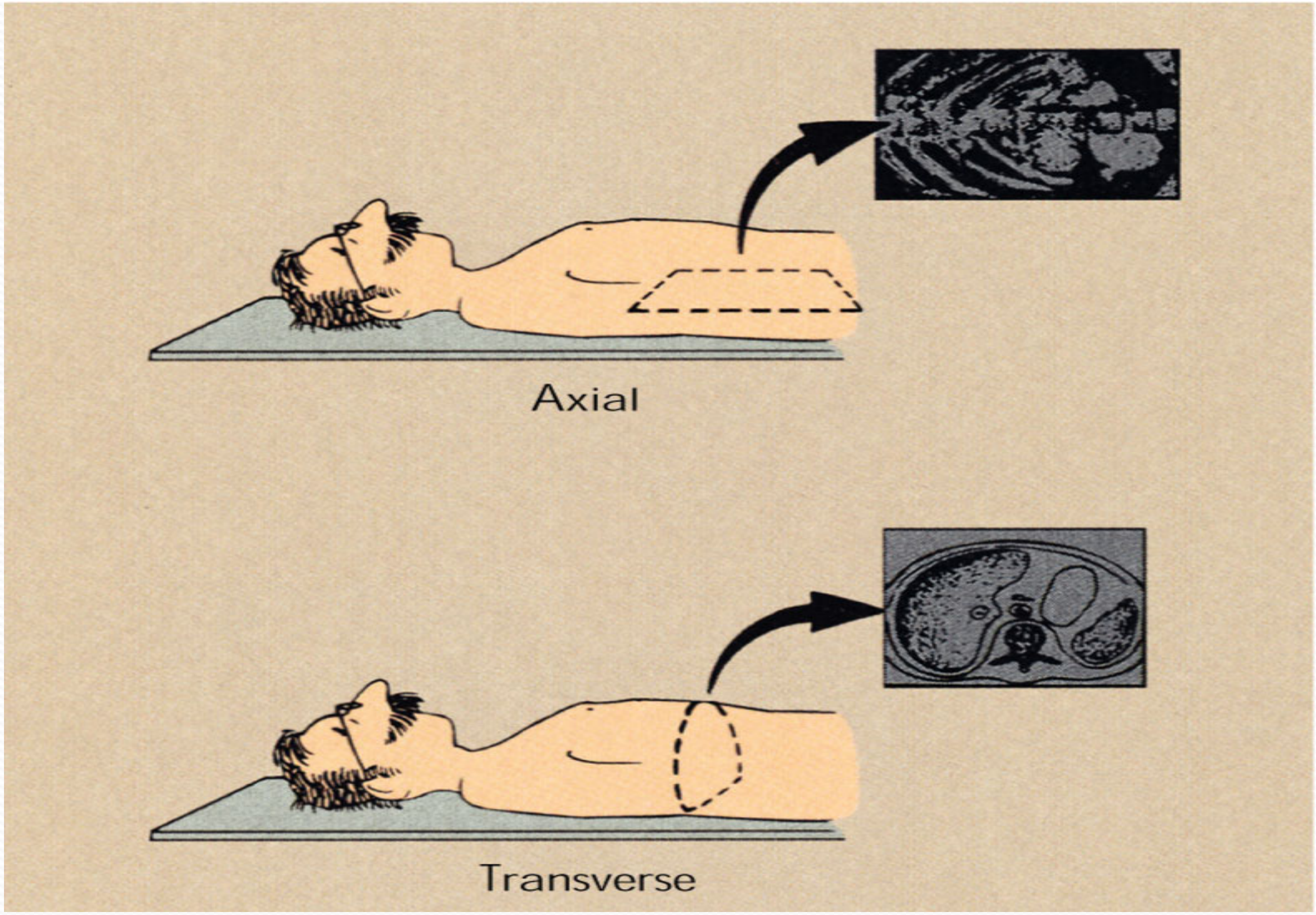
CAT:Equipment Arrangement





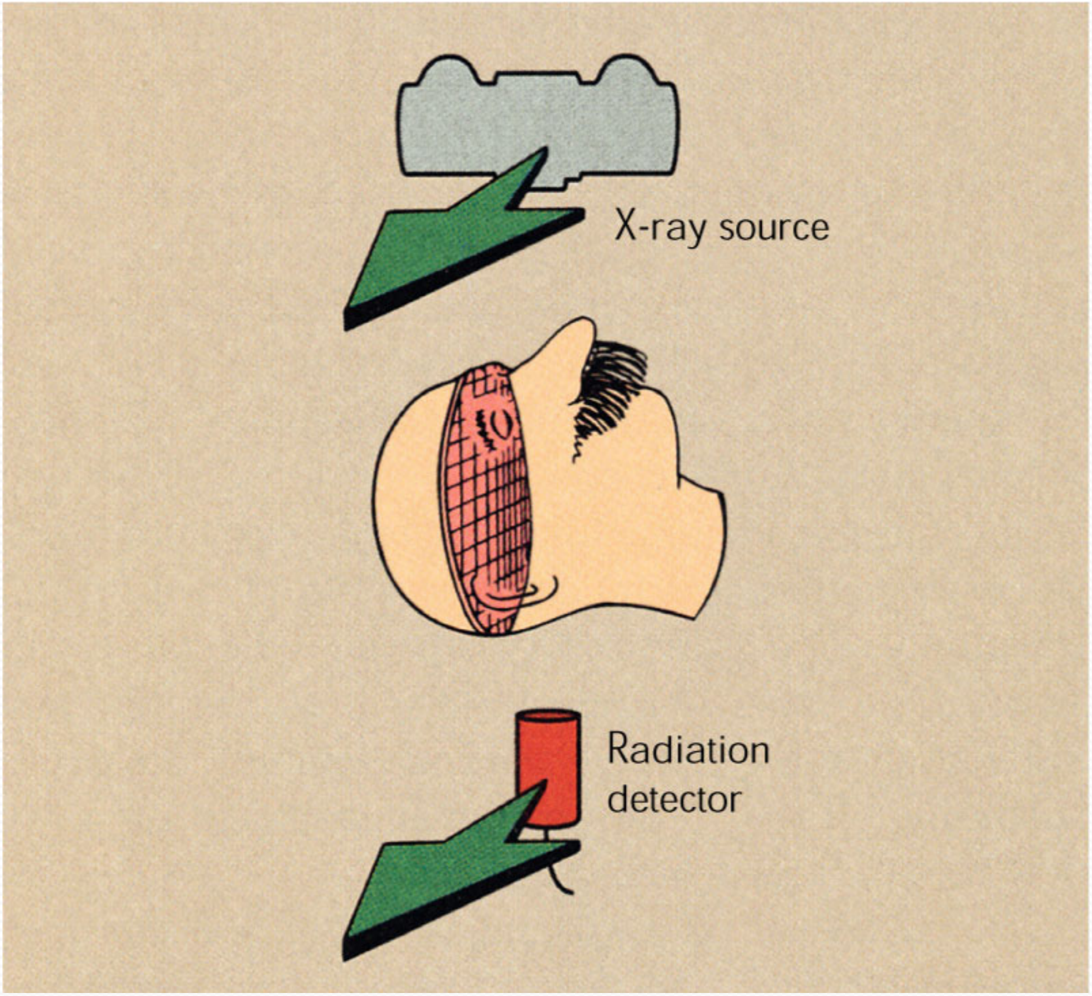
Tomo = image // to long axis of the body

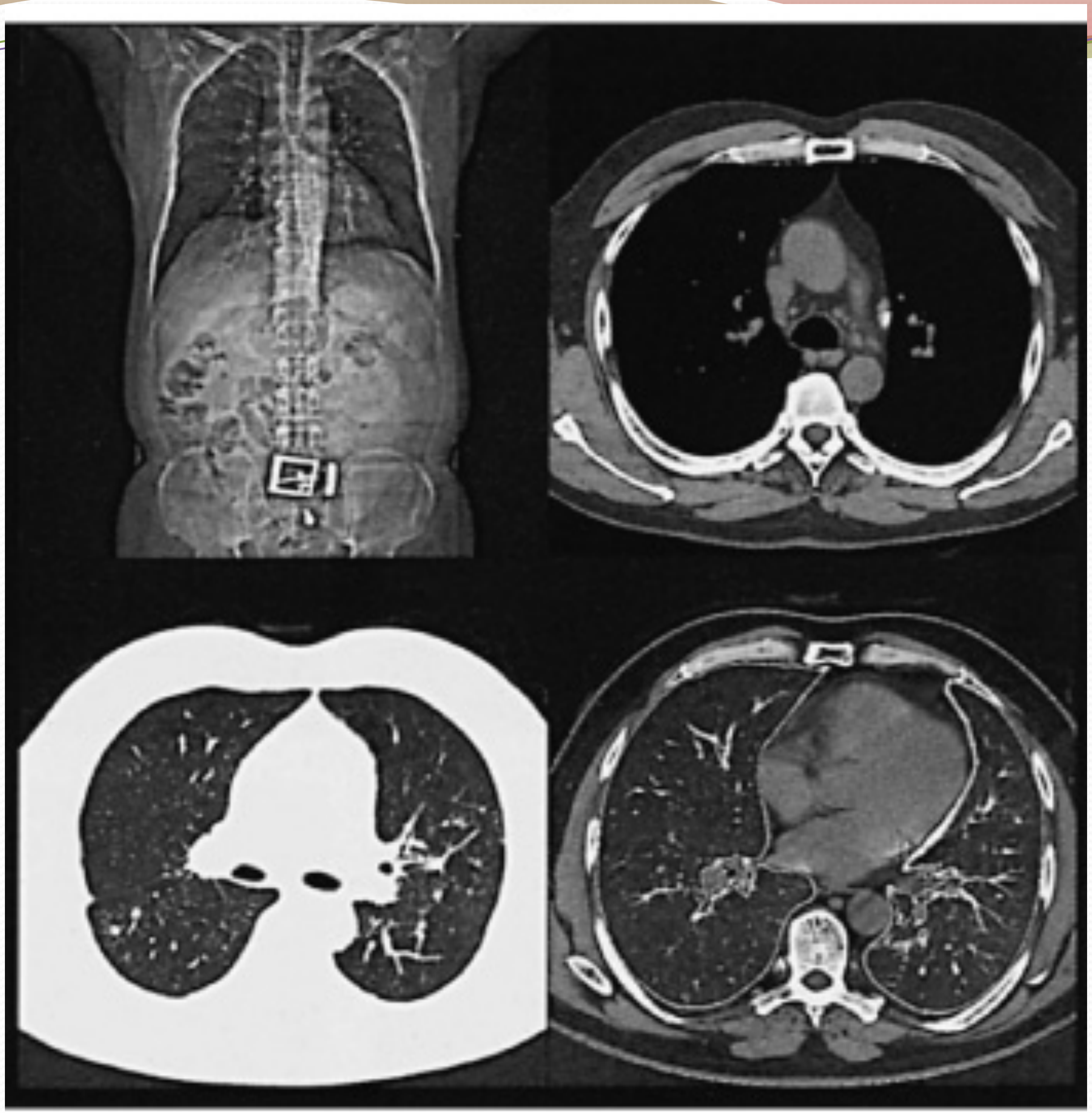
CT = image is transverse to the body

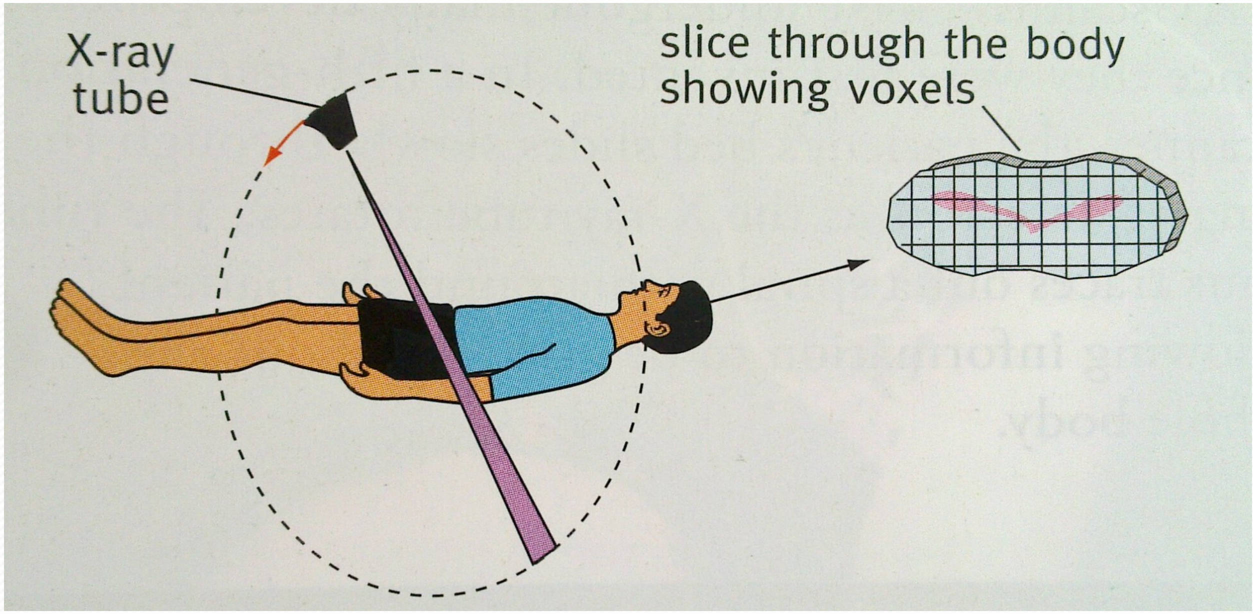


In its simplest form, a CT imaging system consists of a finely collimated x-ray beam and a single detector.

- both moving synchronously in a translate rotate mode.
- Translation = one rotation of source and detector





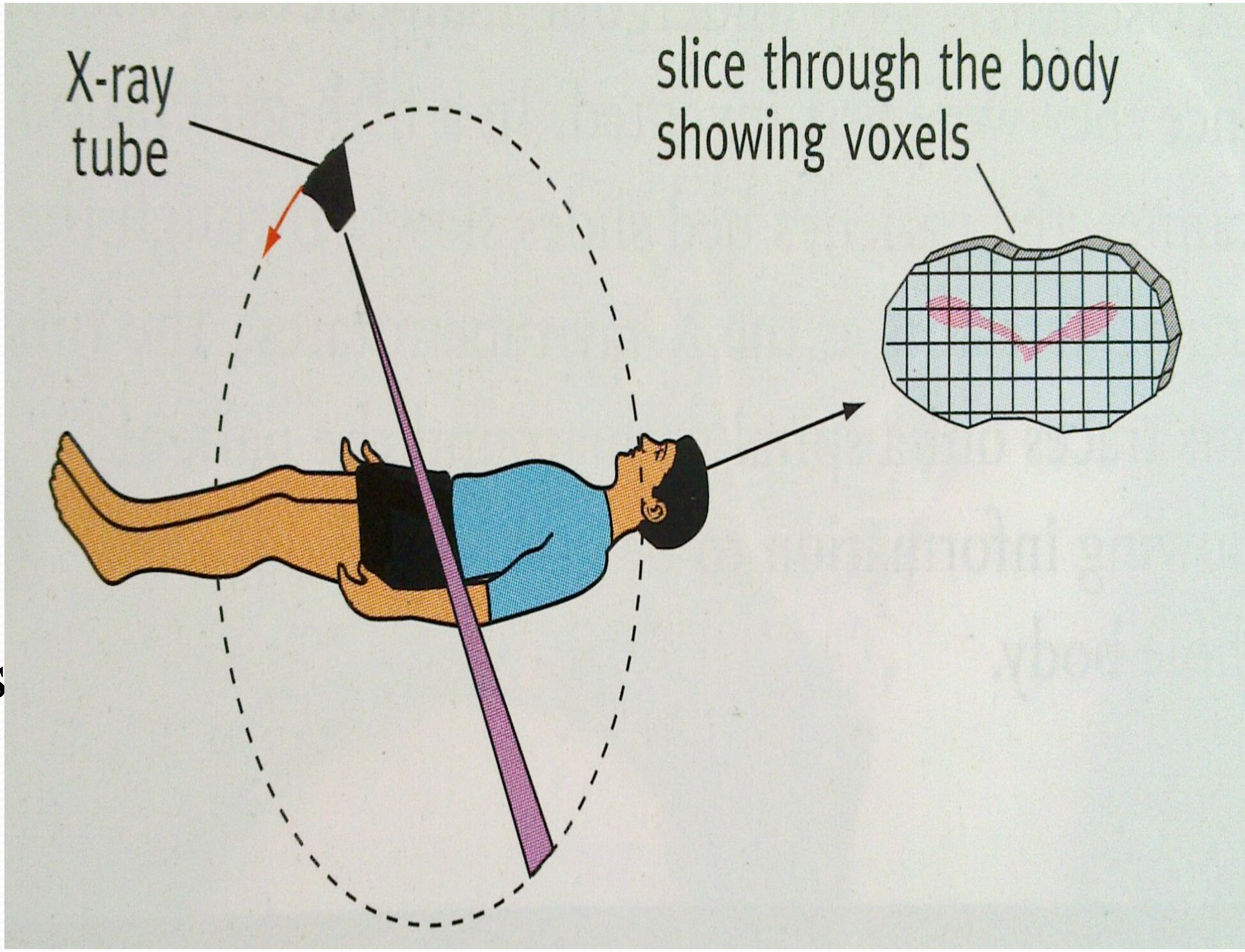

X-ray tube
slice through the body showing voxels

Digital Image

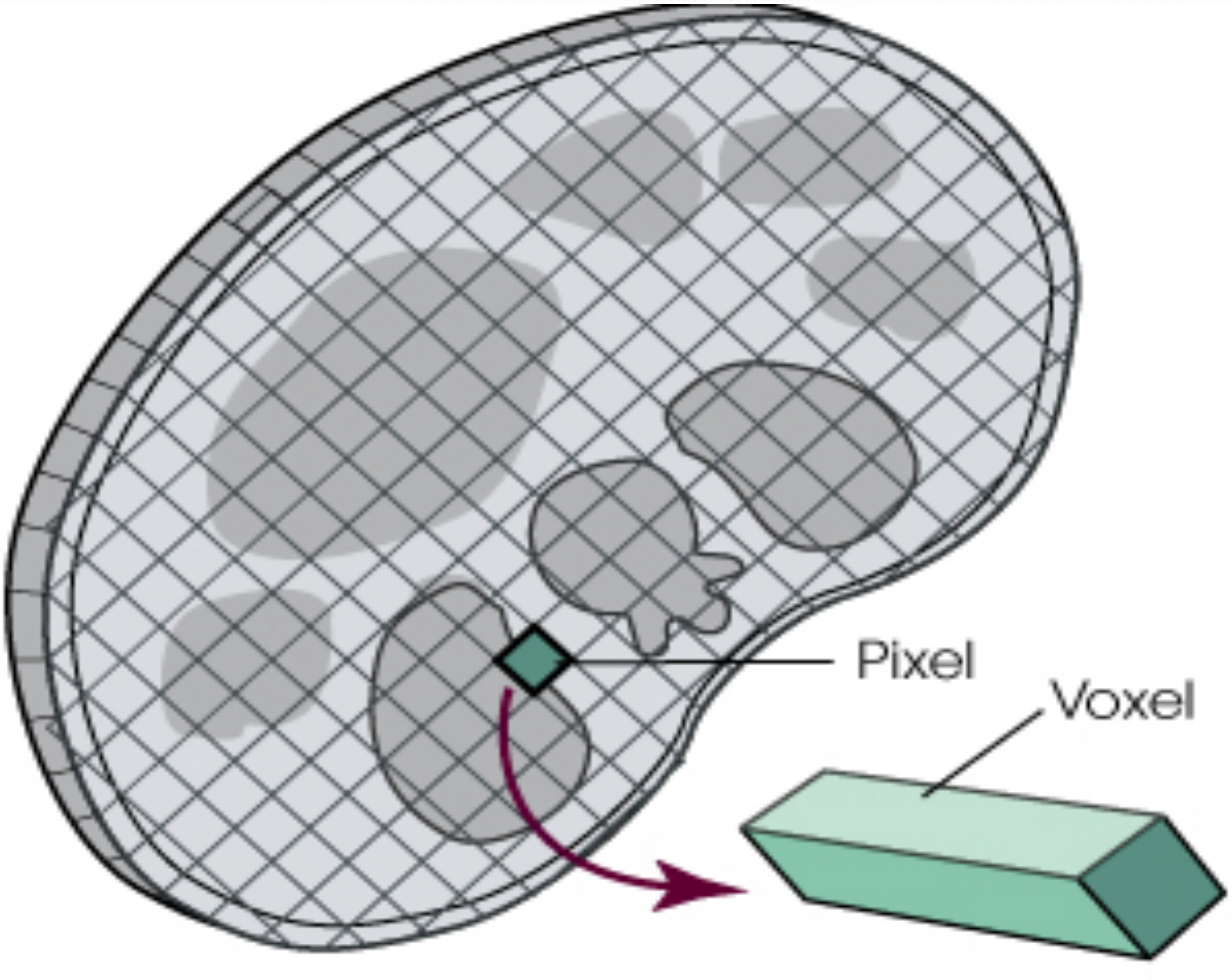
- Array of numbers arranged in a grid of rows and columns called a matrix.
- Single square, or picture element, with in the matrix is called a pixel.
- Slice thickness gives the pixel and added dimension called the volume element, or voxel

Voxel vs. Pixel(1)

- Each pixel in the image corresponds to the volume of tissue in the body section being imaged.
- The voxel volume is a product of the pixel area and slice thickness

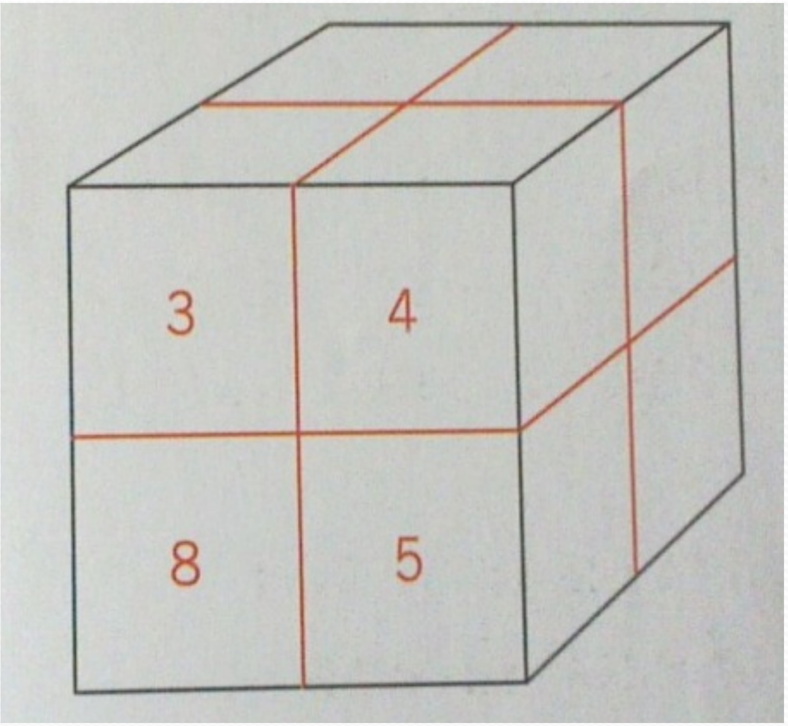


Voxel vs. Pixel (2)



VOXEL vs. PIXEL (3)

- The section or ‘slice’ through the body is divided into a series of small units,called VOXEL.
- Each voxel absorbs the X-ray beam to different extents.
- The intensity transmitted through each voxel alone can be assigned a number,called a PIXEL.
- Pixels are built up from measurements of X-ray intensity made along a series of different directions through section or ‘slice’
- The picture in RHS shows that the cube is divided into 8 voxels.



How image is developed from data..(1)

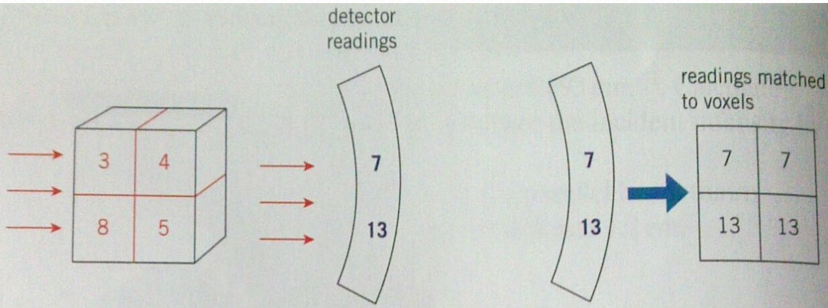


Figure 15.16 The first set of detector readings

The X-ray tube and the detectors are now rotated through 45°. The new detector readings are 4, 8 and 8. These readings are added to the readings already in the voxels, as shown in Figure 15.17.

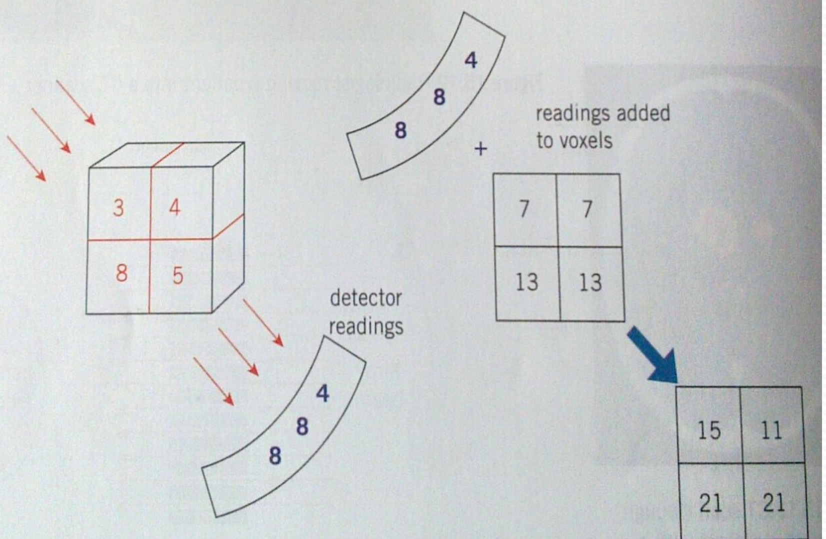


Figure 15.17 The second set of detector readings

After rotation through a further 45°, a third set of detector readings is taken. These readings are added to the voxel readings. The result is shown in Figure 15.18.

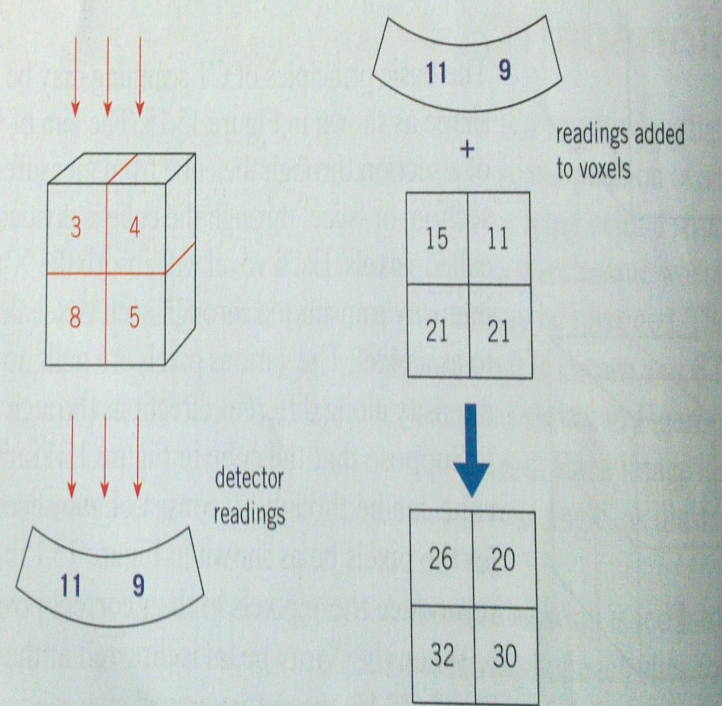


Figure 15.18 The third set of detector readings

How Image is developed from data….(2)

- “*Background*” intensity must be removed.The background reading is the sum of the detector readings for each set.Here ,it is 2o,which is deducted from each pixel.
- The result,after deduction of background, must be divided by 3 for the duplication of the views of the section.

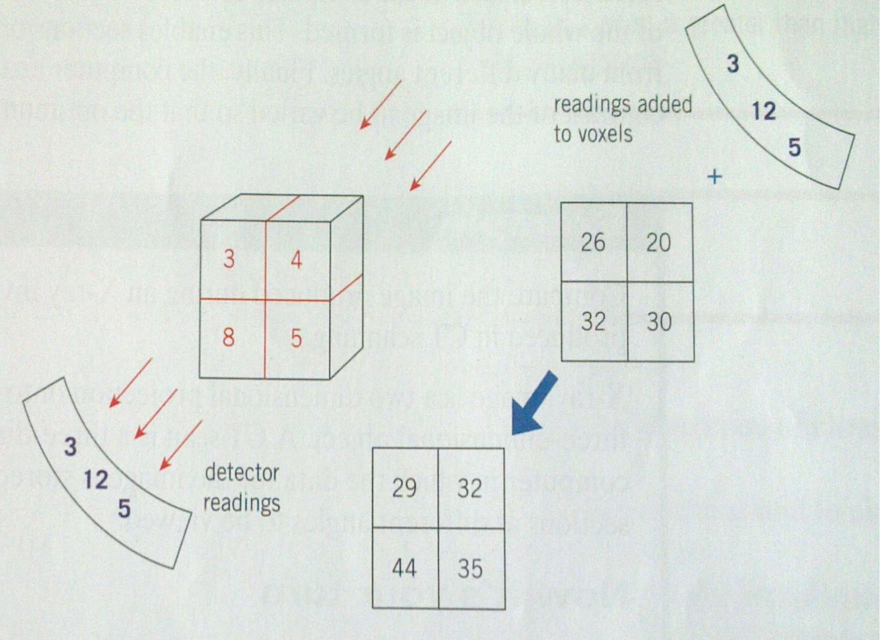


Figure 15.19 The fourth set of detector readings

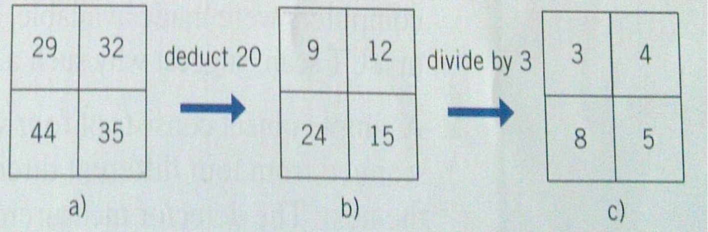
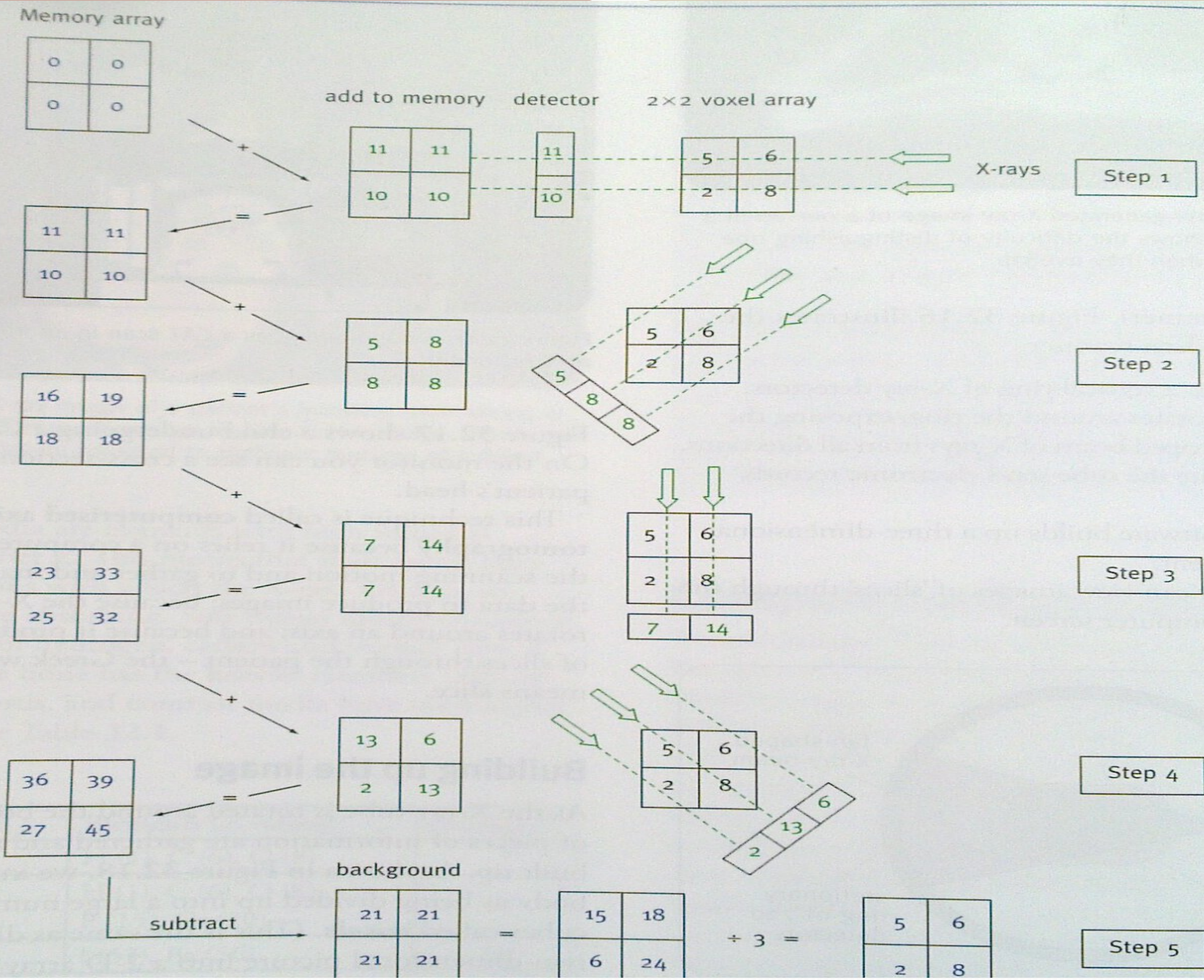
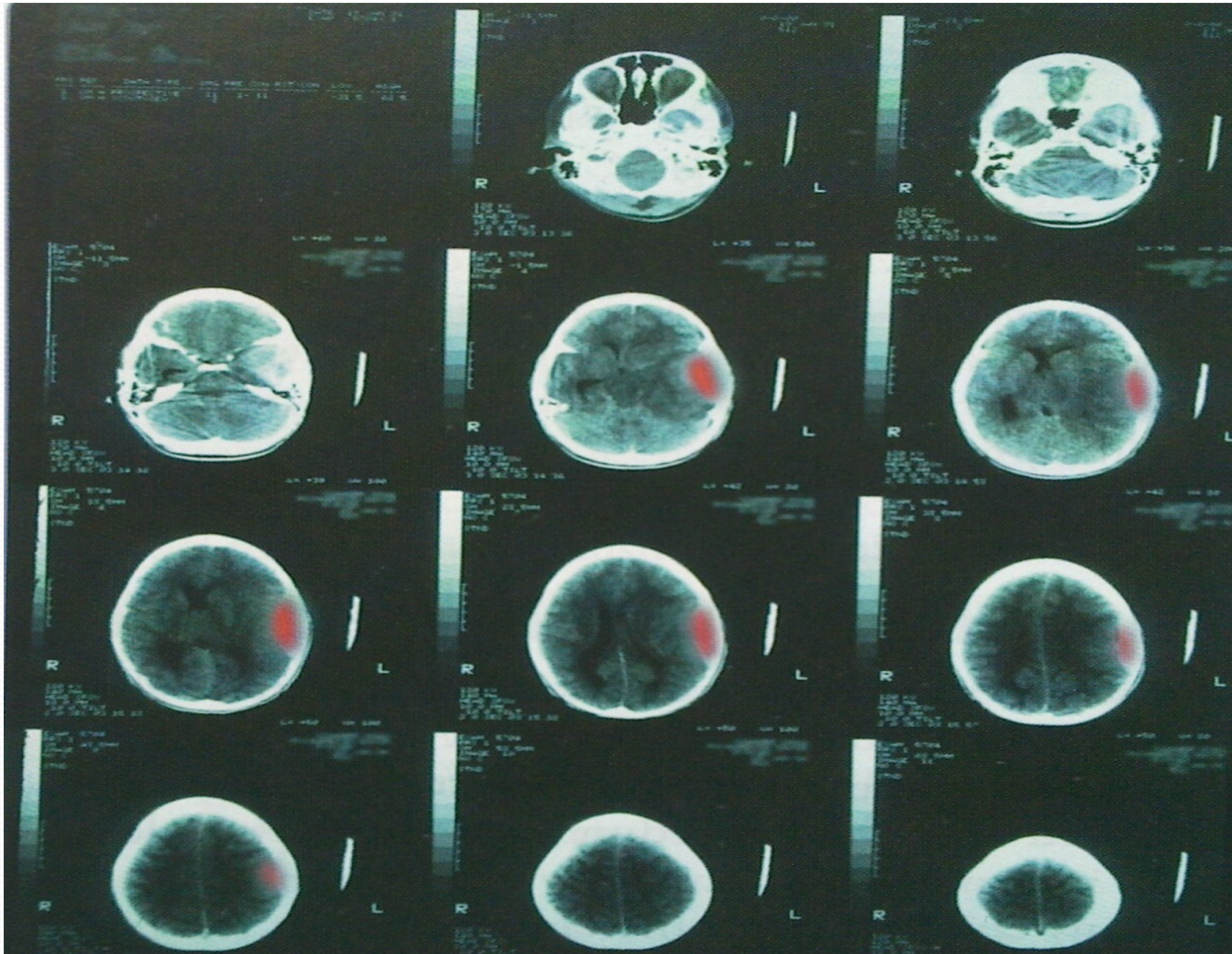


Figure 15.20 The final result

Figure 32.17 A boy undergoes a CAT scan in an investigation of an eye condition.


Memory array
add to memory
detector
2×2 voxel array
X-rays
Step 1
Step 2
Step 3
Step 4
background
subtract
÷ 3 =
Step 5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