

Methods in Image Analysis
Theory Lecture 1 – The Poet's Eye

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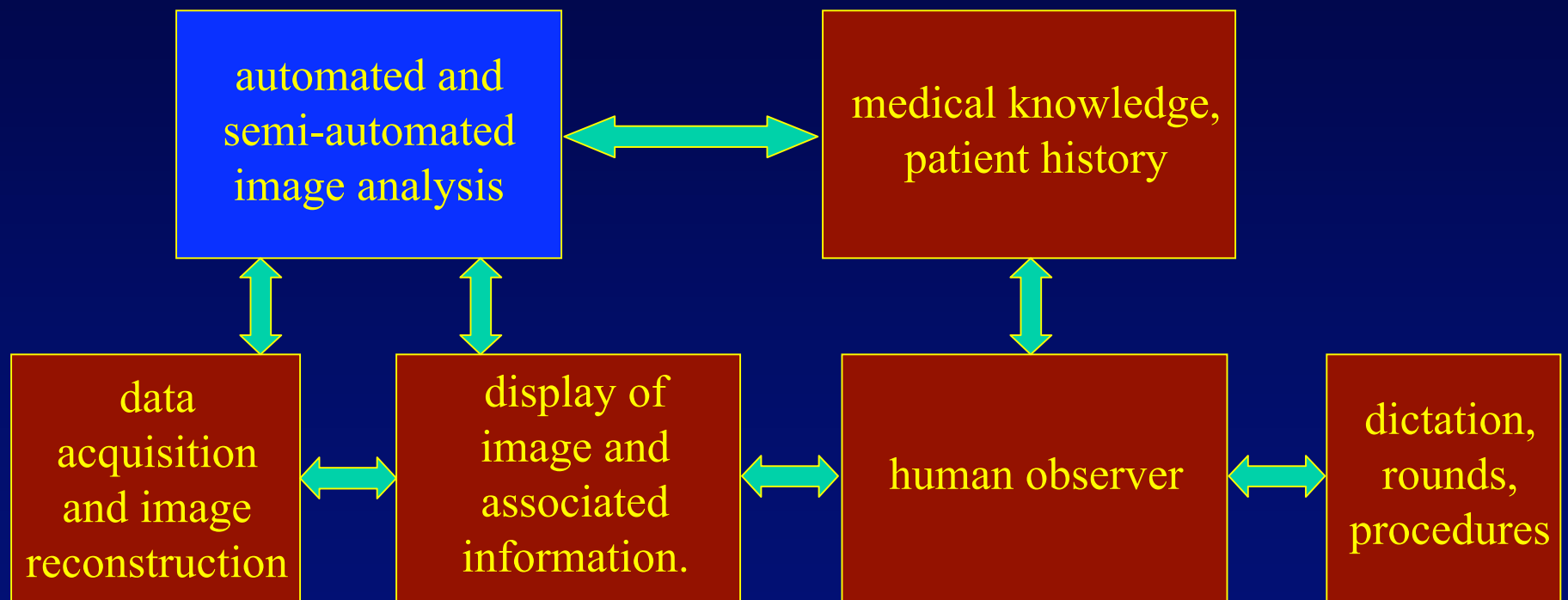
16-725/BioE 2630 Course Structure

- Review our website
- Very project oriented
- ITK community
- Strong computer vision community at CMU
- Analogy to the factory floor
 - Computer vision works there, discard irregulars
 - In medicine, every patient is irregular

Methods in Medical Image Analysis

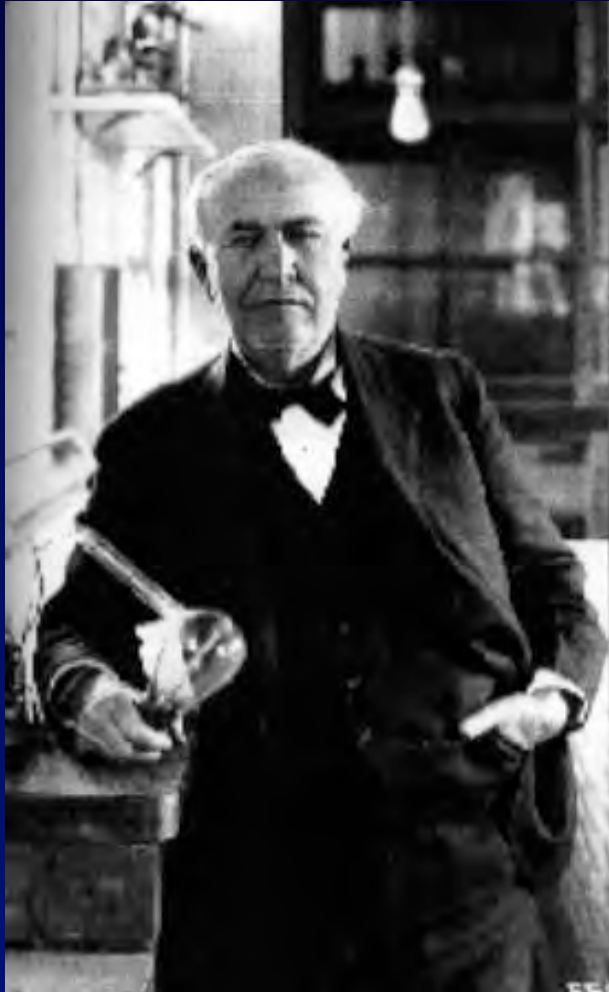
- There is a patient out there.
- Medicine is a war:
 - Surgeons are the marines.
 - Anesthesiologists are the air force.
 - Psychiatrists are the diplomats
 - Radiologists (and Pathologists) are reconnaissance.
- Life-&-death decisions on insufficient information.
- “Truth” is whether the patient recovers.
- The “Practice” not the “Theory” of medicine.
- Shadow Program

Model of a Modern Radiologist



Methods in Medical Image Analysis

- Simultaneous measurements on a spatial grid.
- Many modalities: mainly EM radiation and sound.

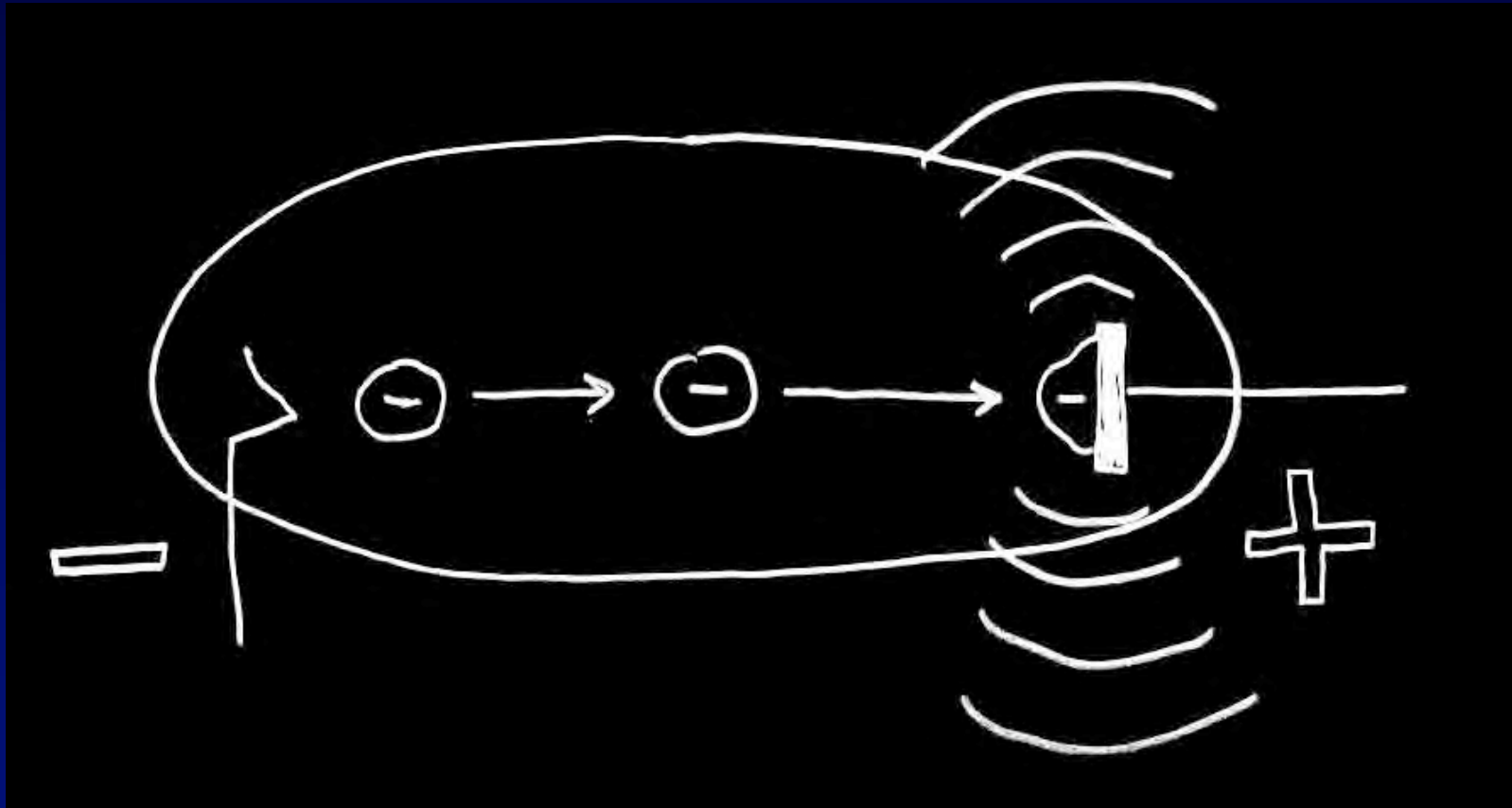


“To invent you need a good imagination and a pile of junk.”

Thomas Edison

1879

Bremsstrahlung

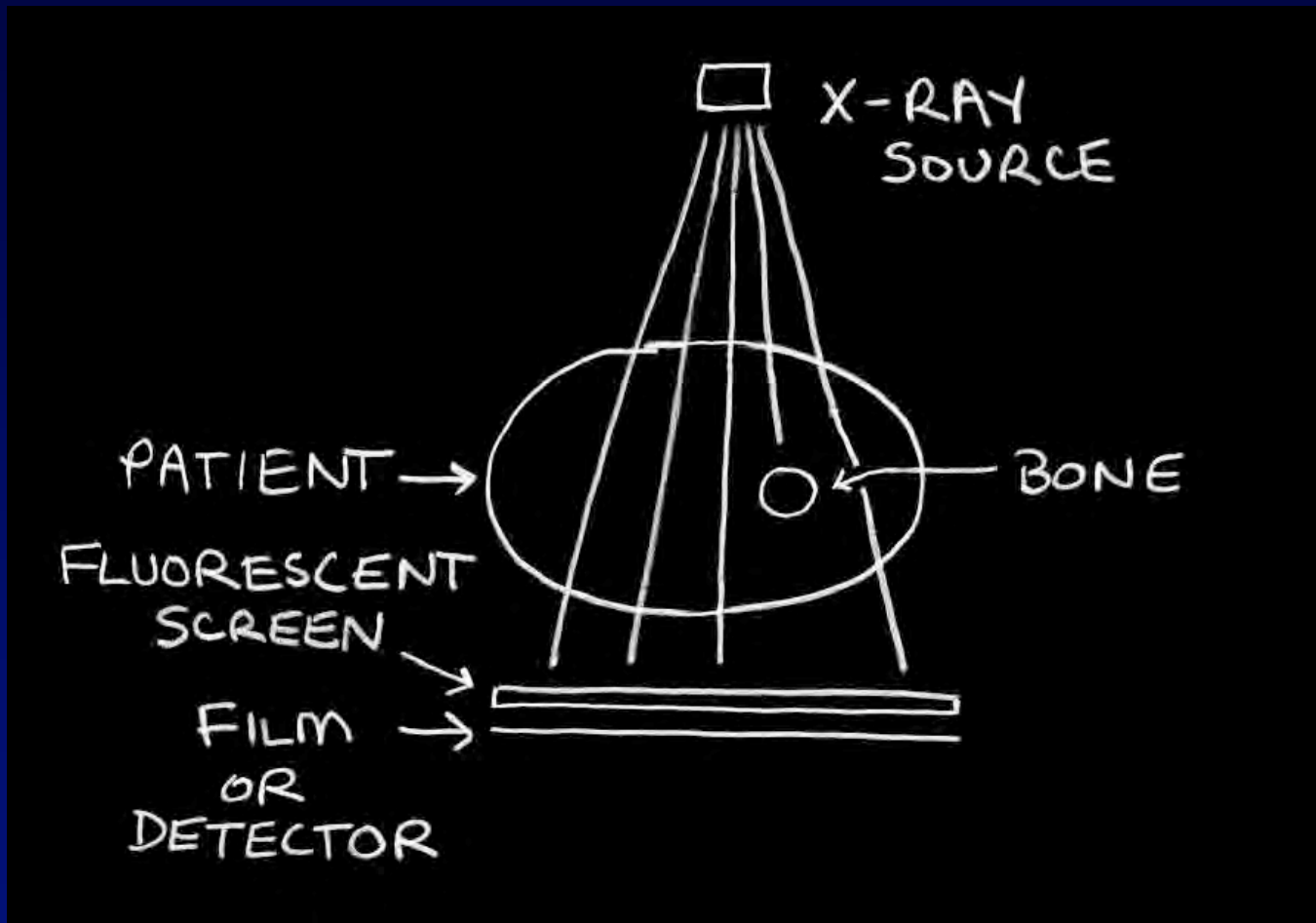


Electron rapidly decelerates at heavy metal target, giving off X-Rays.



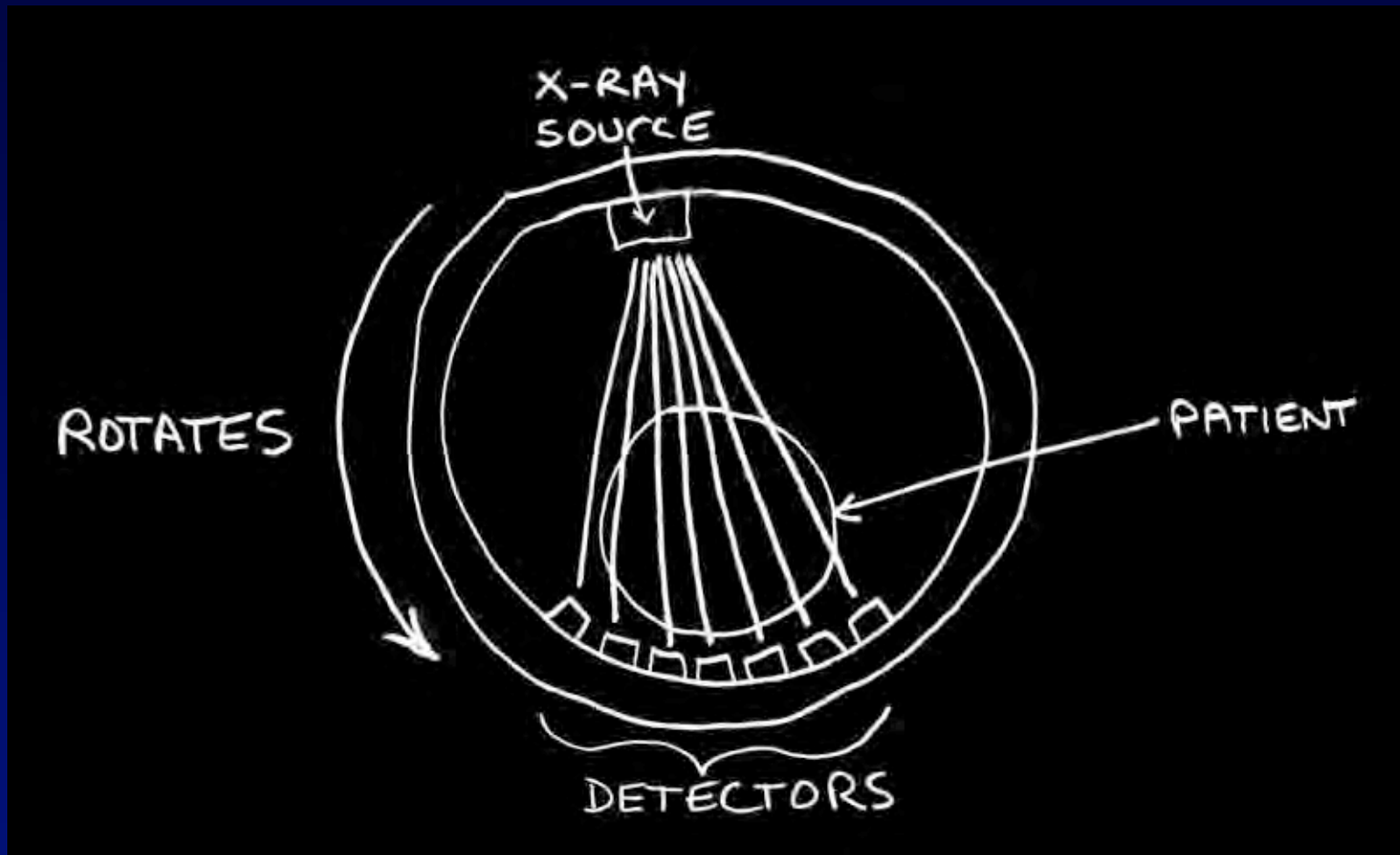
1896

X-Ray and Fluoroscopic Images



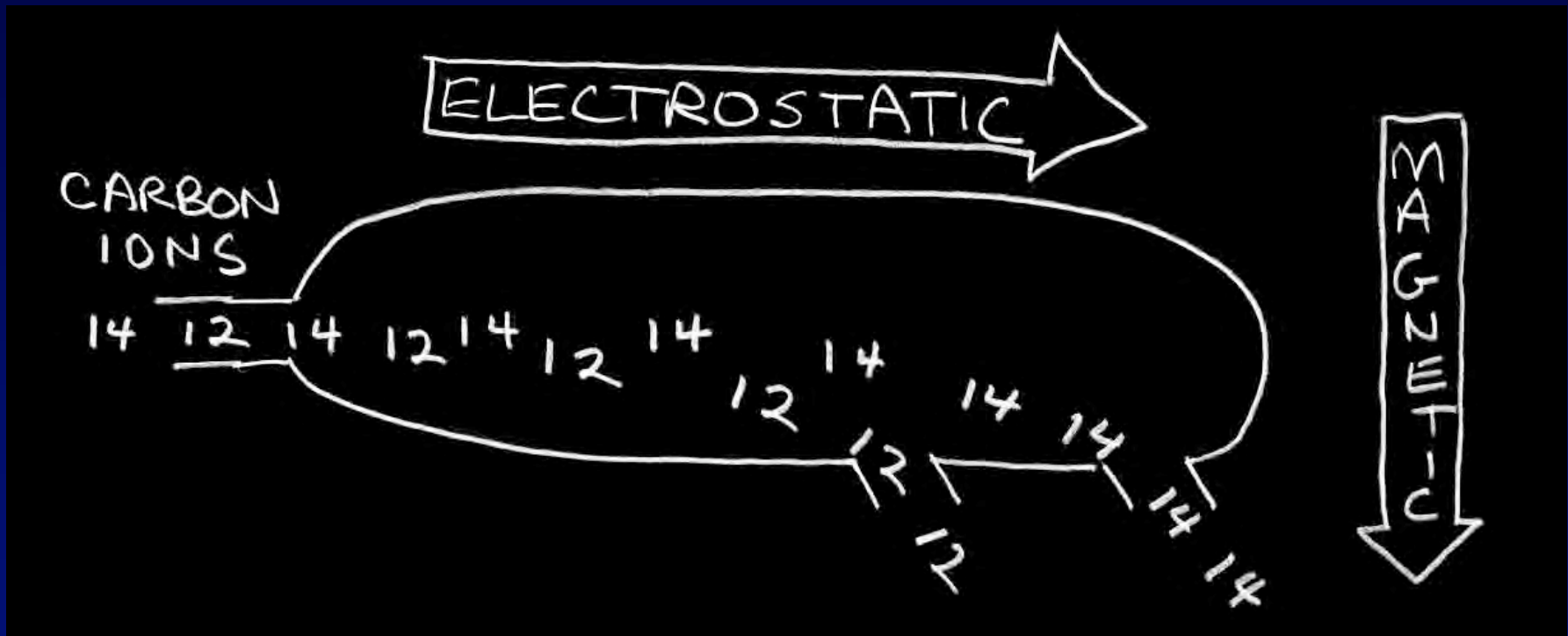
Projection of X-Ray silhouette onto a piece of film or detector array, with intervening fluorescent screen.

Computerized Tomography



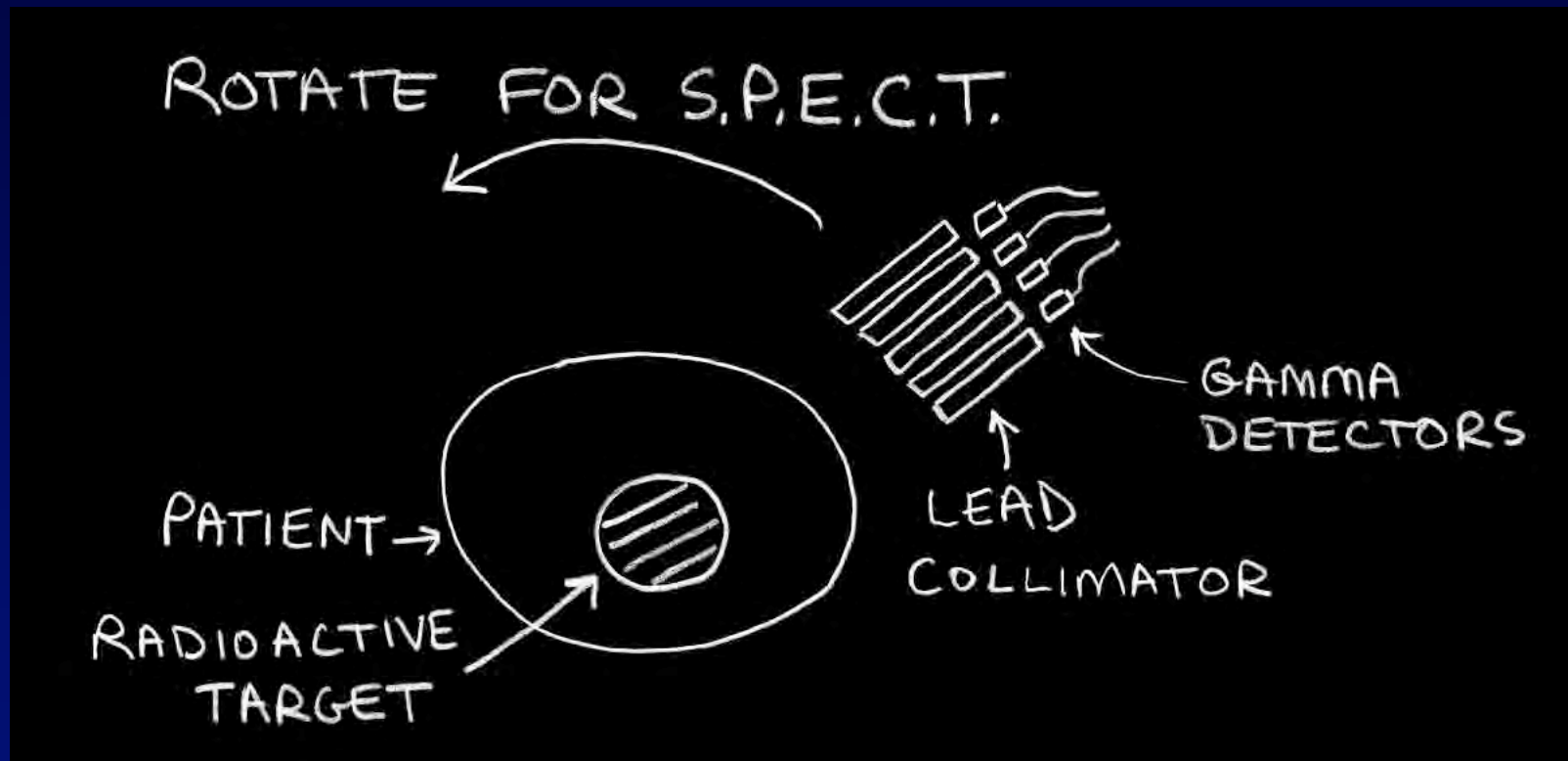
From a series of projections, a tomographic image is reconstructed using Filtered Back Projection.

Mass Spectrometer



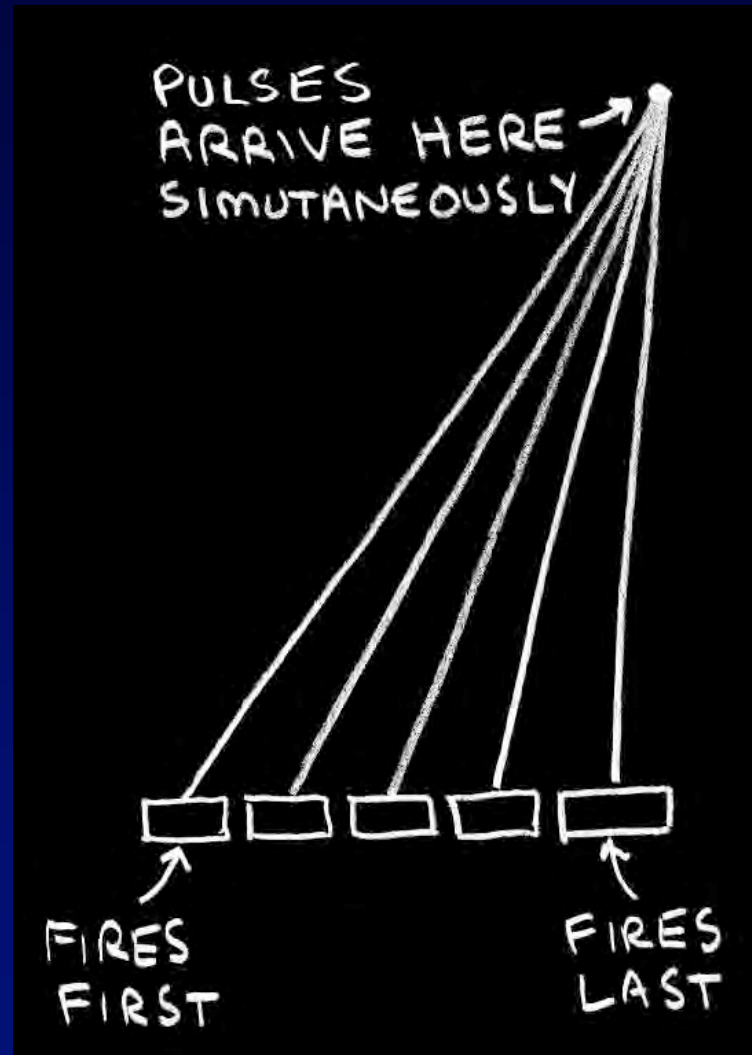
Radioactive isotope separated by difference in inertia while bending in magnetic field.

Nuclear Medicine



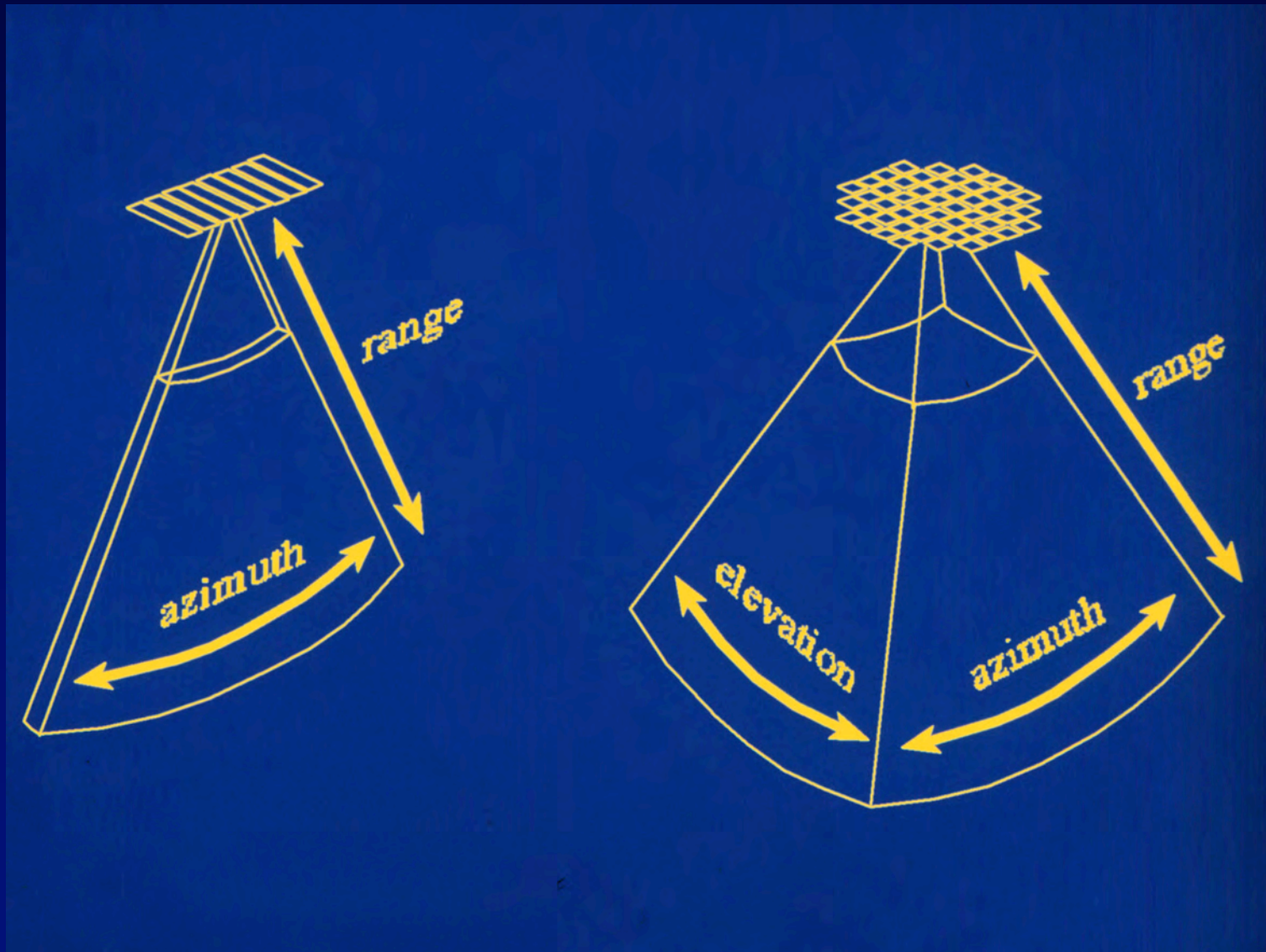
Gamma camera for creating image of radioactive target. Camera is rotated around patient in SPECT (Single Photon Emission Computed Tomography).

Phased Array Ultrasound

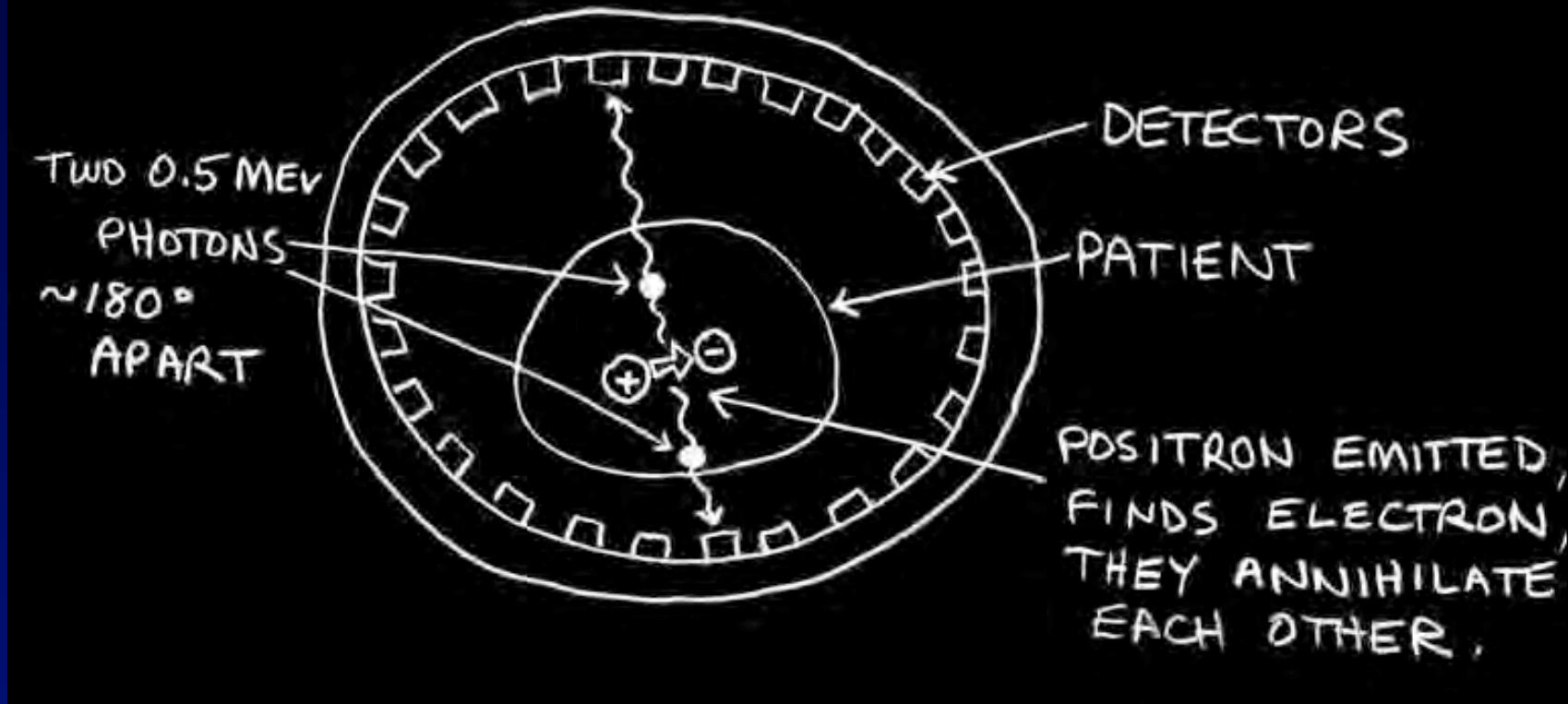


Ultrasound beam formed and steered by controlling the delay between the elements of the transducer array.

Real Time 3D Ultrasound



Positron Emission Tomography



Positron-emitting organic compounds create pairs of high energy photons that are detected synchronously. No collimators, greater sensitivity. Attenuation is not location dependent, so quantification is possible.

Other Imaging Modalities

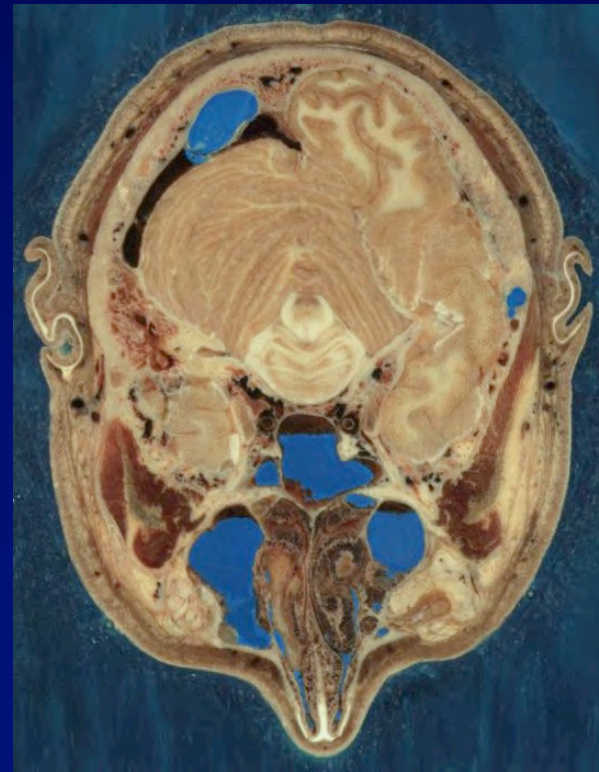
- MRI (will review later, with Fourier lecture)
- OCT
- Pathology (in addition to Radiology)
- Other modalities coming down the pike

Current Trends in Imaging

- 3D
- Higher speed
- Greater resolution
- Measure function as well as structure
- Combining modalities (including direct vision)

The Gold Standard

- Dissection:
 - Medical School, Day 1: Meet the Cadaver.
 - From Vesalius to the Visible Human



Methods in Medical Image Analysis

- Different from “Image Processing”
- Results in identification, measurement, judgment
- Produces numbers, words, and actions
- People talk of “Computer Aided Diagnosis”
- Present state of art:
Segmentation / Registration



Donning his new canine decoder, Professor Schwartz becomes the first human being on Earth to hear what barking dogs are actually saying.

Segmentation

- Labeling every voxel
- Discrete vs. fuzzy
- How good are such labels?
 - Gray matter (circuits) vs. white matter (cables).
 - Tremendous oversimplification
- Requires a model

Registration

- Image to Image
 - same vs. different imaging modality
 - same vs. different patient
 - morphing Superman: topological variation
- Image to Model
 - deformable models
- Model to Model
 - matching graphs

What are these models?

- Top-Down
 - Landmarks
 - Preconceived, optimized to the humans
- Bottom-Up
 - Image primitives, features
 - Unsupervised, optimized to the computer
- Internal Energy vs. Image Energy
 - Often viewed as a Bayesian compromise
 - Perhaps it should, instead, be a *consensus*?

What is Shape?

- Geometric relationships between boundary points
- Curvature
- Medialness (Symmetry)
- Hierarchical structure
- Difficult parameterize in 3D

Analysis and Visualization

- *Visualization* used to mean *to picture in the mind*.
- Retina is a 2D device
- Analysis needed to visualize surfaces
- Doctors prefer slices to renderings
- Visualization is required to reach visual cortex
- Computers may first beat humans in 3D

Methods in Medical Image Analysis

- Computer programs (fully- and semi-automated).
- Equations that function: crafting human thought.
- Very application-specific, no general solution.
- ITK is a library, not a program.
- A kitchen of recipes, a “pile of junk.”
- Supervision / Apprenticeship of machines

*"The poet's eye, in a fine frenzy rolling,
Doth glance from heaven to earth, and earth to heaven,
And as imagination bodies forth
The forms of things unknown, the poet's pen
Turns them to shapes, and gives to airy nothing
A local habitation and a name."*

*King Theseus, from A Midsummer Night's Dream,
by William Shakespeare*