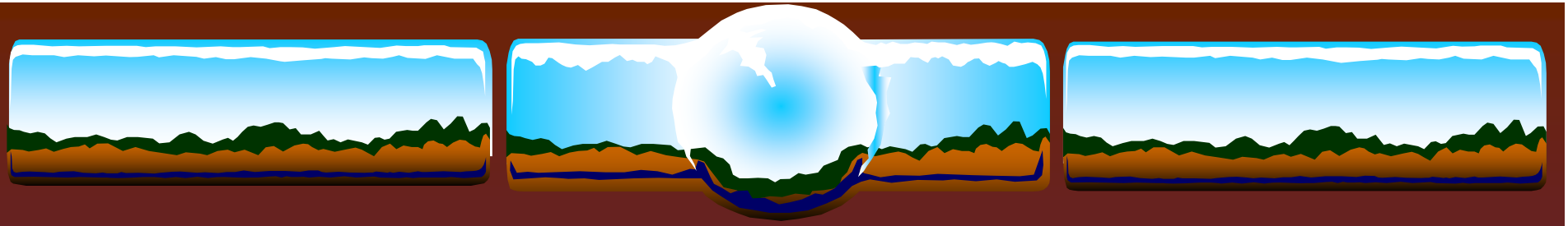
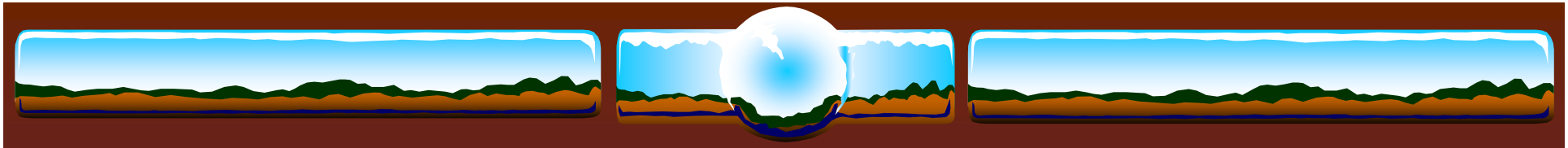


Positron Emission Tomography

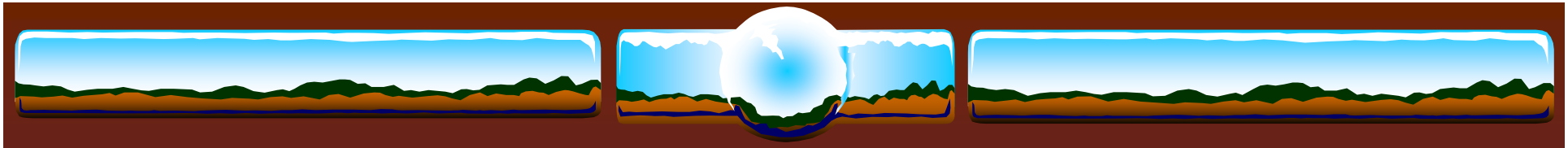
Molecular Imaging

Rene Hyder, AHEC/ NRC



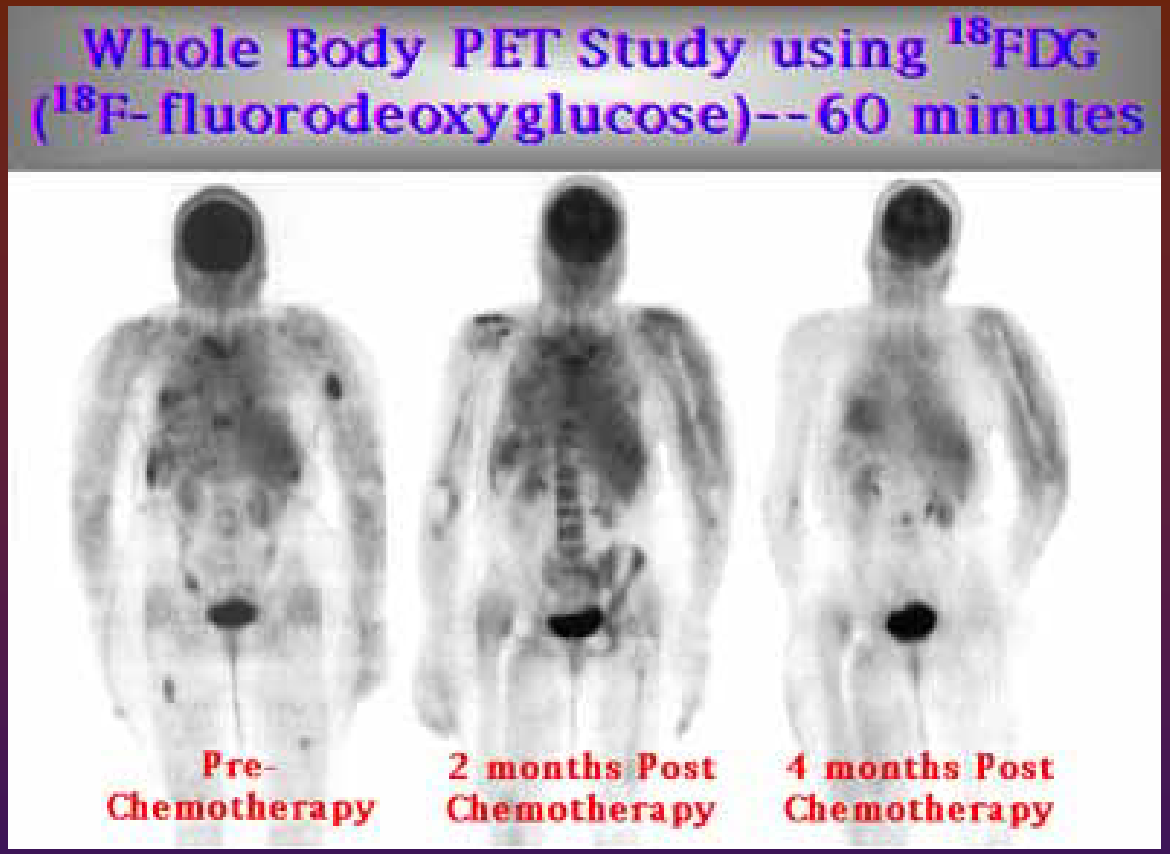
Molecular Imaging

- Showing biological activity at the chemical/physiological level
- Using biological compounds
  - H_2O-15
  - Glucose – F-18-FDG
- Metabolic & biologic changes precede anatomical changes or symptoms

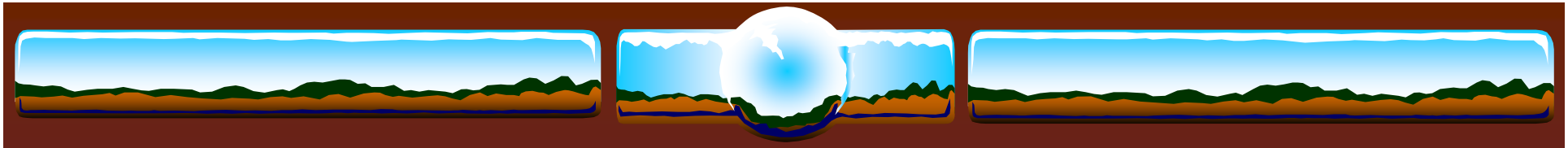


Anatomy & Physiology

- **CT, MRI, PET & SPECT given three-dimensional images**
- **Unlike CT or MRI, which look at anatomy or body form, PET studies metabolic activity or body function.**



Other imaging modalities image the results (damage) that has occurred, while PET allows us to find and treat problems earlier or monitor the effectiveness of treatments being given.

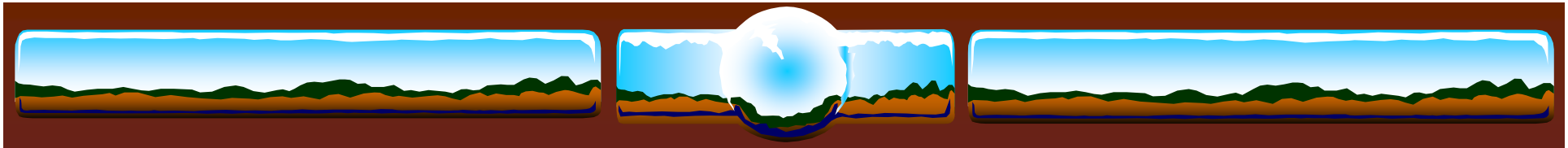


PET Radionuclides

	Tp	Range
❖ Rb-82 -	75 sec	⇨ 2.6 - 15 mm
❖ O-15 --	2.1 min	⇨ 1.5 - 8.2 mm
❖ N-13 --	9 min	⇨ 1.4 - 5.4 mm
❖ C-11 --	20 min	⇨ 0.3 - 5.0 mm
❖ F-18 --	110 min	⇨ 0.2 - 2.4 mm

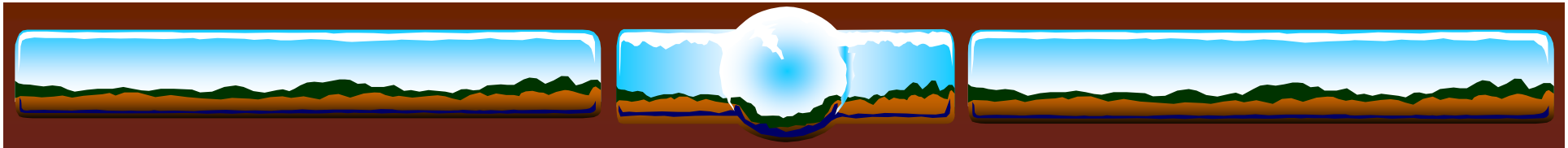
Using biological compounds like

- ❖ Glucose = F-18-FDG



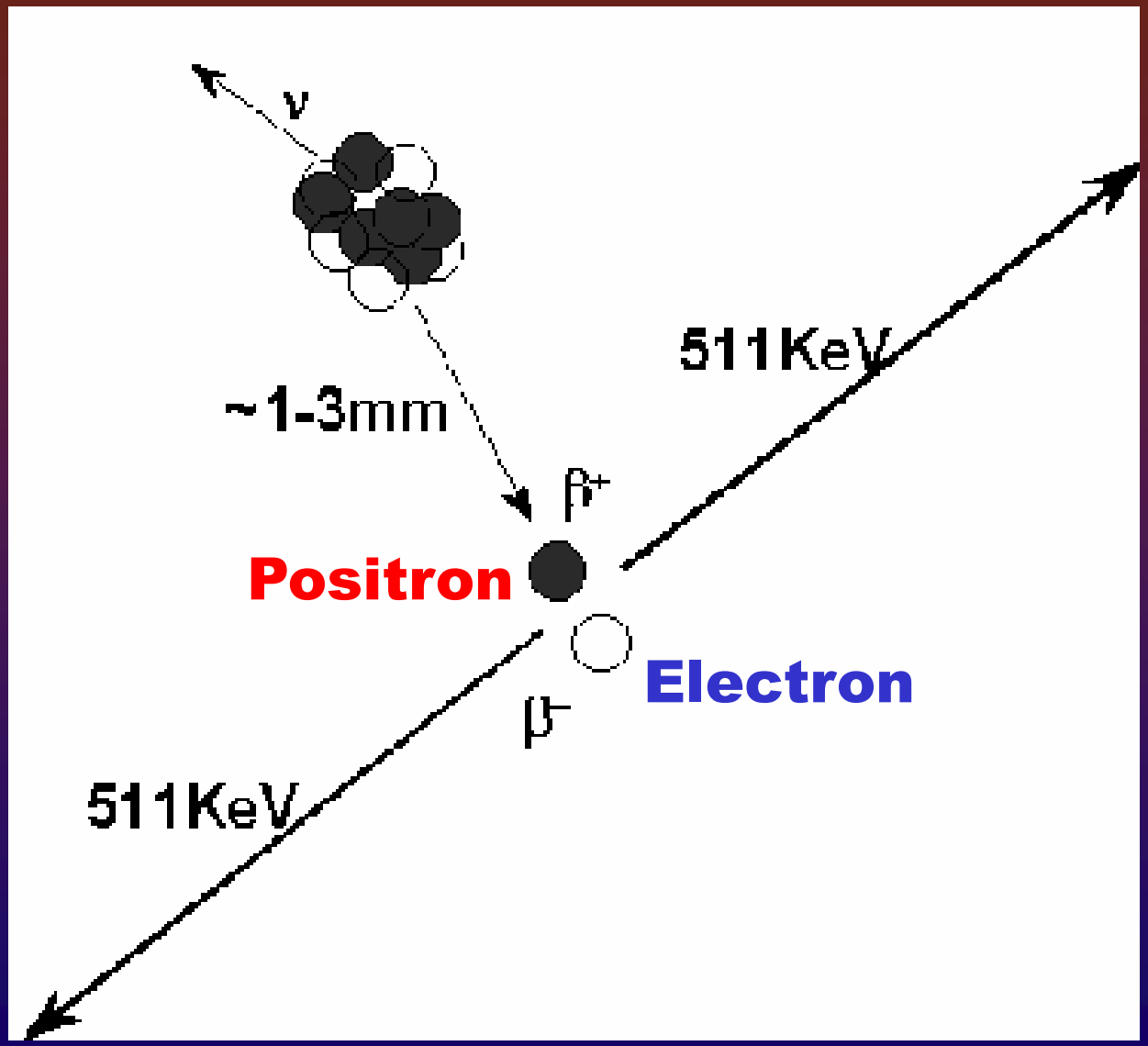
PET Studies

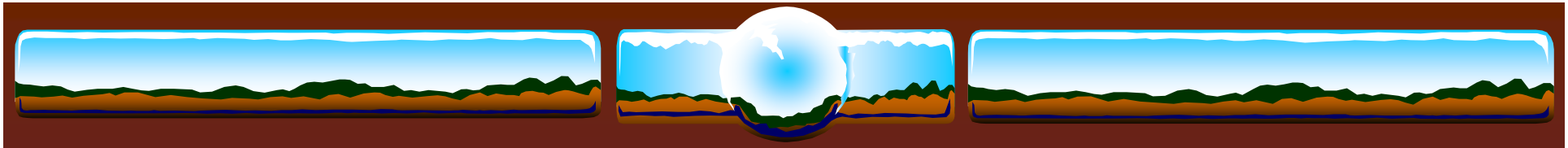
- Oncology (~ 80-85%)
- Brain (~ 5-10%)
- Cardiac (~ 5-10%)



Positrons

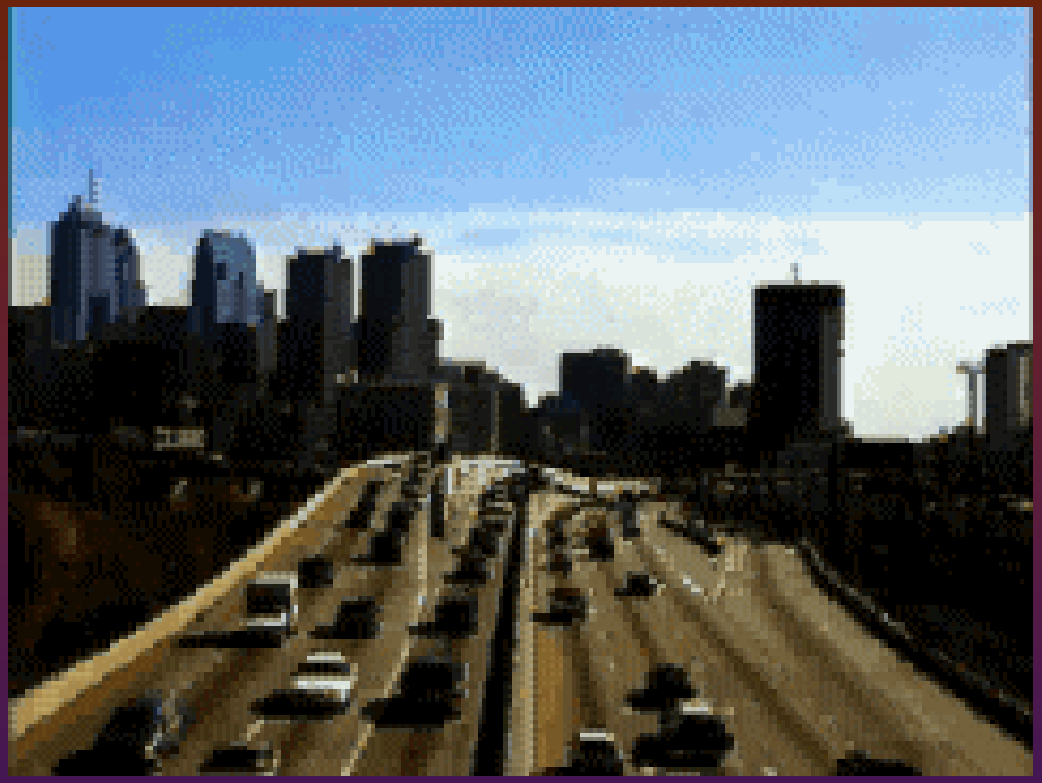
- Proton rich nuclei decay by electron capture or positron emission
- Once a positron is emitted , it spiral toward an electron
- The positron & electron collide temporally producing a positronium; that annihilates resulting in a pair of 511 keV gamma rays moving in nearly opposite directions [180^{0} +/- 0.5^{0}]


ν
~1-3mm
511KeV
β+
Positron
Electron
β-
511KeV

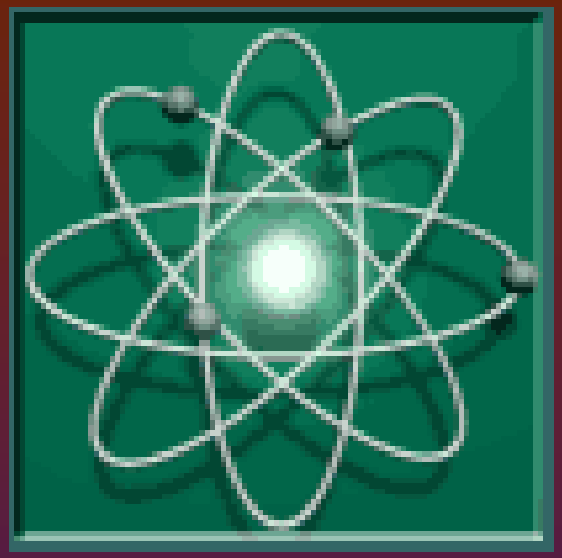


Positrons cont.

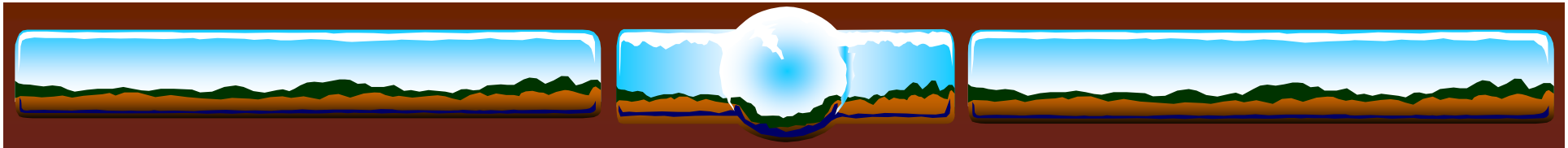
- Each Rn emits positrons with different energies
- The higher the energy; the greater the path length before annihilation
- The shorter the path length; the better the resolution
- All annihilate and emit 511 keV



A few years ago, high-energy positron emitters were only produced in very limited supply using cyclotrons located at research facilities in close proximity to the PET scanners.

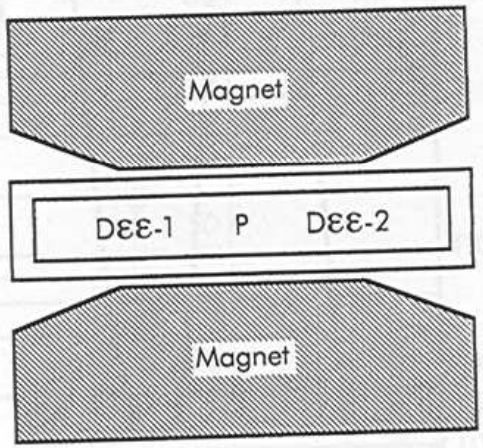


With half-Lives ranging from a few seconds to two hours, there was only a small window from production to administration. Today, rapidly growing regional distribution networks have facilitated the delivery of FDG and other short-lived radiopharmaceuticals to most areas of the United States at a fairly reasonable cost.



PET Rn Production

- Small medical Cyclotrons
- Cost ~ $2 million
- Only F-18 has Tp long enough to transport
- To use others, must have cyclotron in facility
- Rb-82 is produced by generator



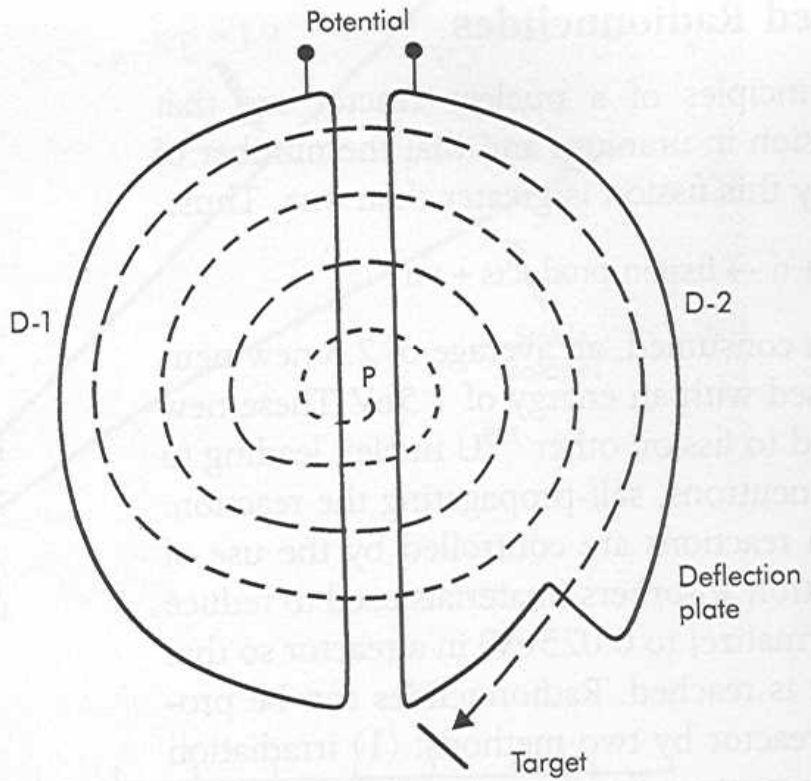
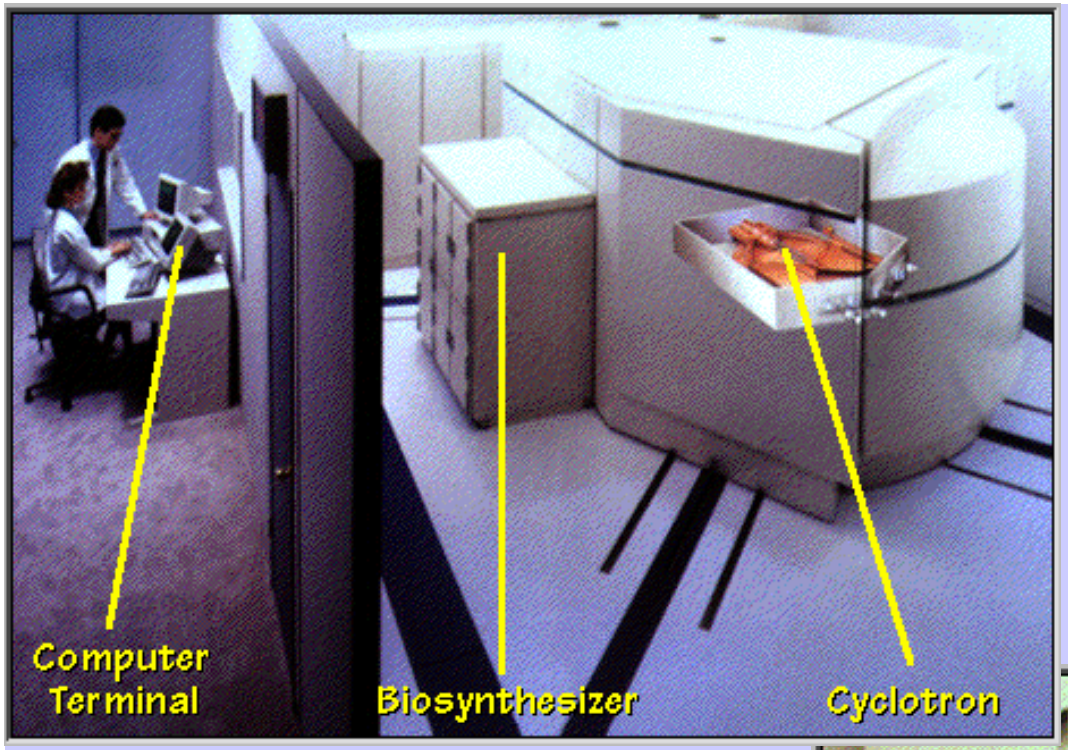
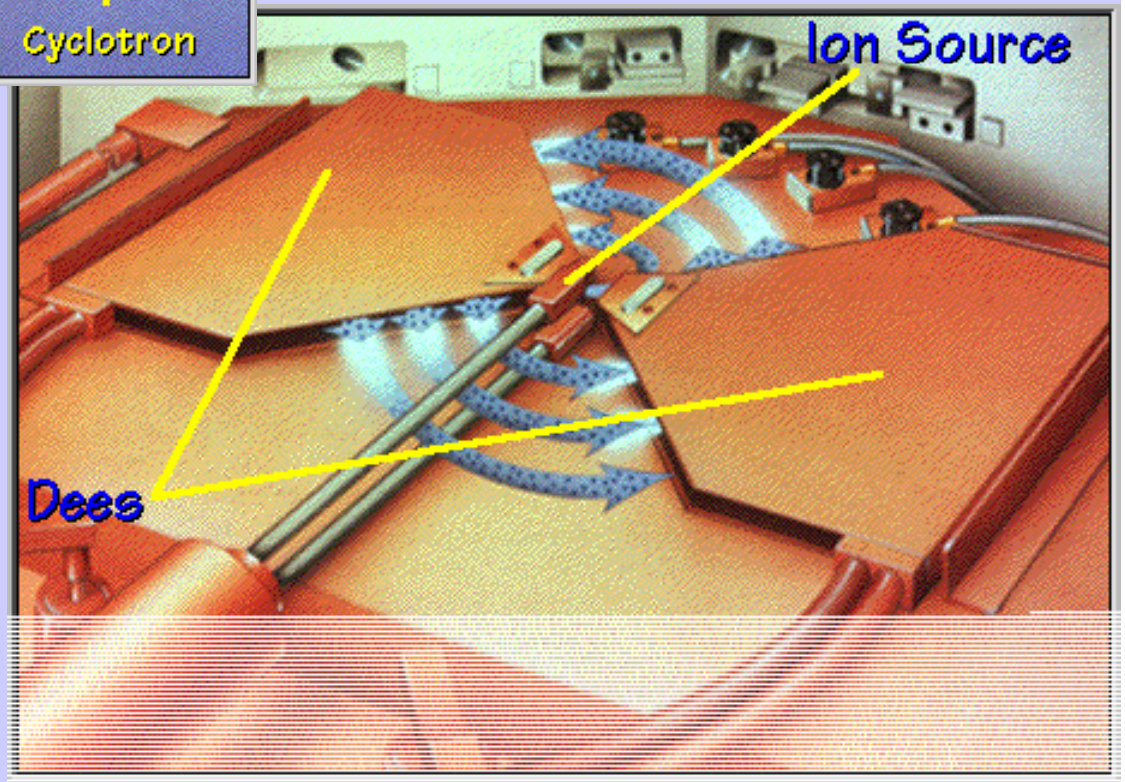
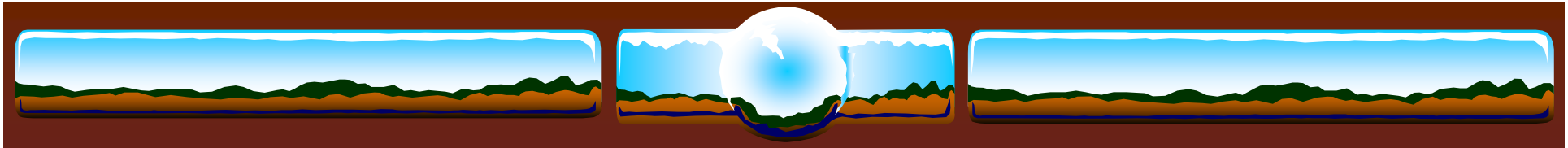


Figure 6-3 Schematic diagram of the operation of a positive ion cyclotron.


Computer Terminal
Biosynthesizer
Cyclotron


Ion Source
Dees



PET Rn Production cont

- Rb-82 is a potassium analog
- FDA approved
- Used for myocardial perfusion
- Rb-82 comes from a generator
- “ too expensive for most facilities

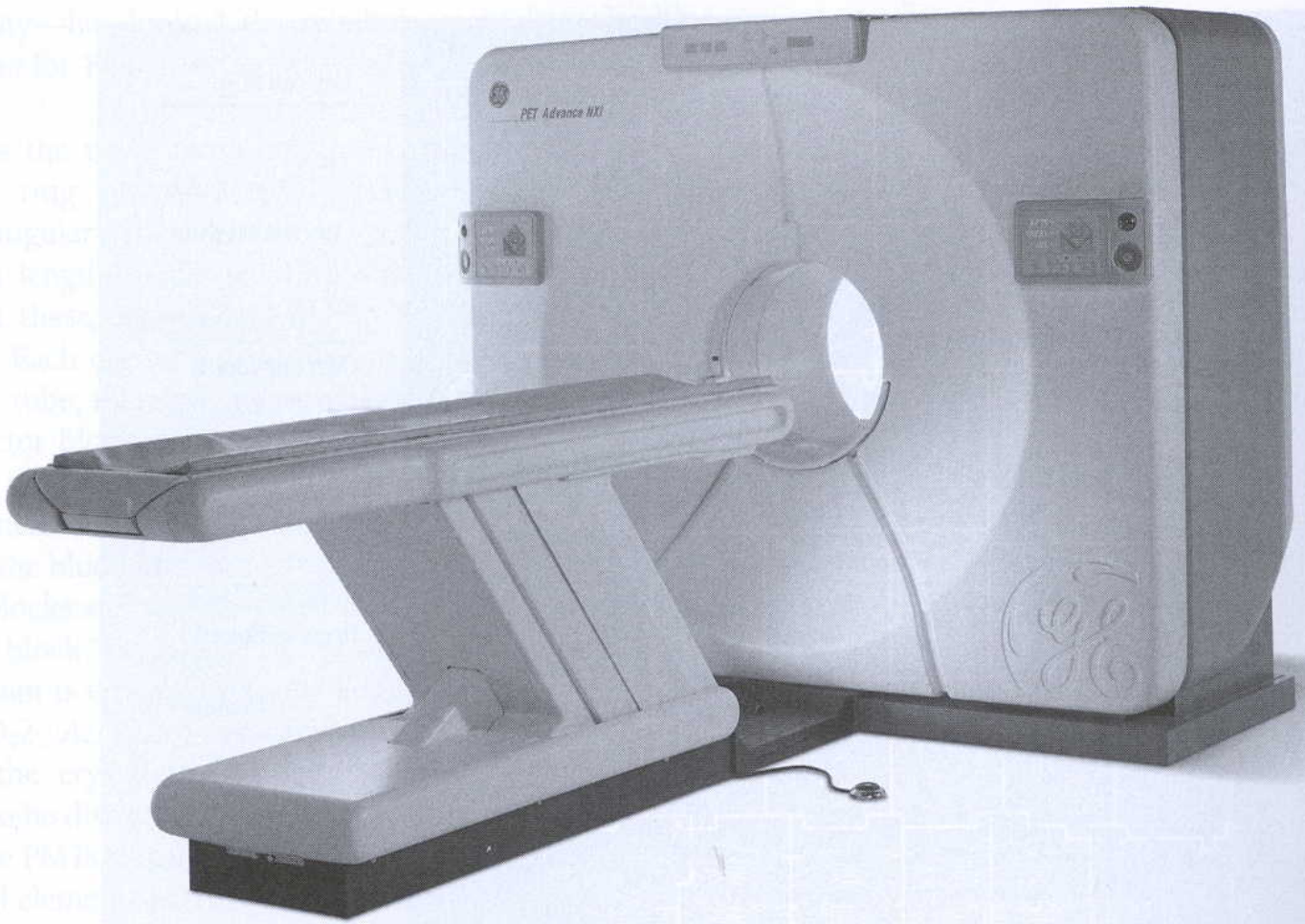
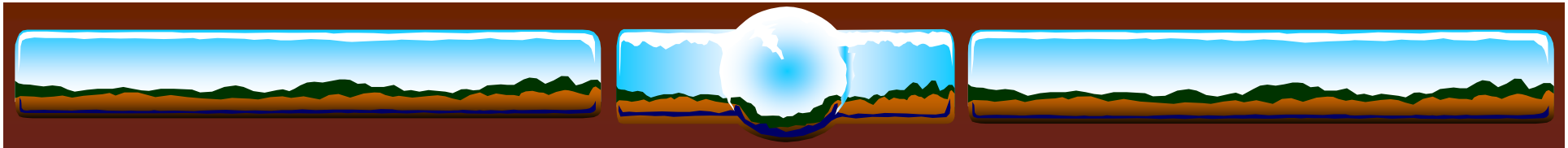


Figure 10-6 Dedicated BGO ring scanner containing 12,096 crystals that obtains 35 slices simultaneously. (Courtesy of General Electric Medical Systems, Waukesha, Wisconsin.)



PET Detectors

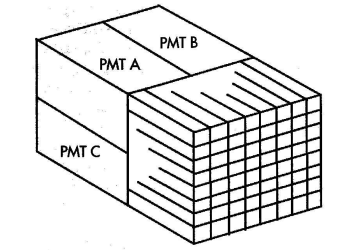
- Higher counts than SPECT = better resolution
- Crystal
  - BGO = Bismuth Germanate
  - LSO = Leutetium Orthosilicate
  - GSO = Gadolinium Orthosilicate
  - LYSO (YLSO) Leutetium Yttrium Orthosilicate
- BGO was used most often for just PET

PET Detectors cont

- LSO, LYSO & GSO faster scintillators
- Less loss to simultaneous events
- Better for 3-D acquisitions

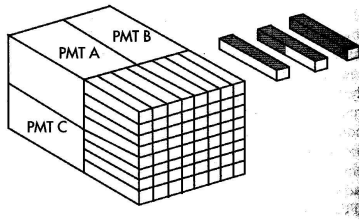
Crystals

- Rectangular 3-4 mm X 10-30 mm
- 8,000 – 20,000 in scanner
- ~64 crystals/ 4 PMT in a block



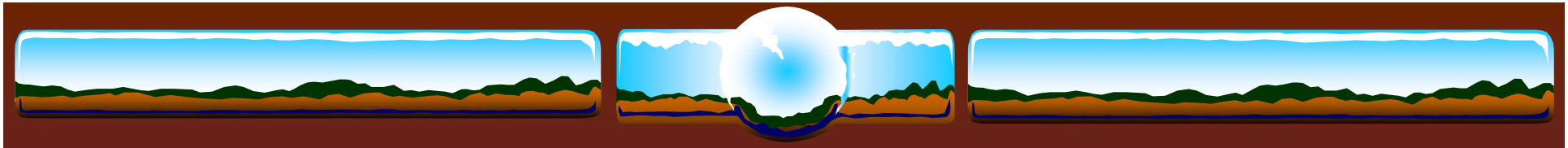
BGO cut-block detector

A



BGO reflection design block

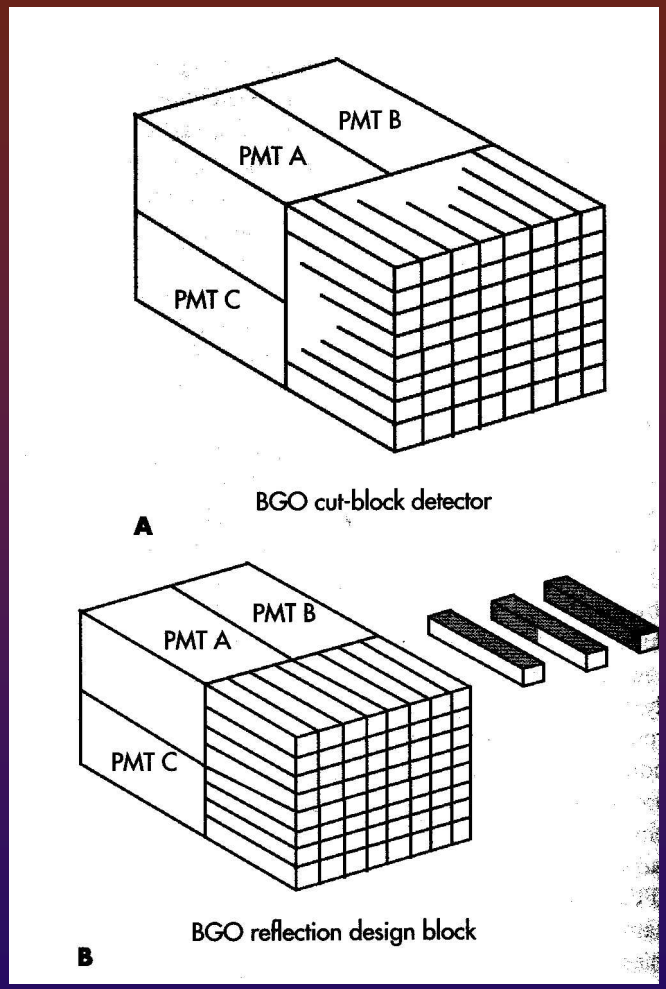
B



PET Detectors

- Several blocks = A module
- Dozens of modules form the rings of the detector
- Each ring acquires one image slice
- 18-30 consecutive rings form a cylindrical field of view about 6” or 15 cm long = 1 bed position
- An oncology study: hips to base of brain

  = ~ 90 cm = 6 bed positions



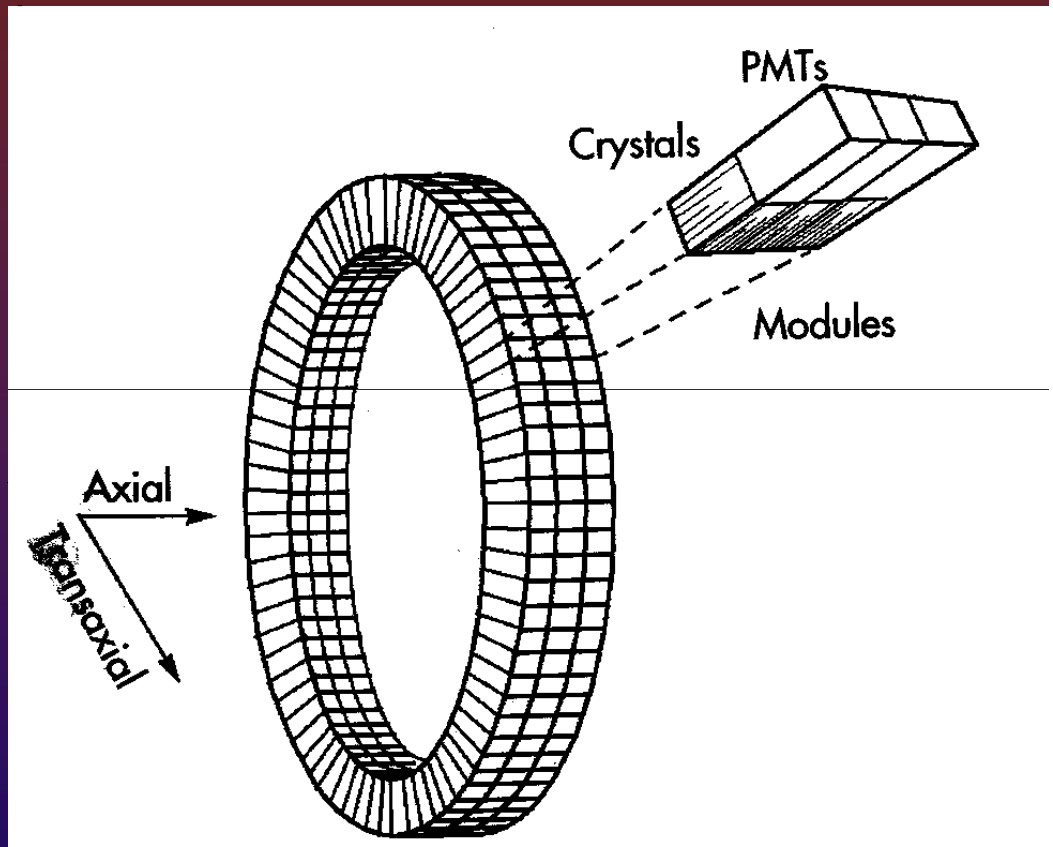
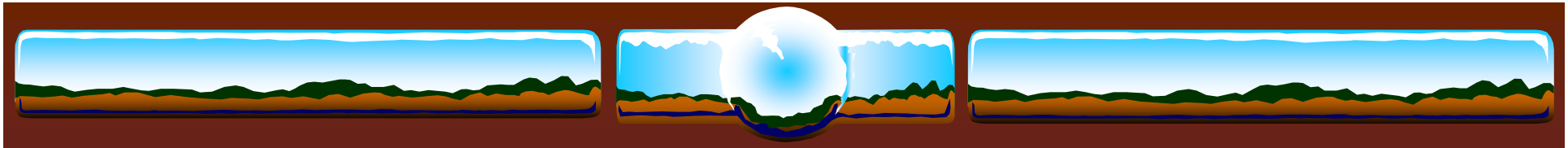


Figure 10-5 Detector blocks, or modules, are used to constr
ring of detectors around the patient. Hundreds of blocks are
used to create 18 to 30 consecutive rings of detectors that forr
cylindrical field of view about 6 inches long and that can acqu
many slices of coincidence data at one time.



- PET scanner 50-100 times more sensitive than a gamma camera
- Must correct for scatter & random events using algorithms
- LOR = line of response (coincidence line)
- 2D = with septa

  [1-3 mm thick: 8-10 cm long]
- 3D = w/o septa
- 3D more sensitive than 2D [4-10 times]

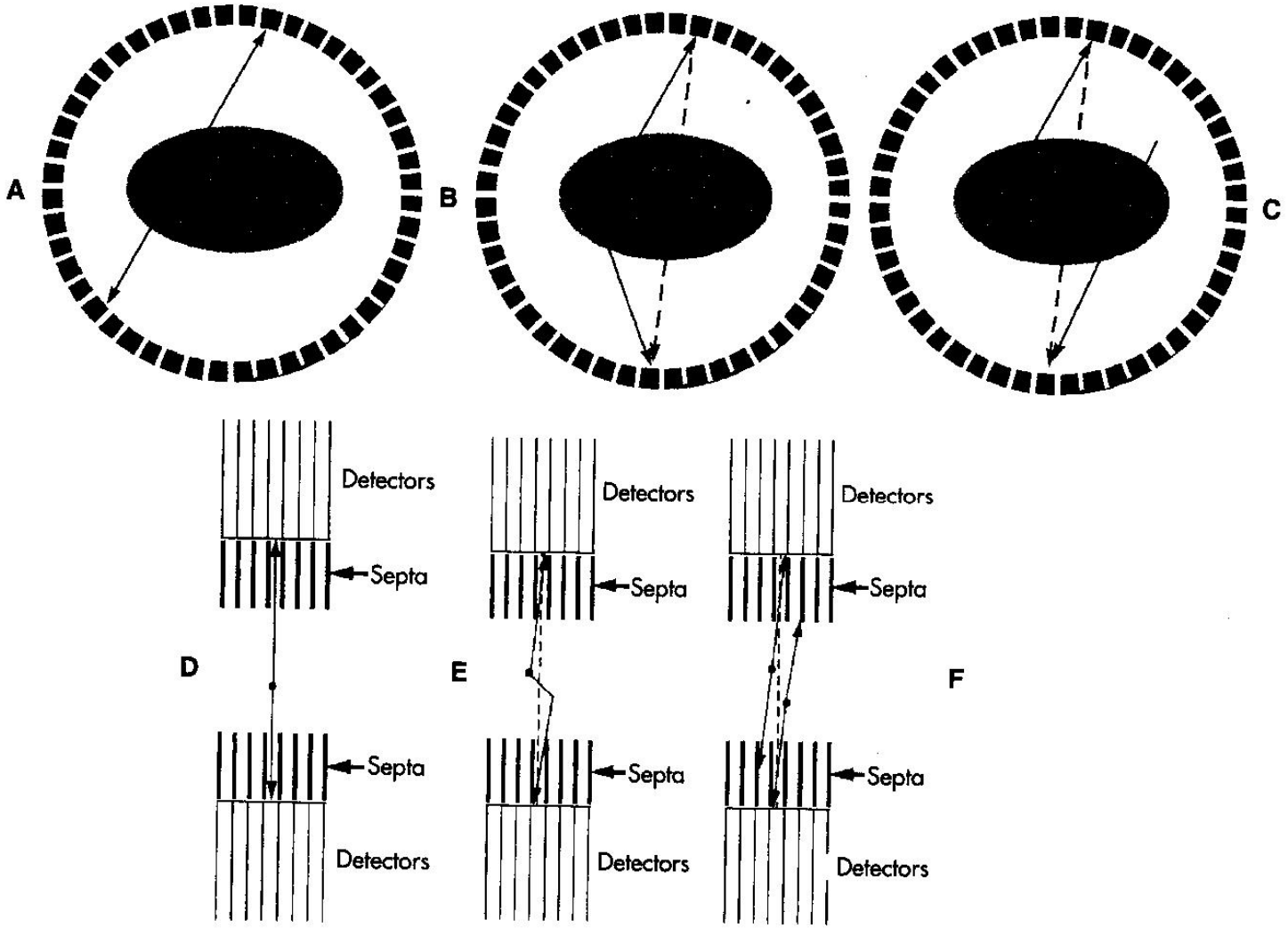
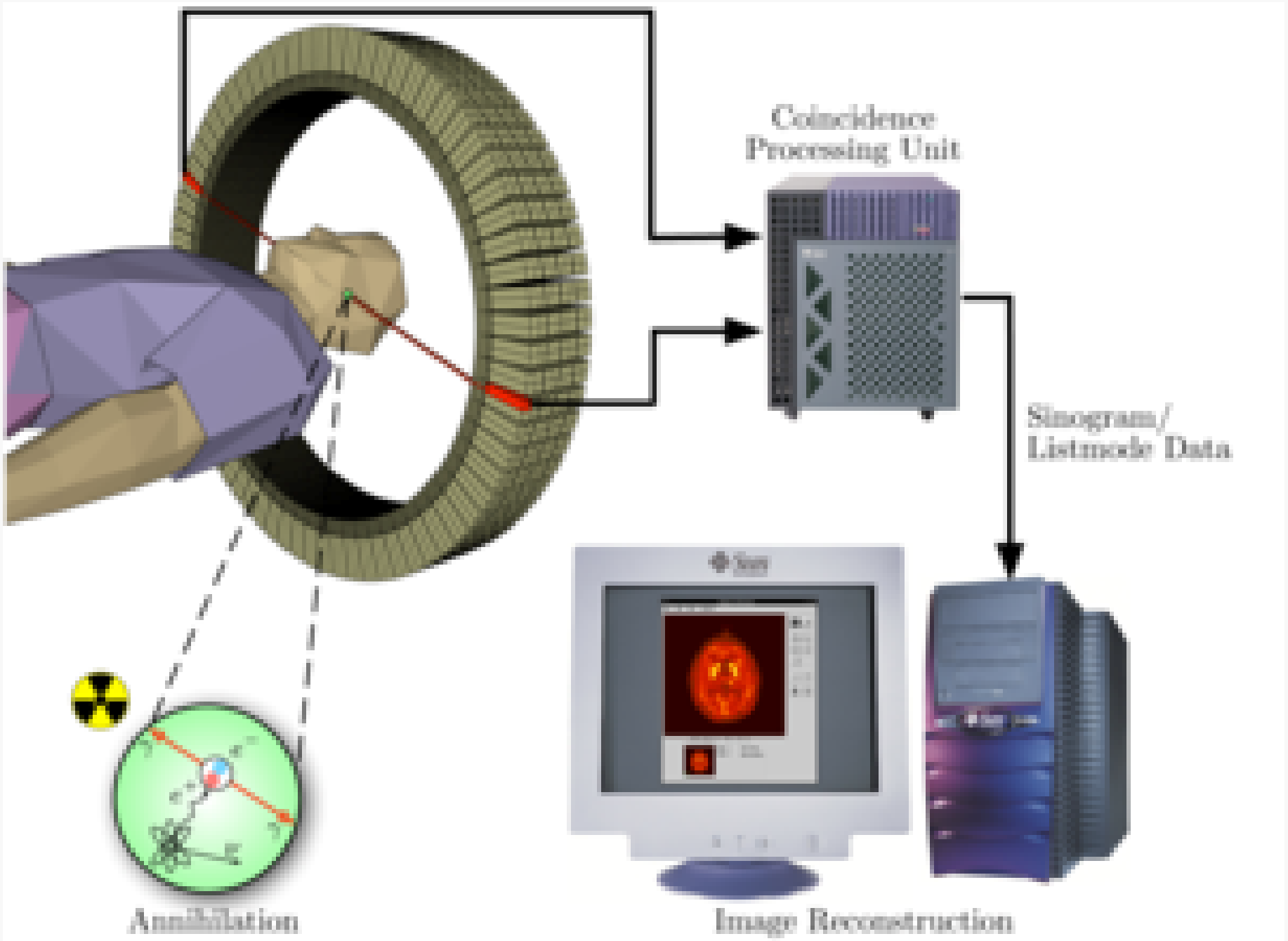
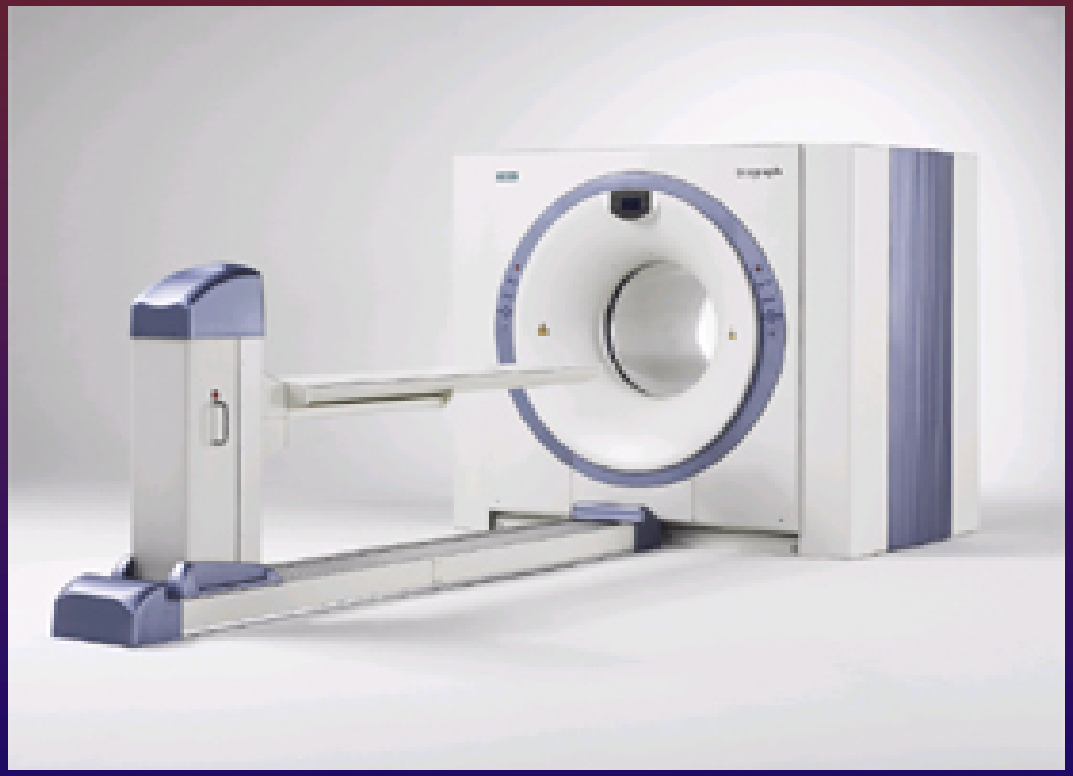


Figure 10-8 True coincidence detections are depicted in the left diagrams (**A** shows transaxial event, while **D** shows axial interactions). Scattered photons (**B, E**) also create a false location of the coincidence *(dotted line)* by misdirecting photons to a false location. Random events (**C, F**) occur when two disintegrations happen within the timing window and one photon from each creates a false coincidence.


Coincidence
Processing Unit
Sinogram/
Listmode Data
Annihilation
Image Reconstruction

PET/CT SCANNER



- PET & CT in the same gantry
- CT first for anatomy and later attenuation correction
- No misalignment between the two studies
- CT FOV usually smaller

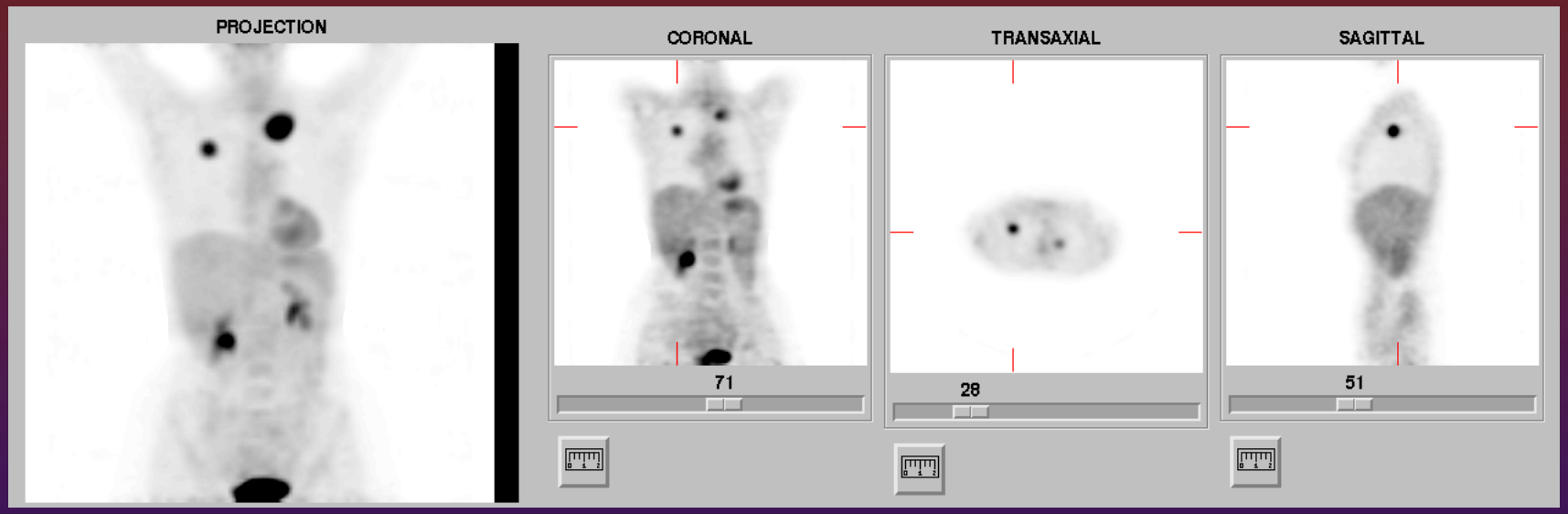
The PET Procedure:

- The technologist administering a tracer, either by injection through an I.V.
- The patient then rests quietly in a dimly lit, shielded room for 30 to 90 minutes to let the tracer distribute throughout the body.

The PET Procedure (cont):

- The patient is placed on the scanner
- The scan takes about 30 minutes for a whole-body study (eyes to thighs)

The image is then generated

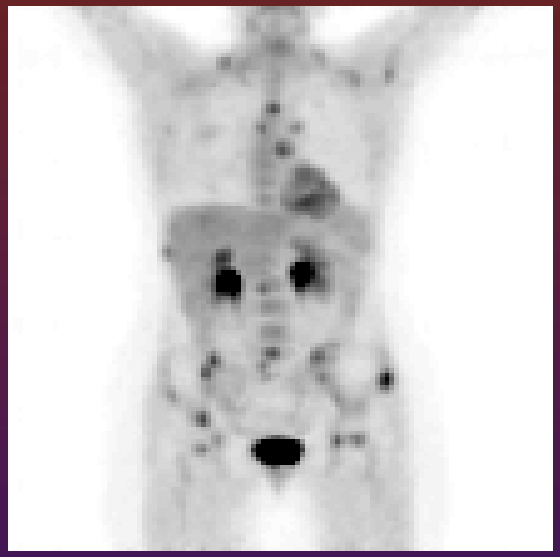


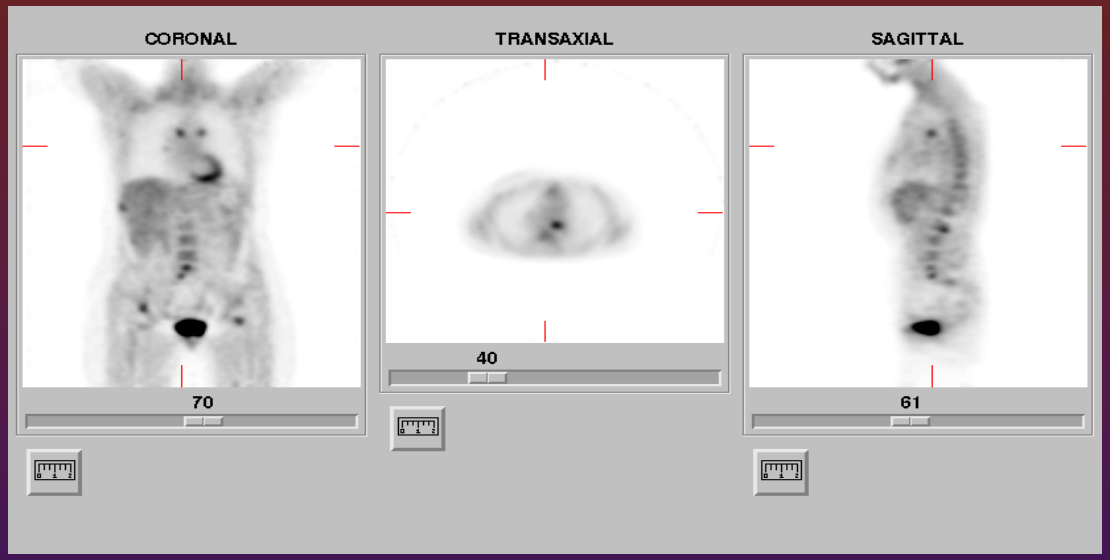
The patient, 47 year-old female with non small cell lung carcinoma, was administered an IV injection of 8.87 mCi of F18 labeled Fluorodeoxyglucose and approximately 45 minutes later the patient underwent whole body imaging.

INTENSE UPTAKE IDENTIFIED IN BOTH THE LEFT APICAL AND RIGHT UPPER LOBE LESION COMPATIBLE WITH CARCINOMA

{ University of Kansas: http://www.rad.kumc.edu/nucmed/ }

Metastasis

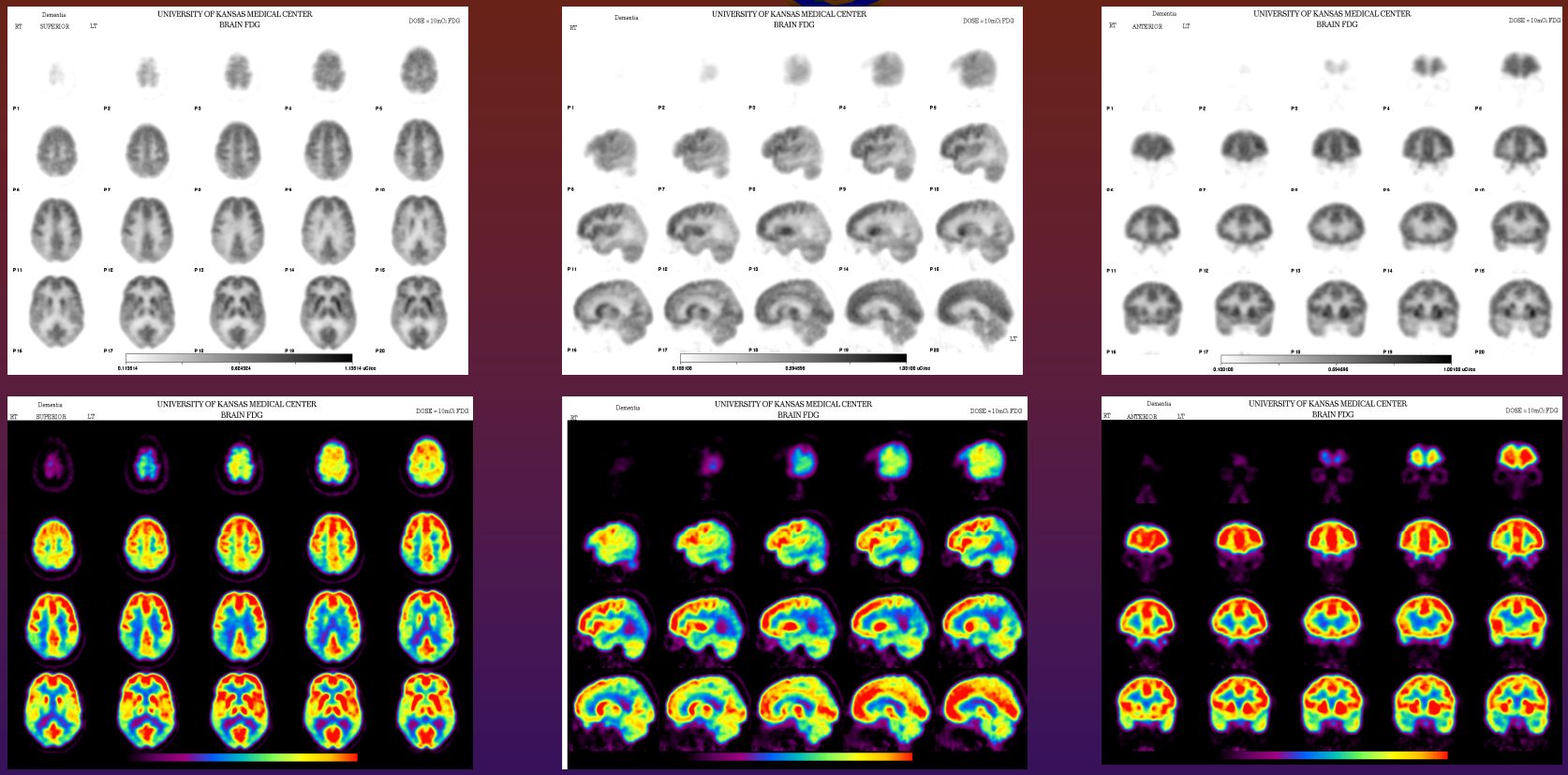




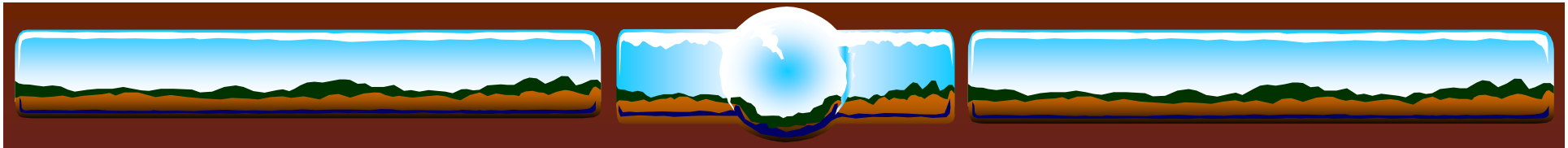
A 47-year-old female with a history of metastatic breast cancer received an intravenous injection of 10 millicuries of F18-FDG and approximately an hour later whole body PET imaging was obtained.

{ University of Kansas: http://www.rad.kumc.edu/nucmed/ }

ALZHEIMER'S DISEASE



This is a 51-year-old female with poor memory, visual tracking, dementia, and jerking. There is diminished F-18 FDG uptake in the parietal lobes bilaterally as well as the medial temporal and anterior temporal regions bilaterally { University of Kansas: http://www.rad.kumc.edu/nucmed/ }



PET Radiation Safety

Facility requires leaded walls and shielded uptake rooms (especially for PET/CT)

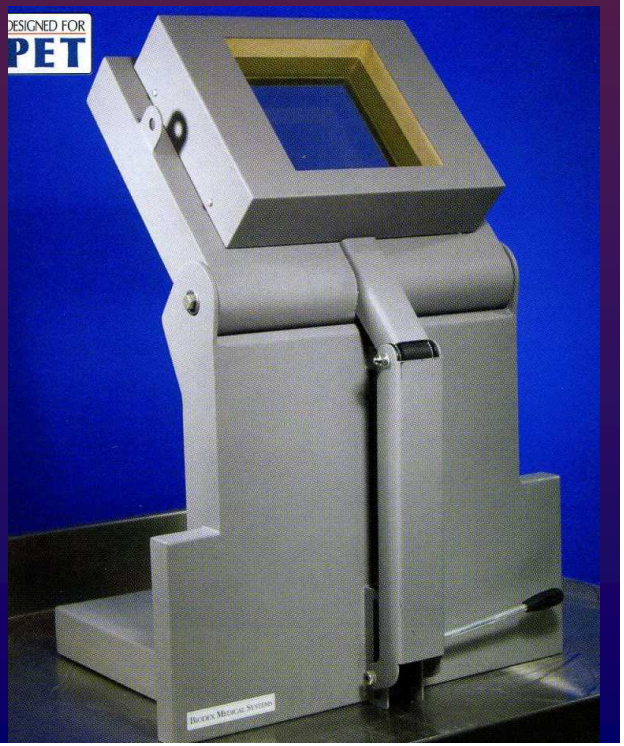
PET Tech commonly have higher rad dose

- **511 keV photons from Rp dose**
- **~200-300 kev photons from patient**
- **Ge-68 or Cs-137 source in gantry used for transmission scans**

PET Radiation Safety cont

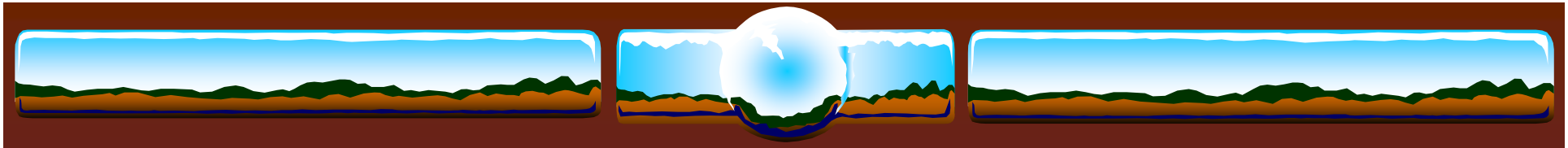
Shielding

- **Tungsten better than lead**
- **HVL for 511 keV using tungsten = 4 mm**
- **Tungsten 1.4 times as effective as lead**
- **L-block should have 1-2” thick lead & 4” thick leaded glass**



PET Radiation Safety cont

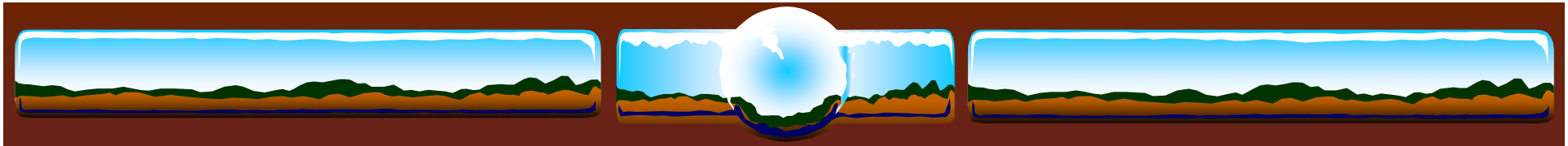
- Use special syringe shield or dosing device
- Store used IV line, syringe, etc, behind shielding



PET Radiation Safety cont

Distance

- Exposure 1 meter from Pt w/ 10 mCi dose = 1 mR/hr
- Explain procedure and answer questions before dosing
- Keep distance from patient
- Keep patient isolated in shielded room during the uptake period = 45-90 minutes
- Prove exposure to MOP is acceptable



CT

- Stay out of the room during the CT scan
- Don’t do unnecessary scout scans, which increase patient dose