Intelligent Analysis of Biomedical Images

Presenter: Mohammad H. Rohban, Ph.D.

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Courtesy: Some slides are adopted from CSE 377 Stony Brook University and CS 473 U. Waterloo

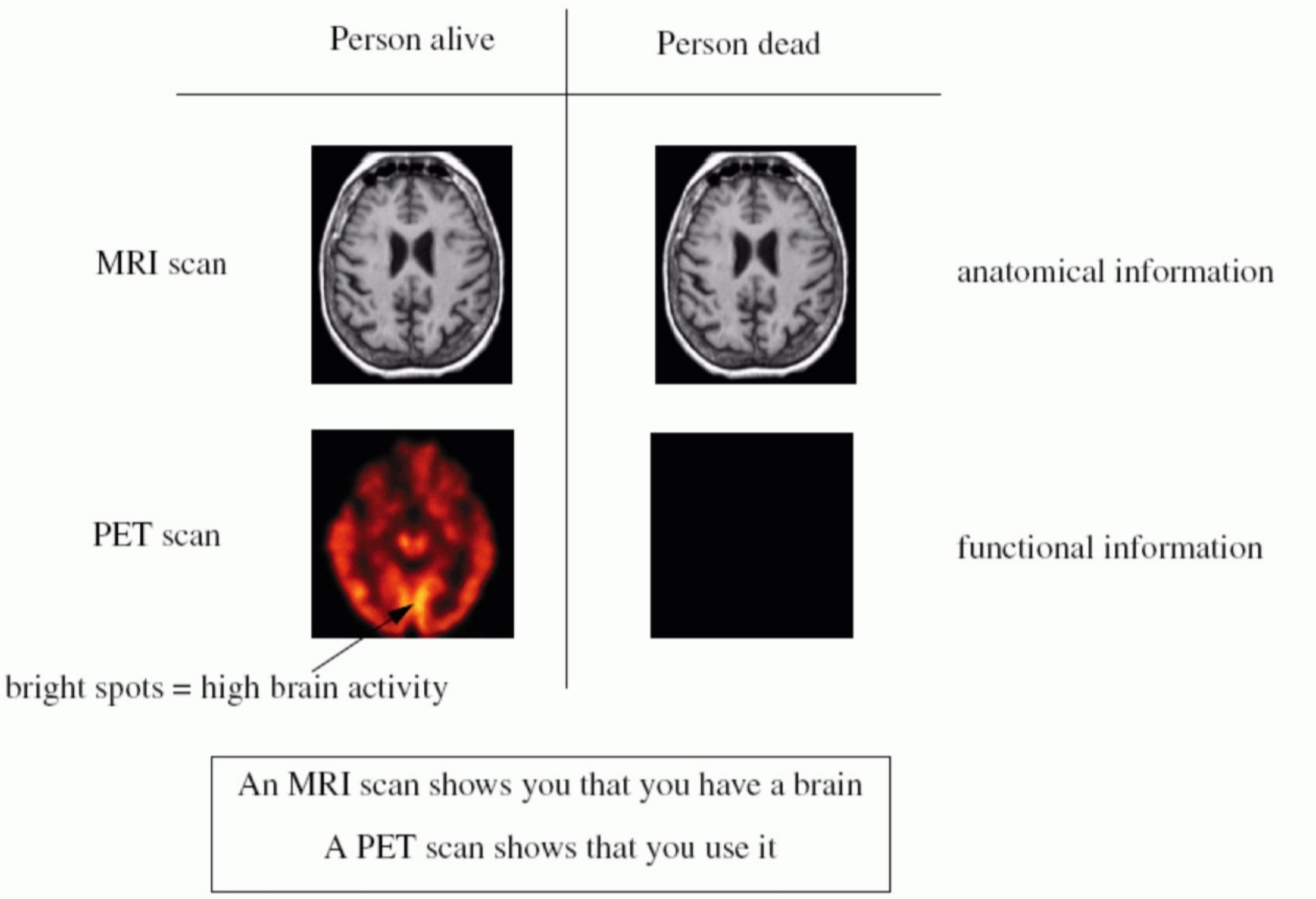
Positron Emission Tomography (PET)

Goal: To find out what a PET scan is, how it works (briefly), and what it is used for.

PET stands for "Positron Emission Tomography" .
Similar to CT in that the scanner detects radiation using a ring of detectors.

Different than a CT scanner because the radiation is emitted from inside the body, rather than being transmitted through the body (as in CT)

PET is a functional imaging modality. That means it is used to observe where in the body a particular function is occurring. For example, one might want to know where rapid tissue growth is taking place (to locate growing tumors). This is different from viewing the tissue itself.

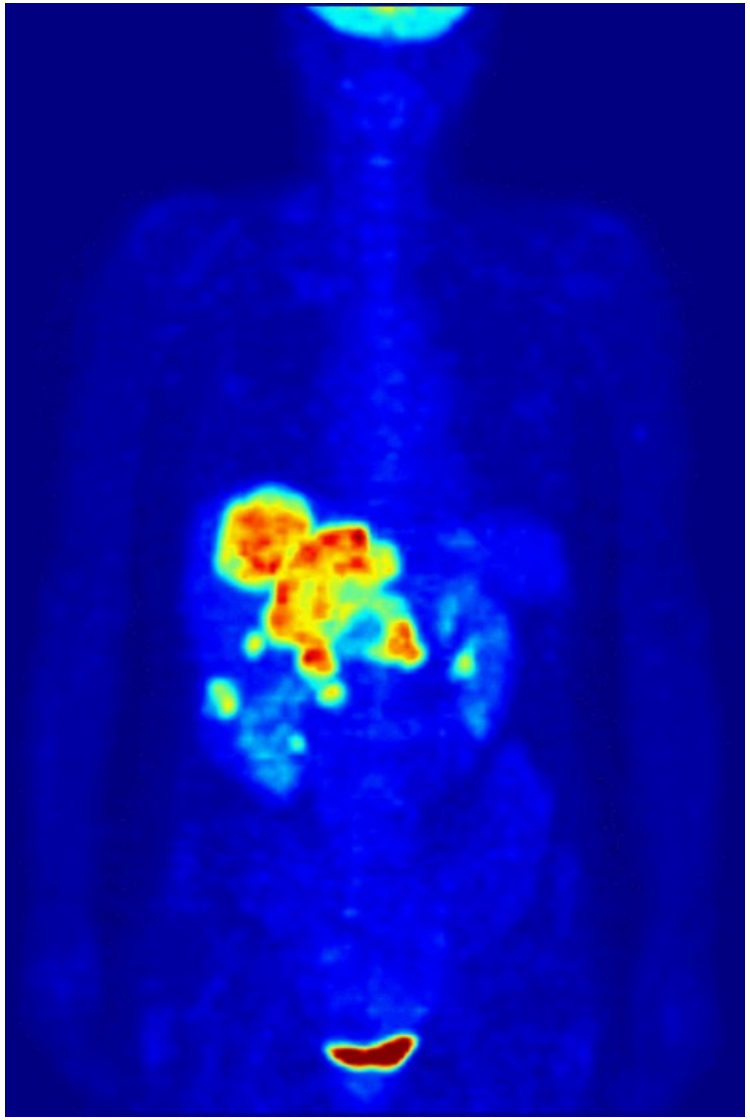

Person alive
Person dead
MRI scan
anatomical information
PET scan
functional information
bright spots = high brain activity
An MRI scan shows you that you have a brain
A PET scan shows that you use it

How does it work?

A small amount of positron-emitting radioisotope is injected into the subject. This radioisotope is bound to a metabolite that is used in the function we wish to observe. For example, glucose can be tagged to produce

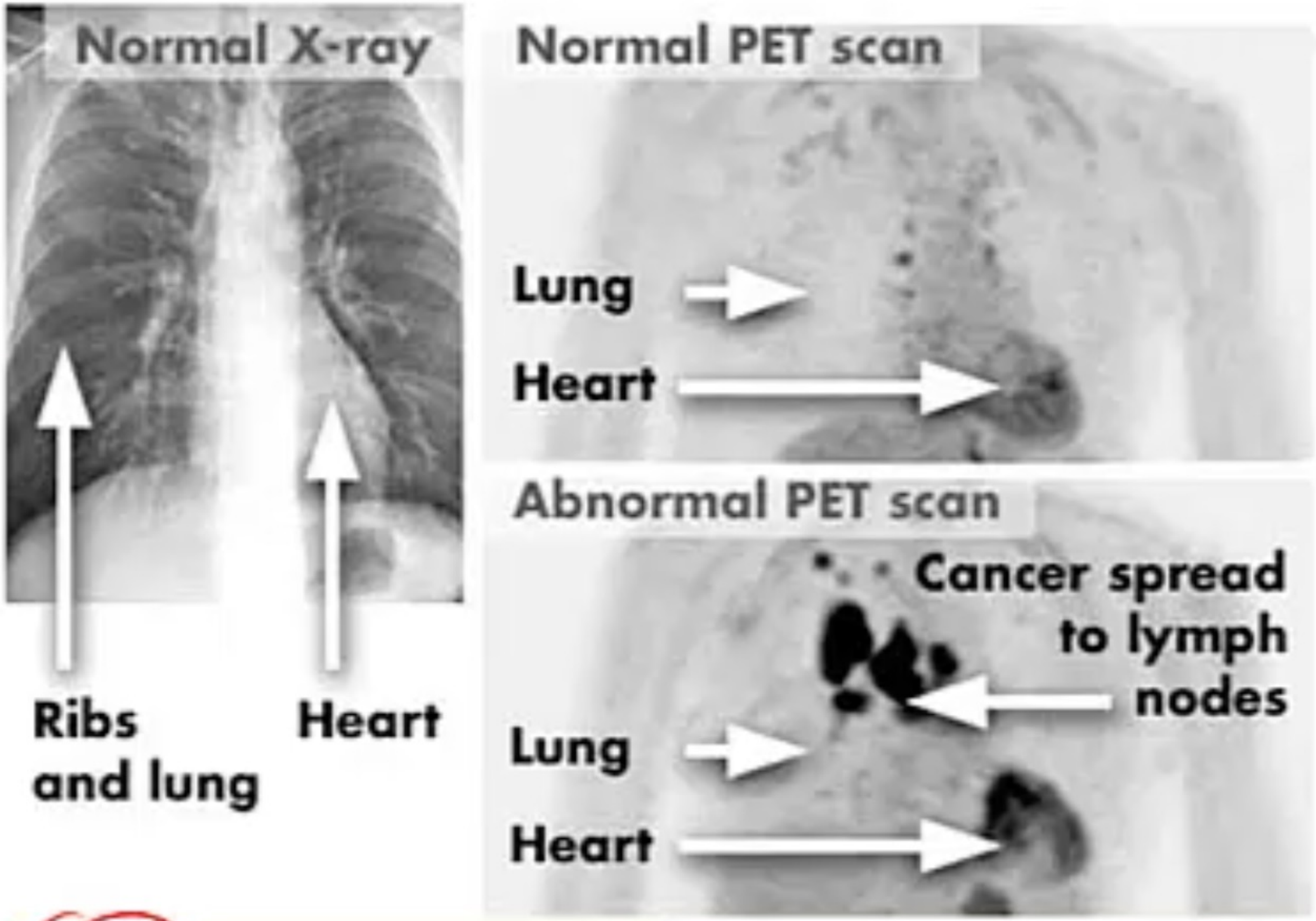
fluoro-2-deoxy-D-glucose (FDG)

Whole-body PET scan using ^{18}F-FDG to show liver metastases of a colorectal tumor



The FDG will migrate to the sites where glucose is being consumed rapidly. Malignant tumors require a lot of glucose to grow, and tend to cause a locally high concentration of FDG. PET imaging can estimate the concentration of the radioisotope in tomographic sections

High concentration is shown dark



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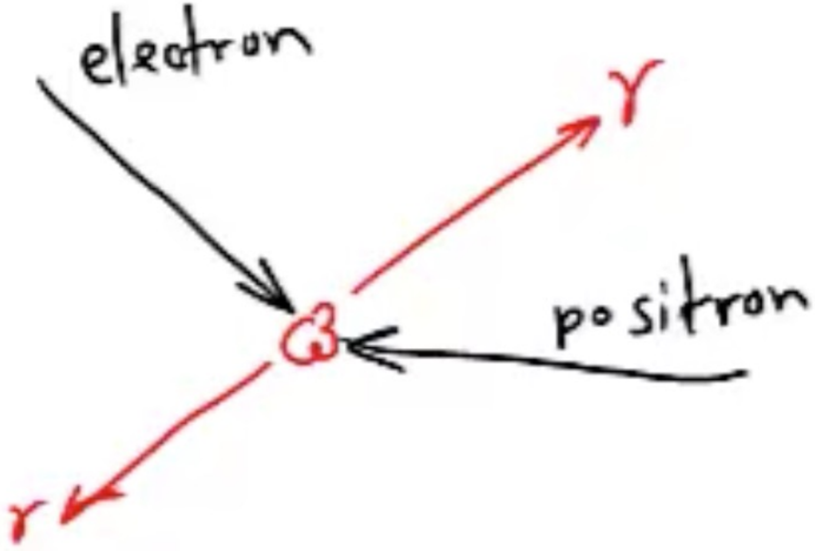
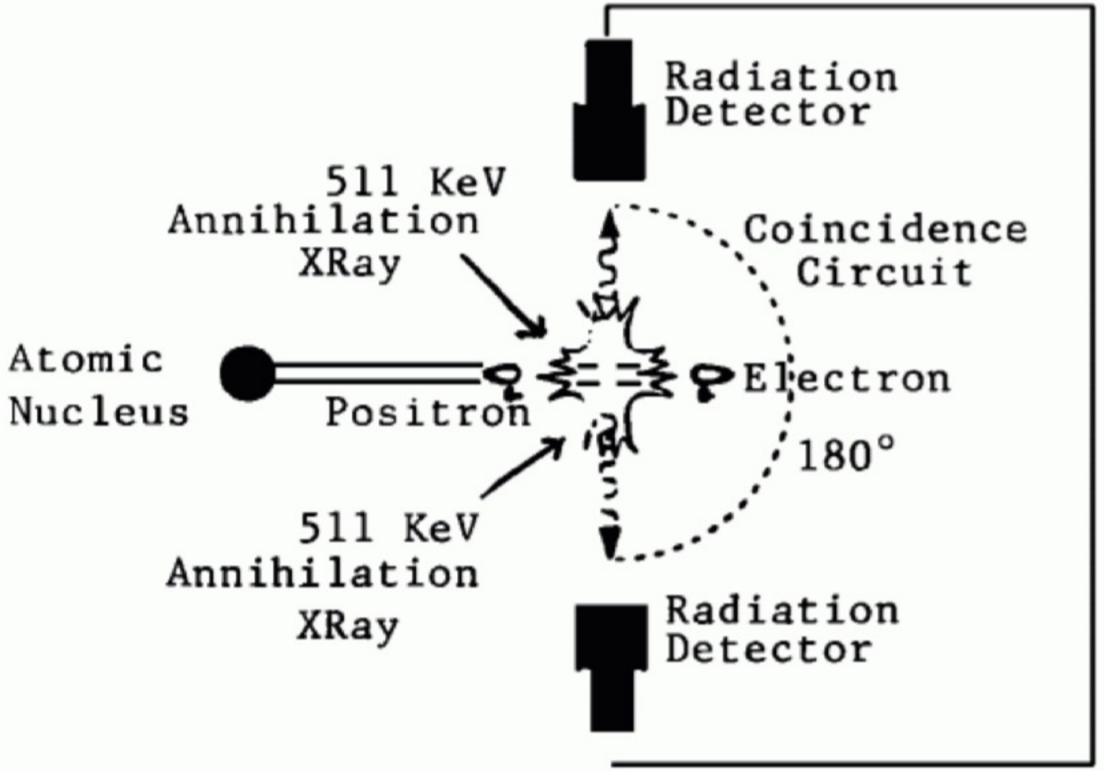
As the radioisotope decays, it gives off positrons. Each positron collides with an electron, and they annihilate each other. But the event releases two gamma rays in opposite directions. These rays are each 511 keV.

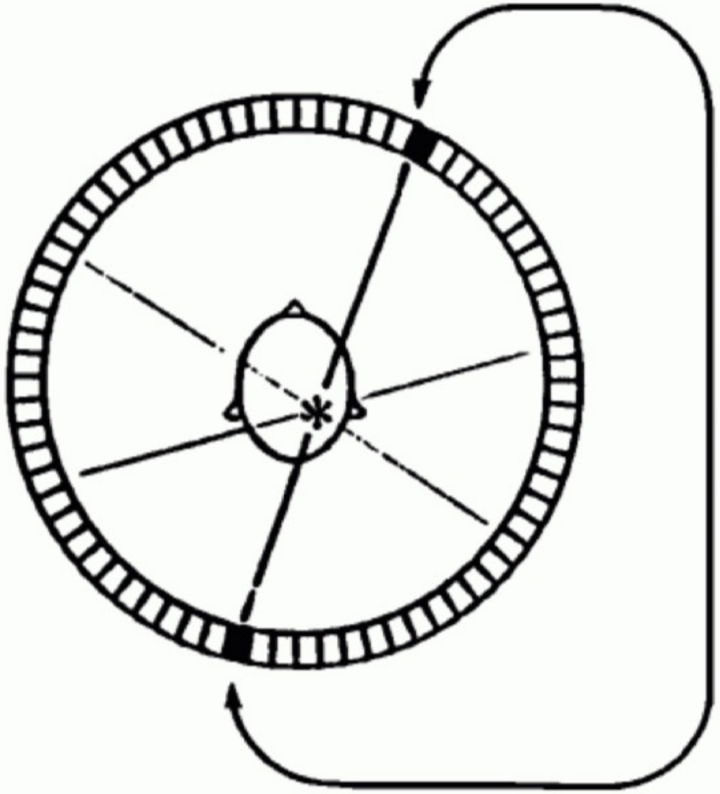


The scanner listens for 2 gamma rays being acquired

these 2 rays likely originated from the same annihilation event. Hence, we know that the radioisotope was somewhere

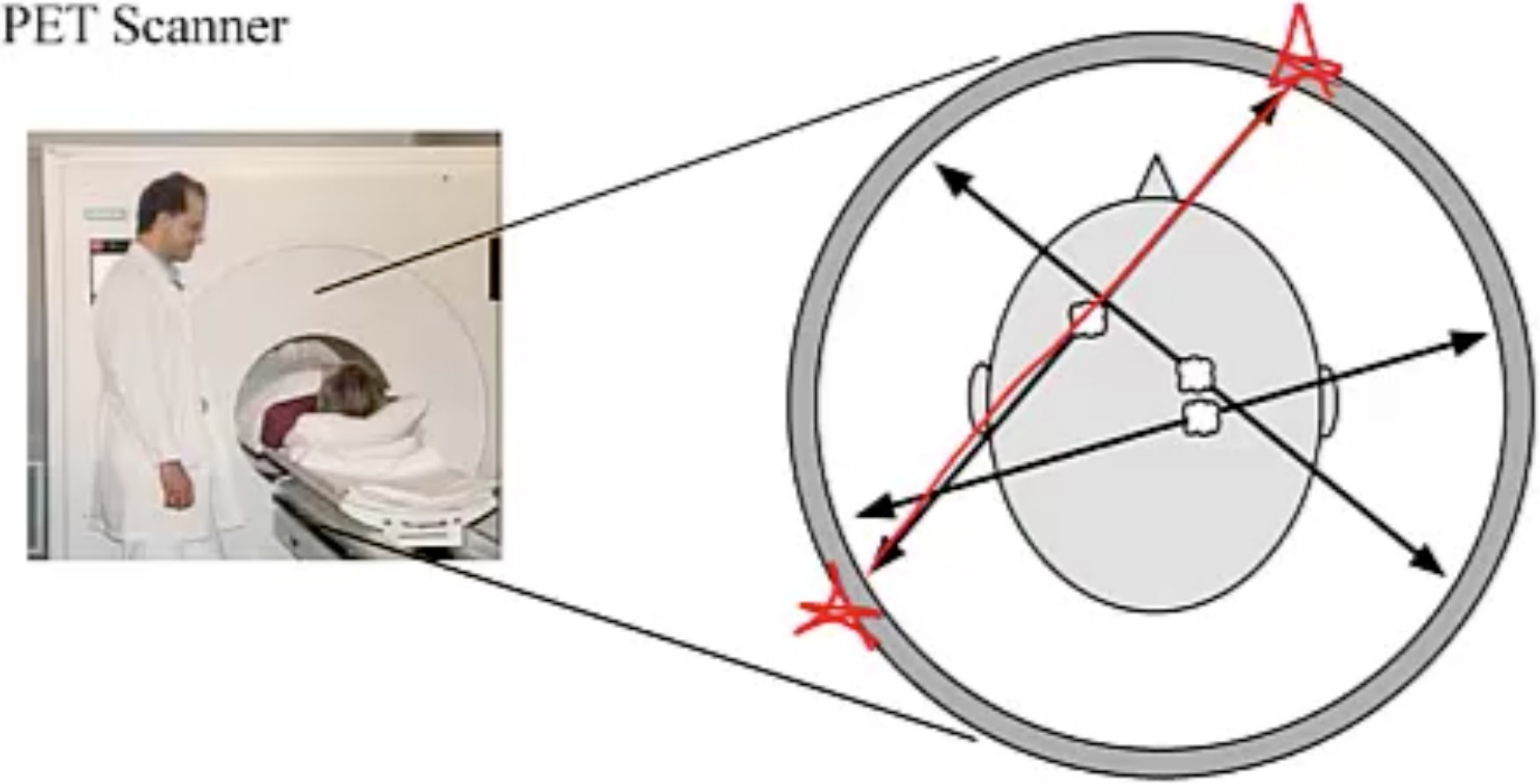


Principles of Decay and Detection



PET Detector Ring Coincidence Imaging

PET Scanner



Properties of PET

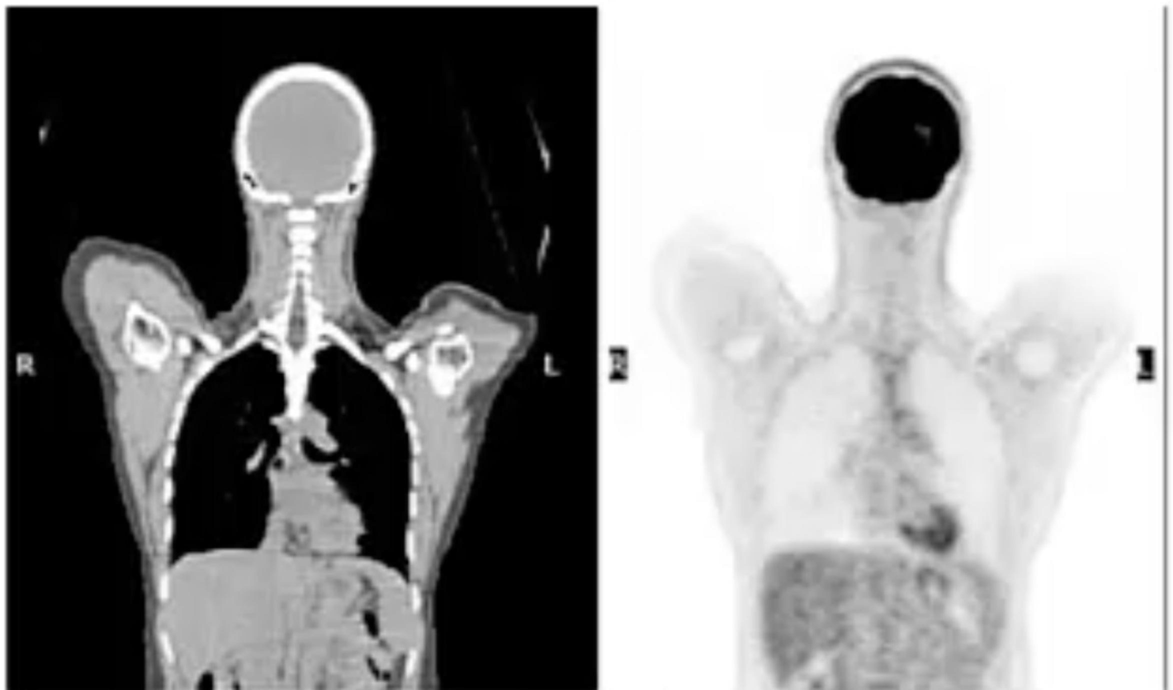
Speed

PET scans take a long time (30 mins. To 3 hrs.), so patient motion is a problem. After that time, the radioisotope has decayed to a very low level; the half-life of FDG is 108 minutes.

Ionizing Radiation

As the gamma rays exit the body, they encounter tissues. Just like in normal x-rays, these gamma rays can be absorbed, and the probability depends on the tissue type (eg. Bone absorbs better than fat).

To properly reconstruct the isotope concentration, one needs to know the map of attenuation coefficients… that's essentially what a CT scan gives. So, a PET scan is always accompanied by a

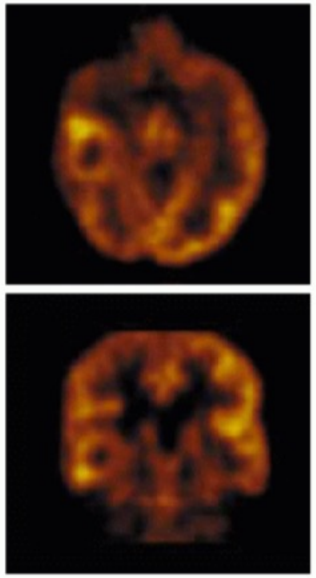


PET scan takes usually 30 min (brain) to 60 min (whole body)

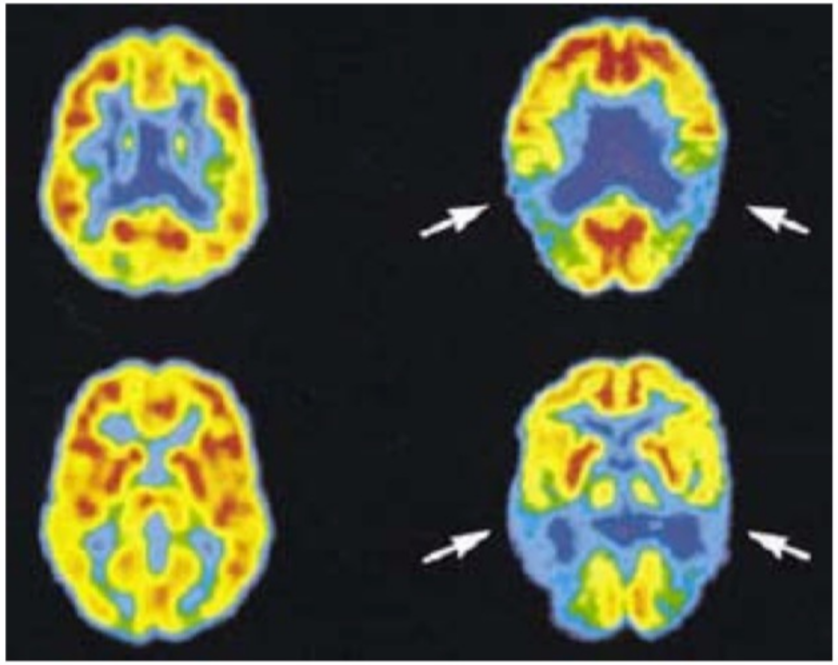
Usually displayed pseudo-colored:

- red, yellow: high activity
- green, blue: low activity

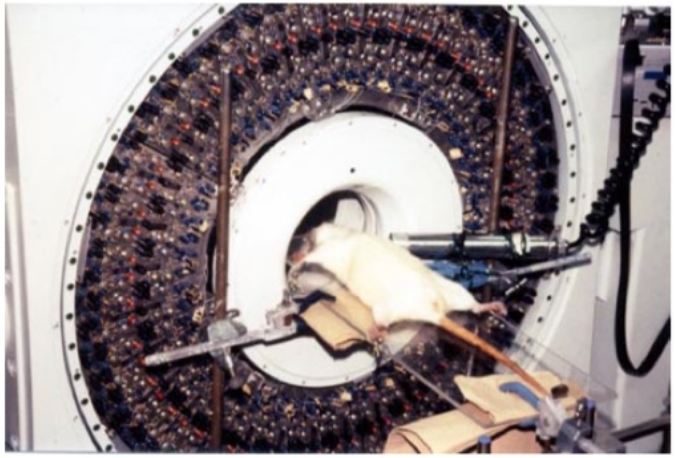
normal Alzheimer’s

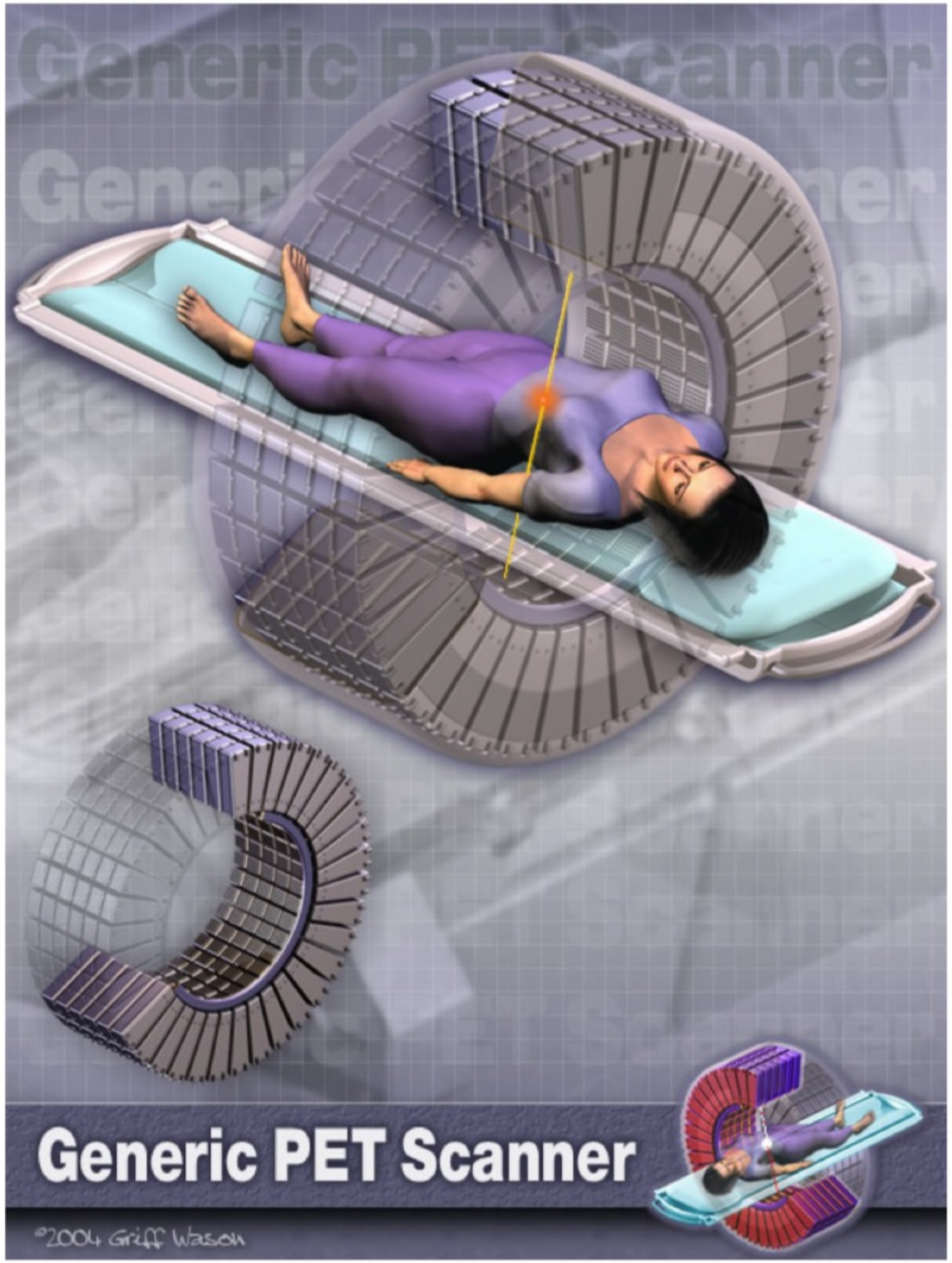


raw



Pseudo-colored




Generic PET Scanner
©2004 Griff Wason

Simultaneous Iterative Reconstruction Technique (SIRT)

Iteration step:

$$\boldsymbol{v}^{(k+1)} = \boldsymbol{v}^{(k)} + \boldsymbol{C}\boldsymbol{W}^T \boldsymbol{R}(\boldsymbol{p} - \boldsymbol{W}\boldsymbol{v}^{(k)})$$

$$\boldsymbol{R} \in \mathbb{R}^{m \times m} \quad r_{ii} = 1/\sum_{j=0}^{n-1} w_{ij}$$

$$\boldsymbol{C} \in \mathbb{R}^{n \times n} \quad c_{jj} = 1/\sum_{i=0}^{m-1} w_{ij}$$

1. Weighted projection difference

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Solves $\boldsymbol{v}^* = argmin_{\boldsymbol{v}} ||\boldsymbol{p} - \boldsymbol{W}\boldsymbol{v}||_{\boldsymbol{R}}$ with $||\boldsymbol{x}||_{\boldsymbol{R}} = \boldsymbol{x}^T\boldsymbol{R}\boldsymbol{x}$

$$v^{(1)} = v^{(0)} + CW^T R(p - Wv^{(0)})$$

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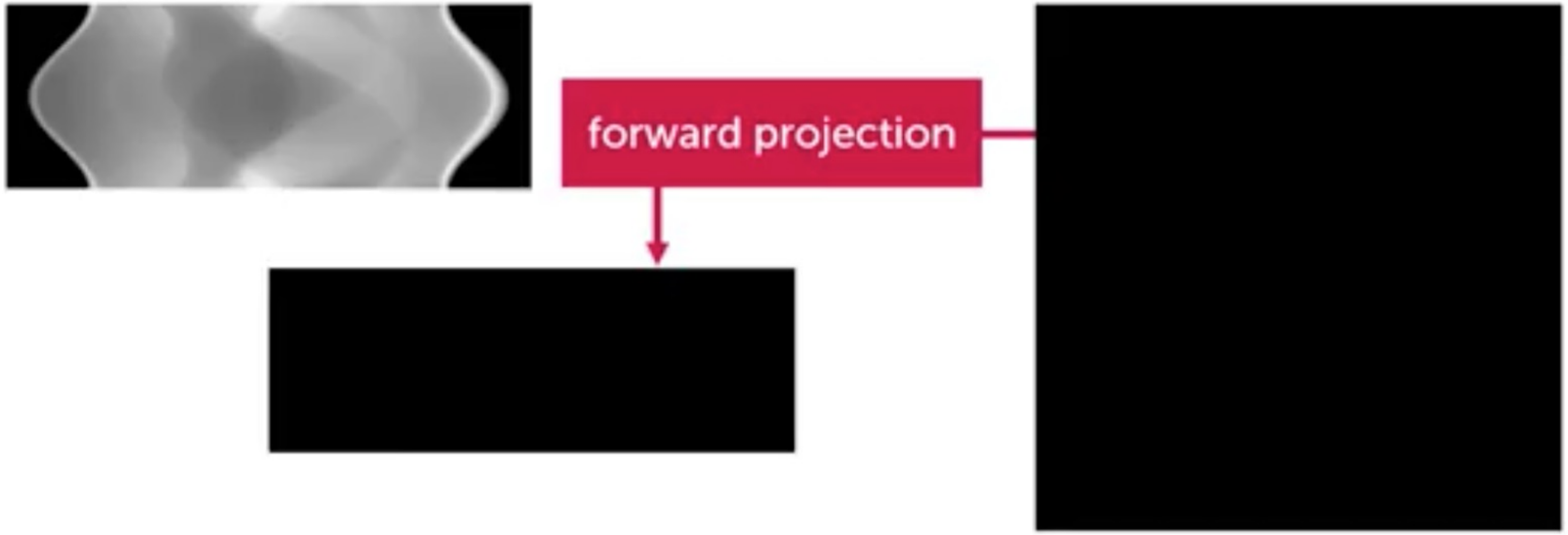

SIRT

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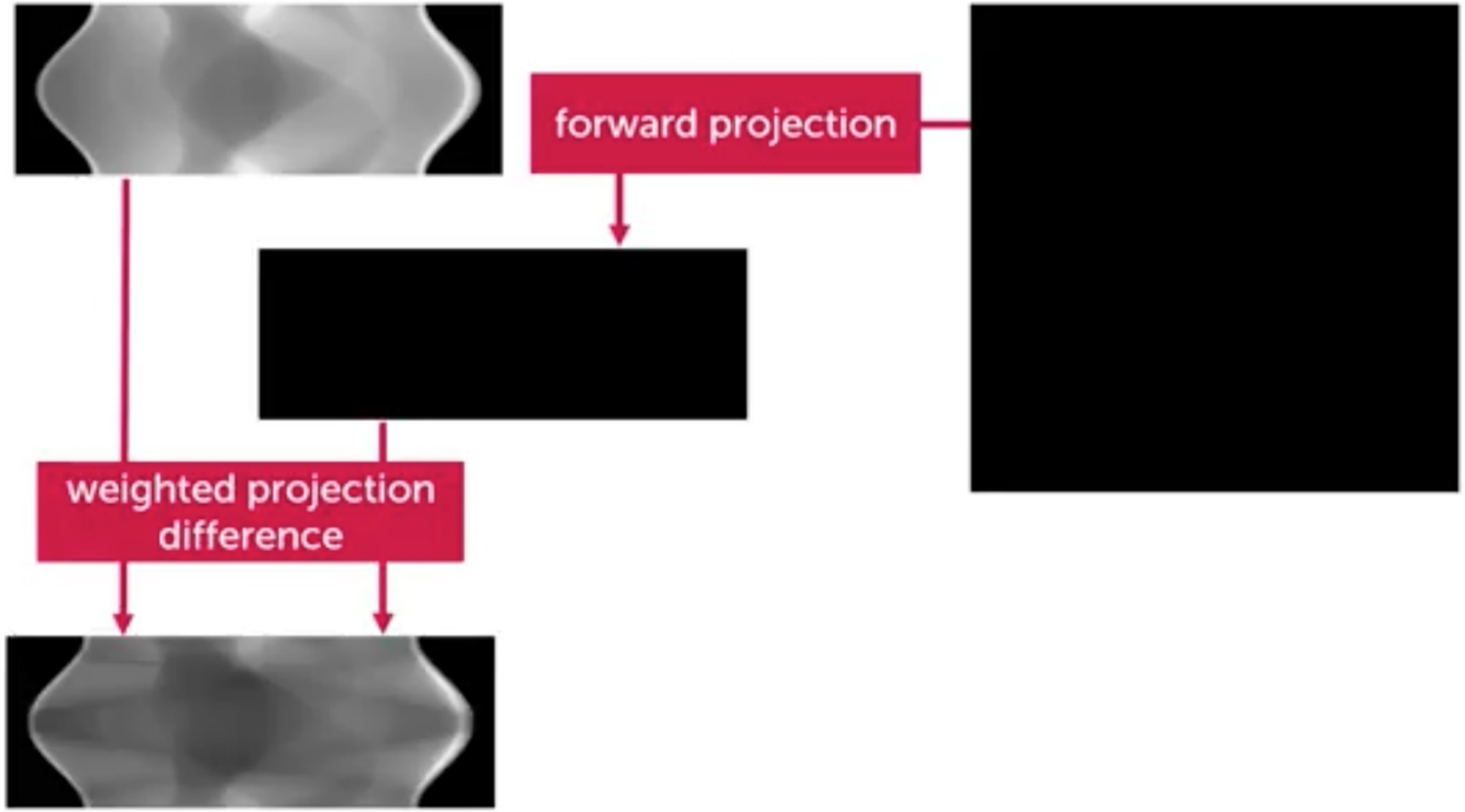

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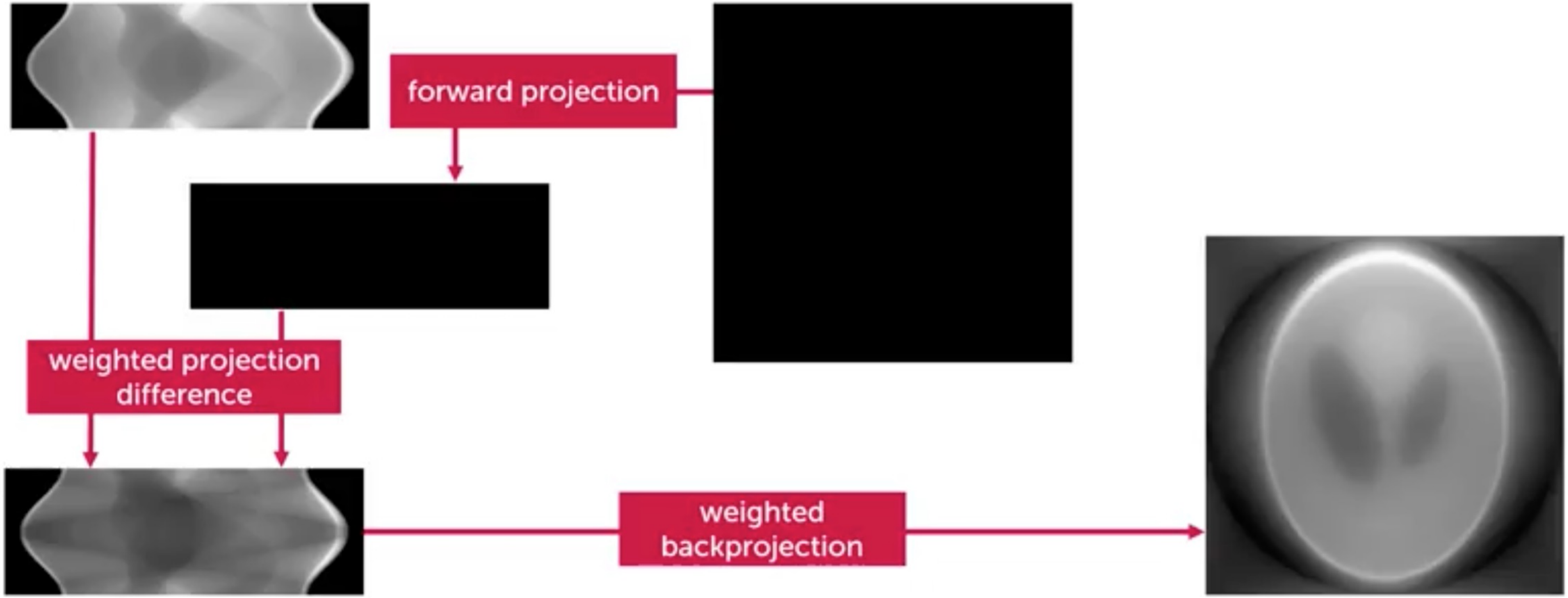

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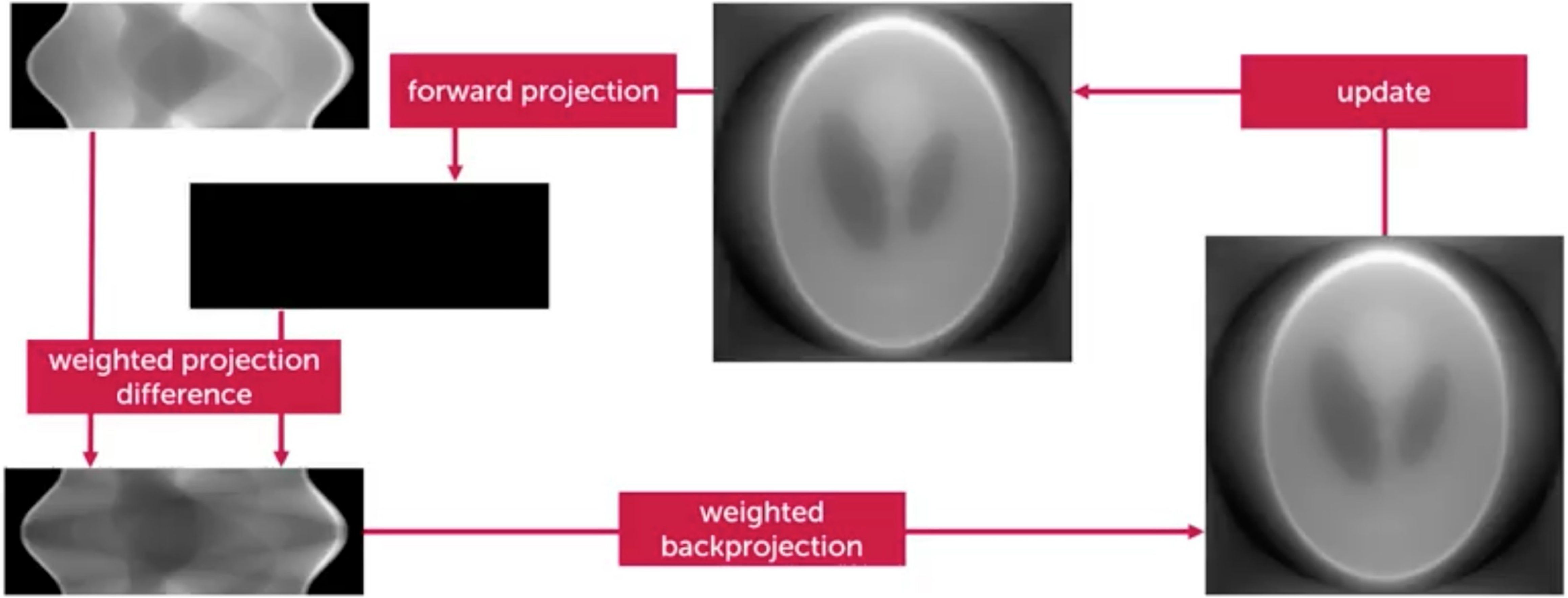

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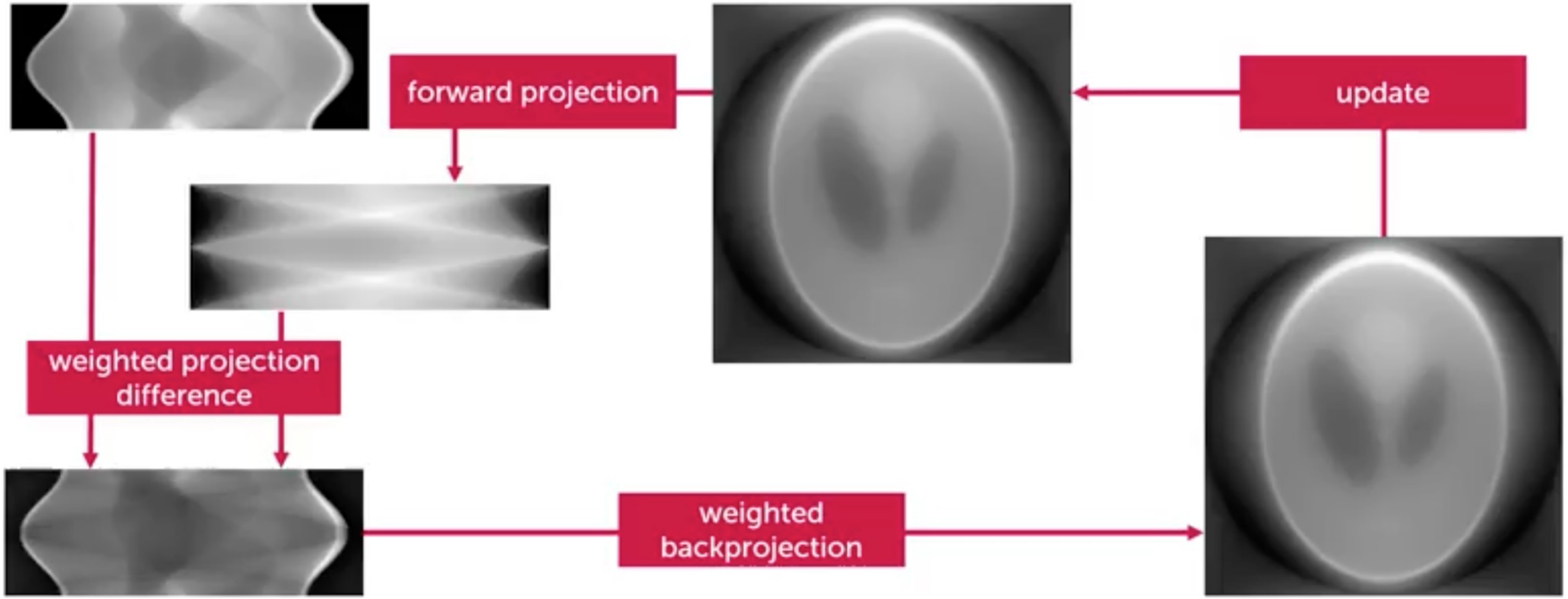

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