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Royal Free London NHS
NHS Foundation Trust

Medical Physics and Nuclear Medicine

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Nuclear Medicine Physicist

Outline

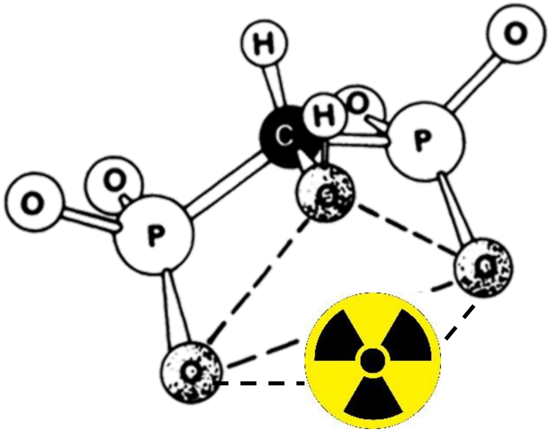
- Nuclear Medicine: what we do
- Nuclear medicine physics: what I do
- My path into medical physics
- The NHS Scientist Training Programme
- Alternative routes

What we do in Nuclear Medicine

- Diagnosis
  - Imaging
  - Non-imaging
- Therapy

What we do in Nuclear Medicine

- “The use of radioactive material in the diagnosis and treatment of illness”
- Take chemicals that will go to particular places in the body
- Attach a radioactive atom
- Inject it into the patient
  (or instead: ingested, inhaled…)
- Allow it to travel to the right place



What we do in Nuclear Medicine

- Imaging: detect radiation being emitted by the radionuclide, built up a picture of the radiotracer location
- Non-Imaging: detect how the radiotracer is cleared from the body e.g. via blood samples. Calculate measures of organ function
- Therapy: the radiotracer is localised to the target (e.g. cancer). The radiation damages the target cells.

What we do in Nuclear Medicine

- Radiotracers are useful and versatile
- There are a large variety of different procedures (hundreds) to investigate and treat a large range of diseases

Radiotracer production

- Radiopharmacy staff perform the reactions to make up the tracers required for the day

Example: bone scan

- Patient arrives in the department
- Nuclear Medicine Technologist:
  - Talks to patient about the procedure
  - draws up the required activity of 99m-Technetium methylene diphosphonate (MDP)

Example: bone scan

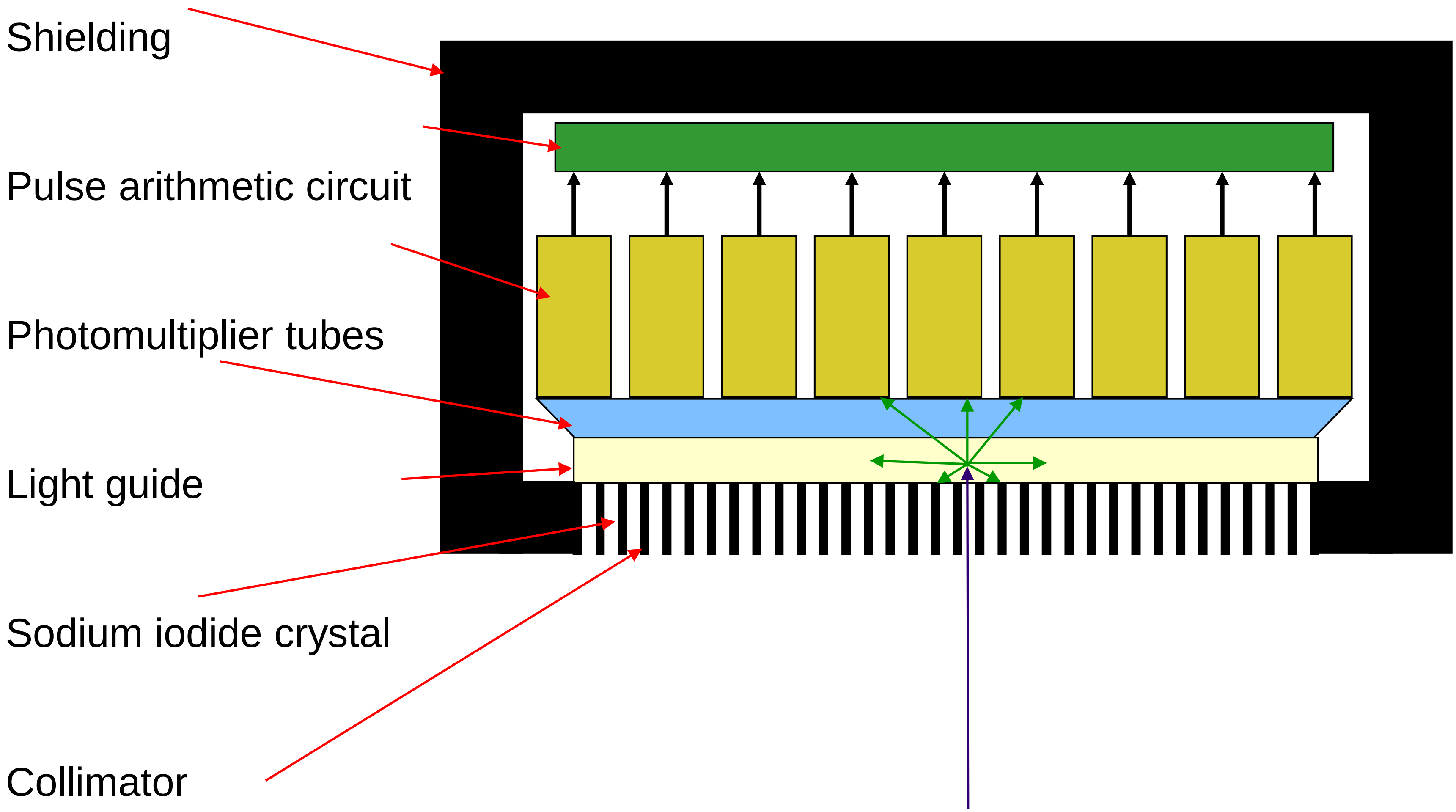
Example: bone scan

Example: bone scan

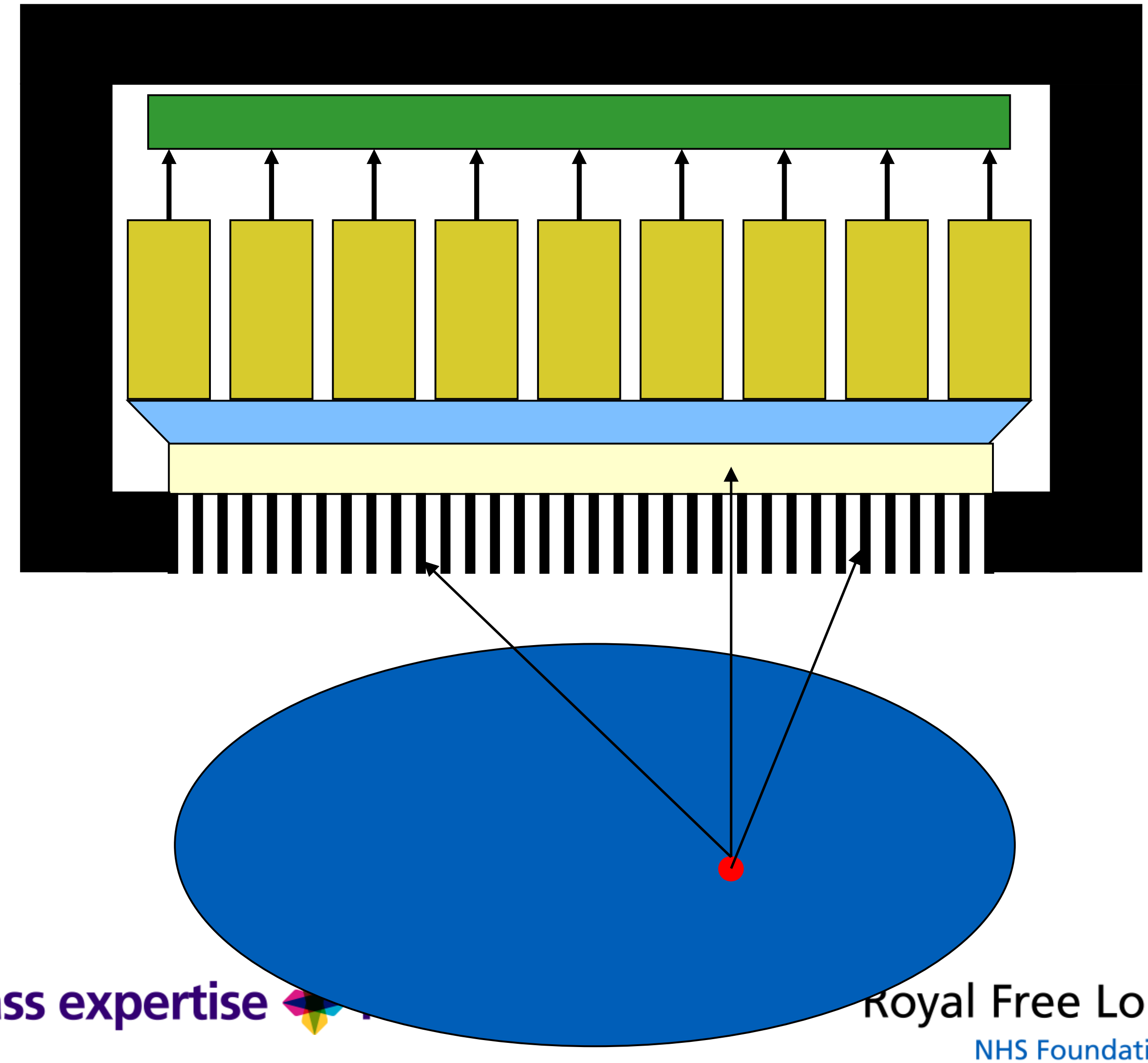
- After the injection, need to wait ~3h
- MDP is absorbed at sites of new bone formation, with uptake proportional to metabolic activity
- Tc-99m emits gamma rays
- Patient returns to the department for their scan on the gamma camera


SIEMENS
Symbia

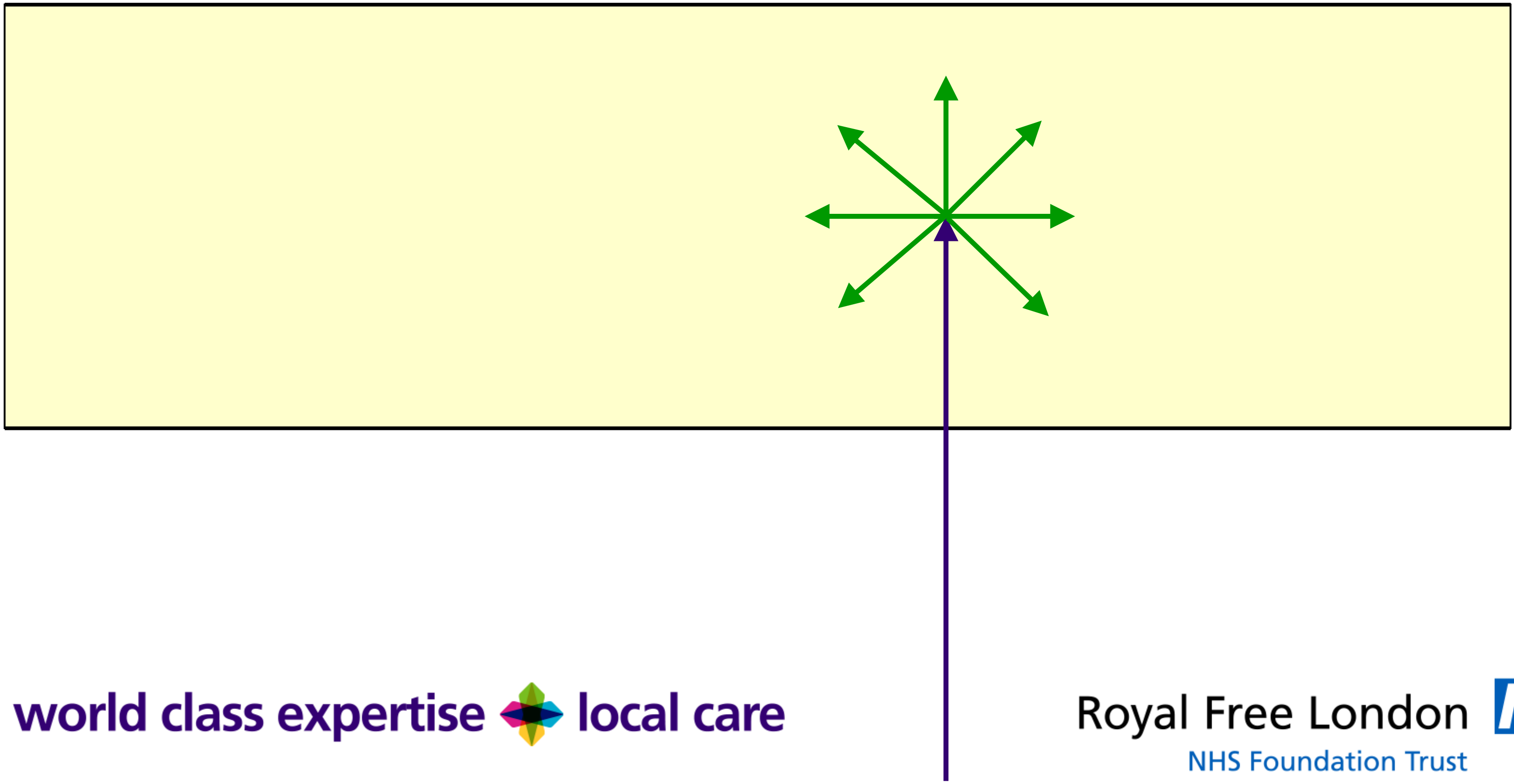
How a gamma camera works



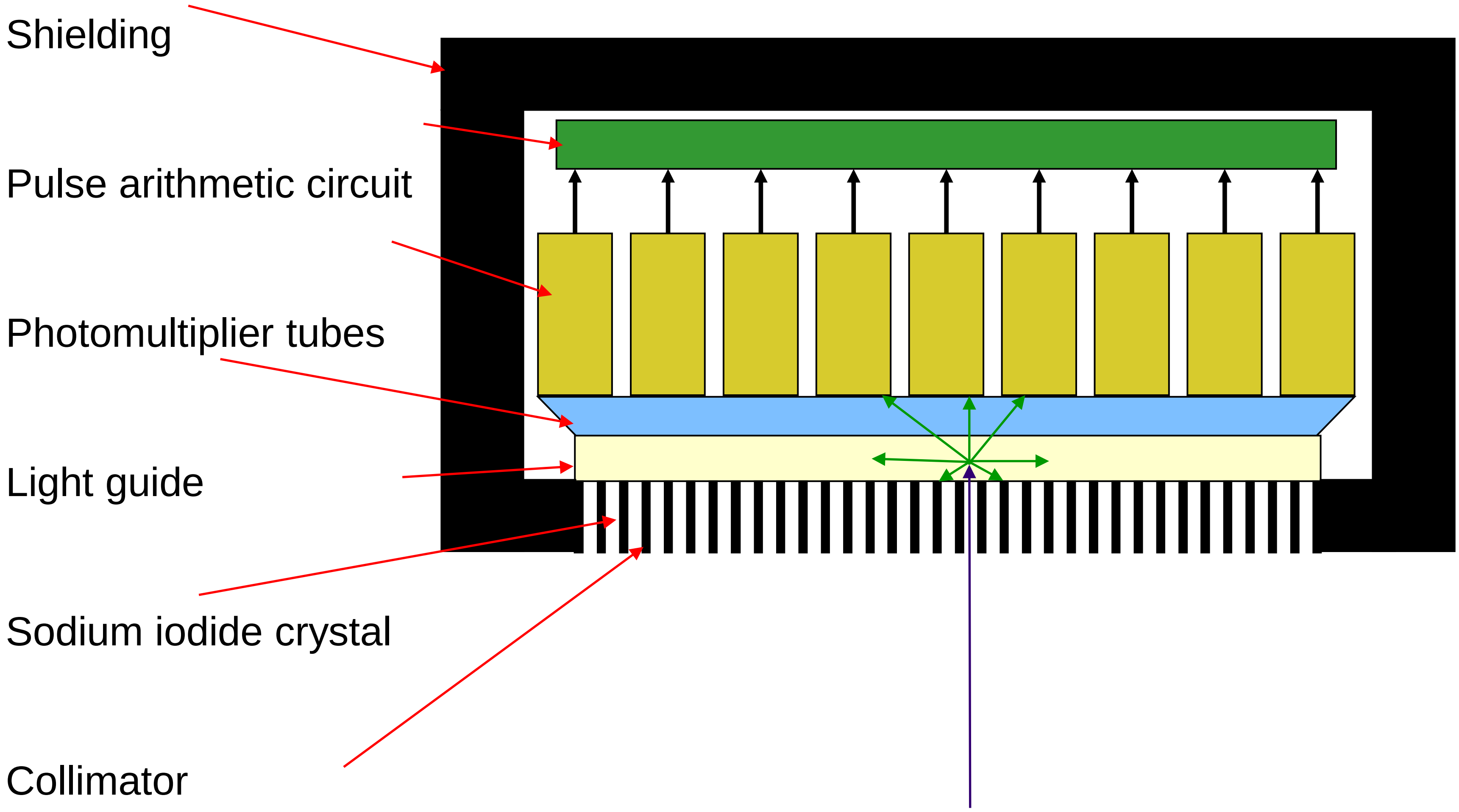
Collimator



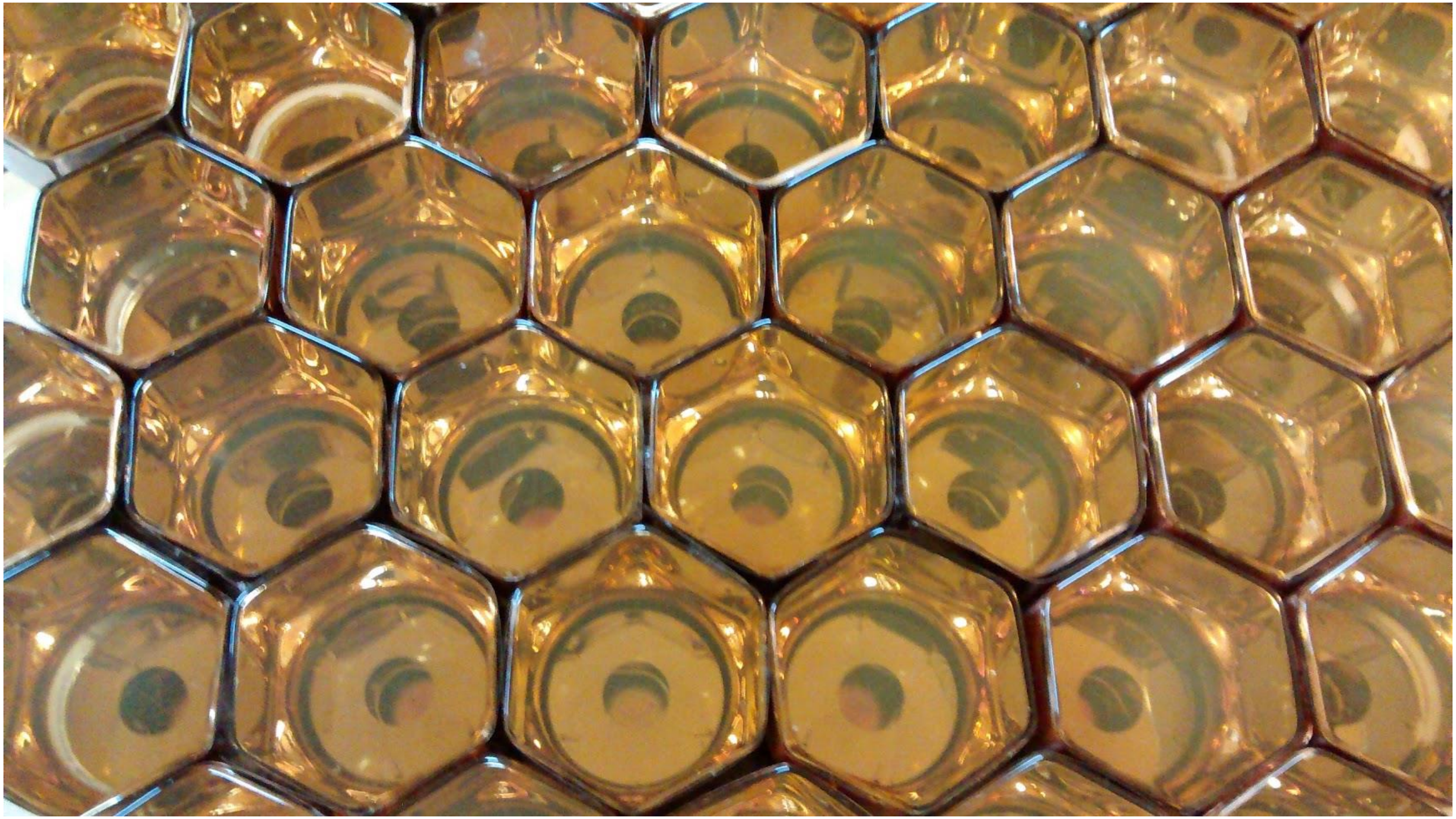
Sodium iodide crystal



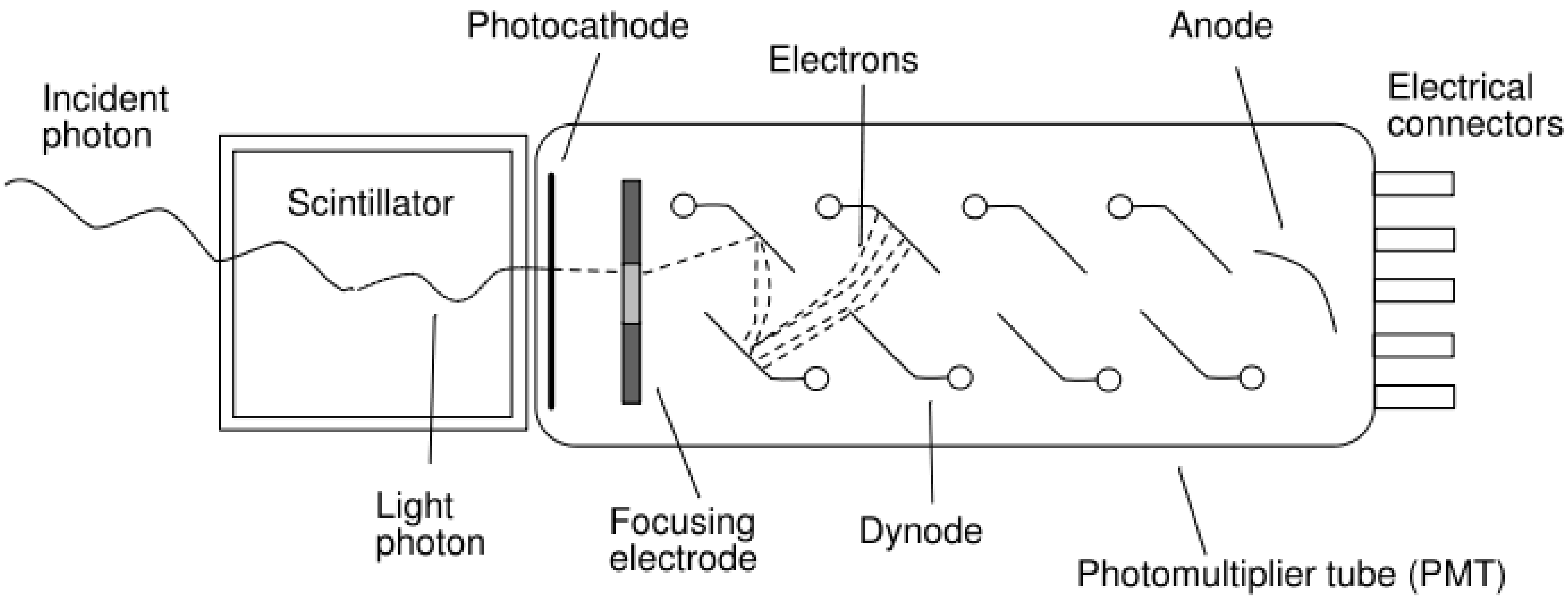
How a gamma camera works



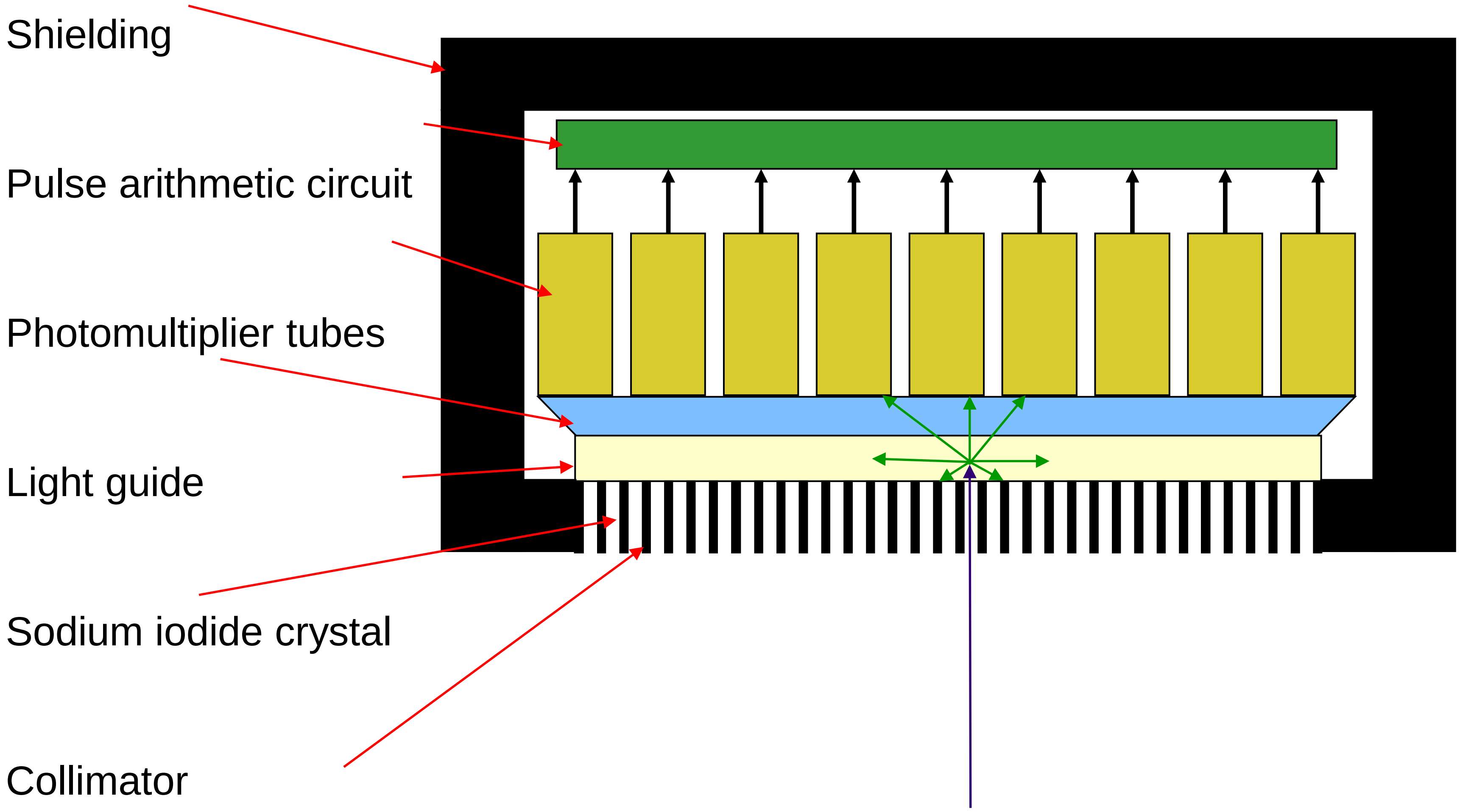
Photomultiplier tubes



Photomultiplier tube



How a gamma camera works



Pulse arithmetic

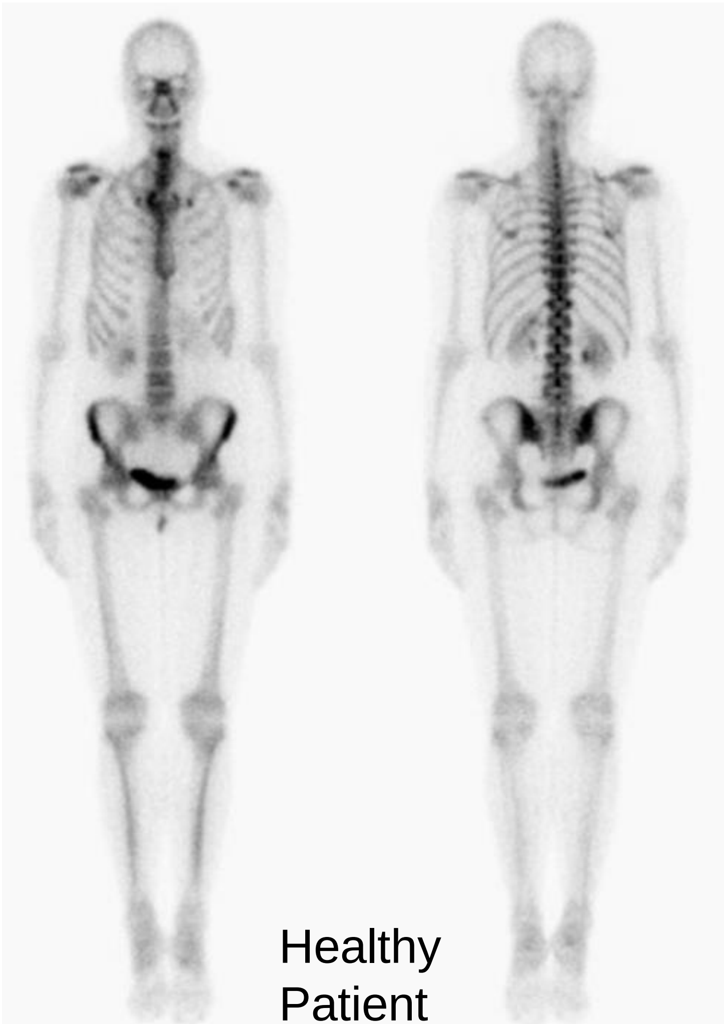
Energy

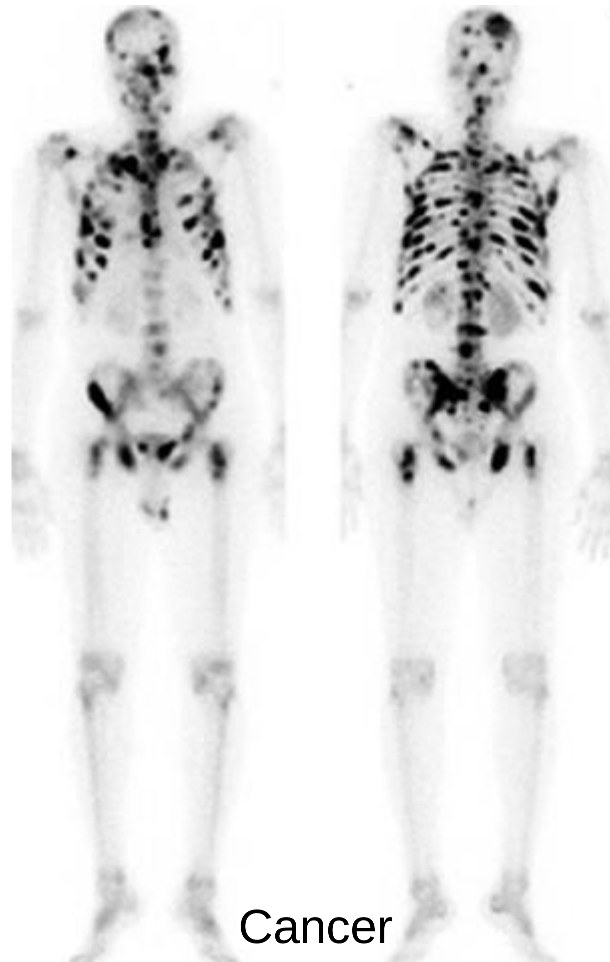
$$E = W_E \sum_i V_i$$

Position

$$x = \frac{\sum_i x_i V_i}{\sum_i V_i} \qquad y = \frac{\sum_i y_i V_i}{\sum_i V_i}$$

Bone Scan

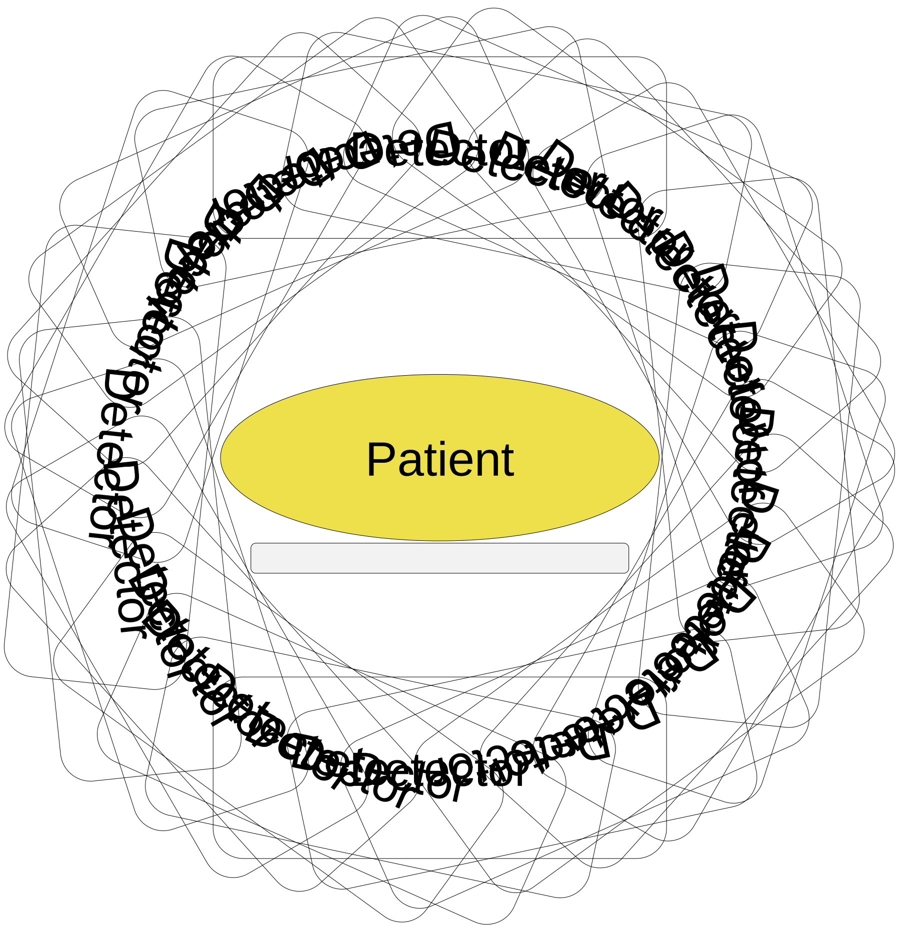


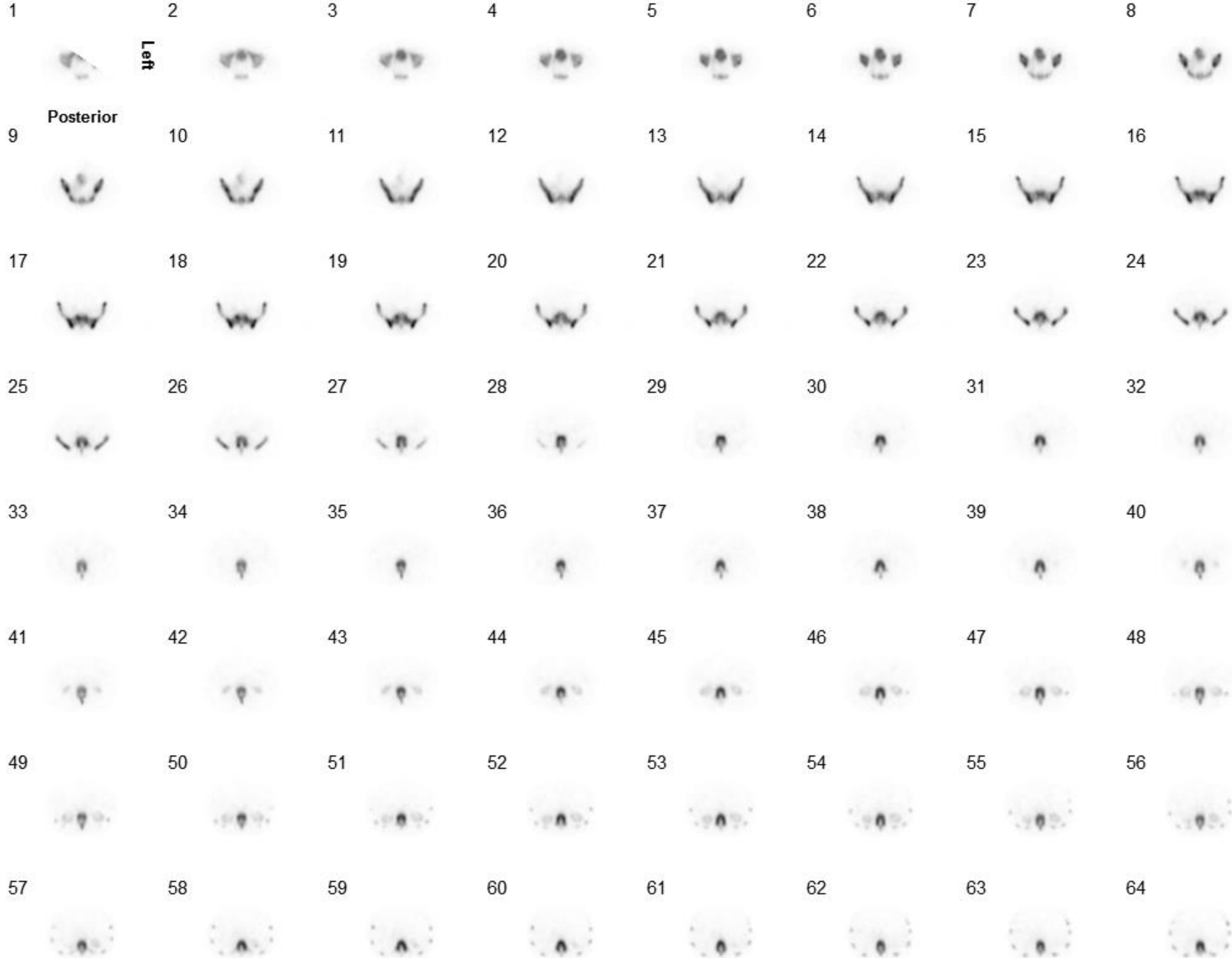


Example: bone scan

- Hot spots may indicate trauma, bone metastasies etc. or just normal growth.
- Cold spots could be due to avascular bone or bone destruction.
- A nuclear medicine bone scan is used to study function, not structure

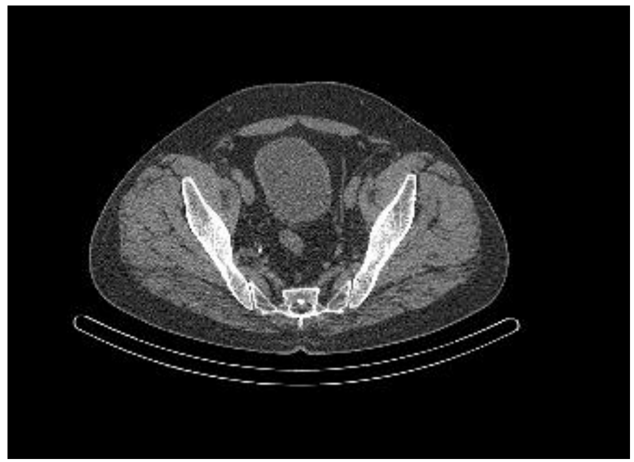
SPECT

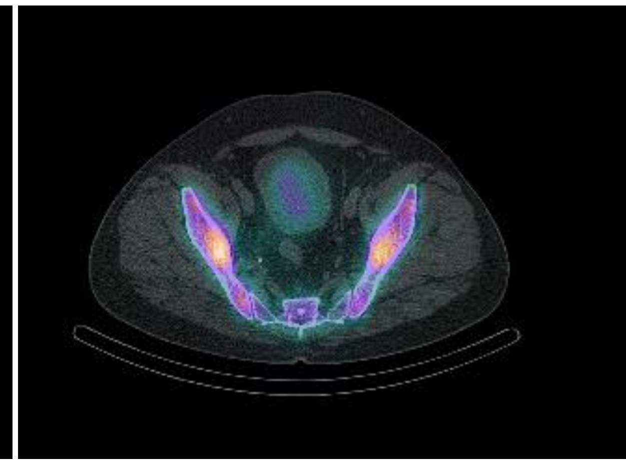


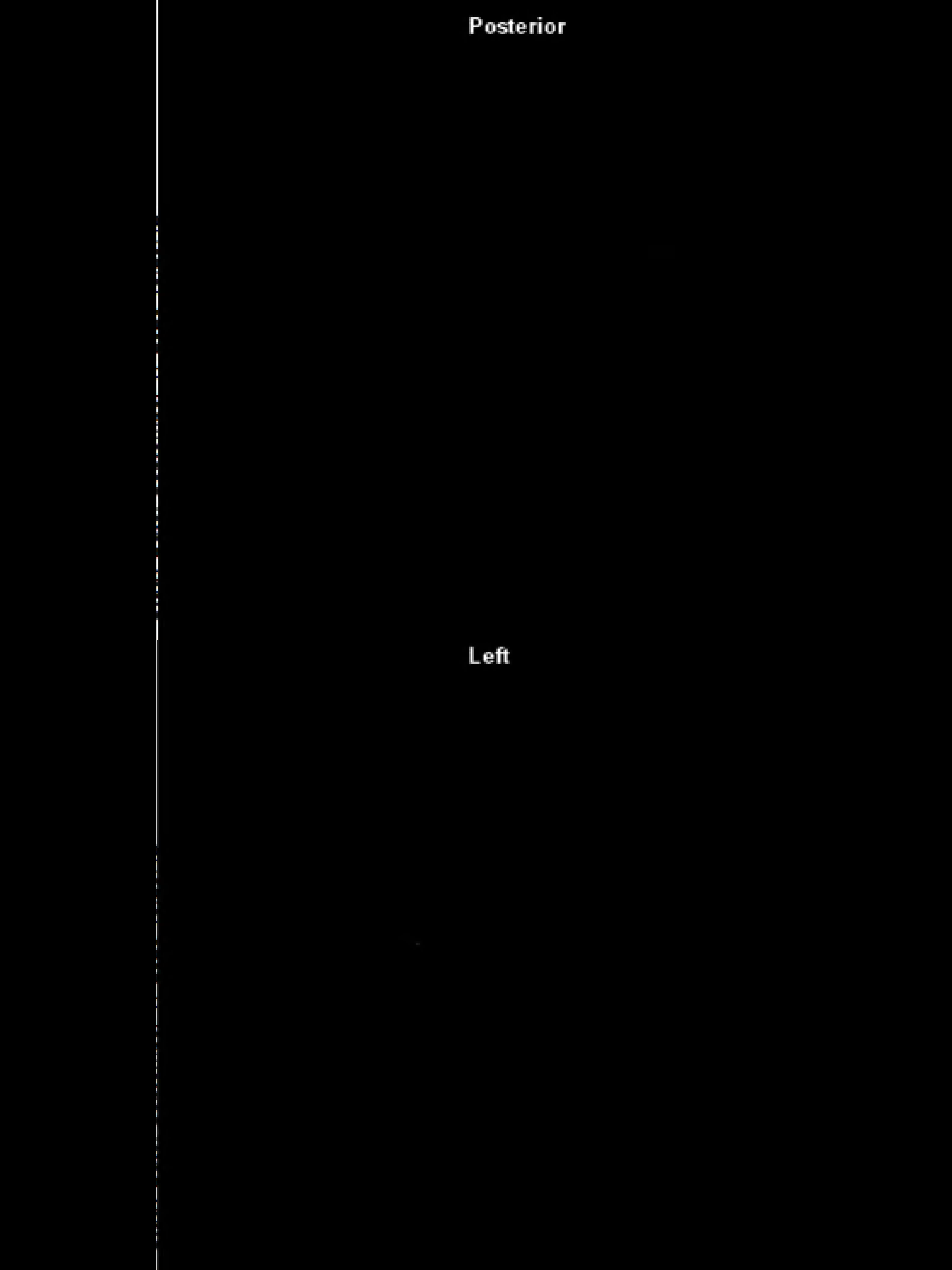


Left
Posterior
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15 16
17 18 19 20 21 22 23 24
25 26 27 28 29 30 31 32
33 34 35 36 37 38 39 40
41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56
57 58 59 60 61 62 63 64

SPECT-CT







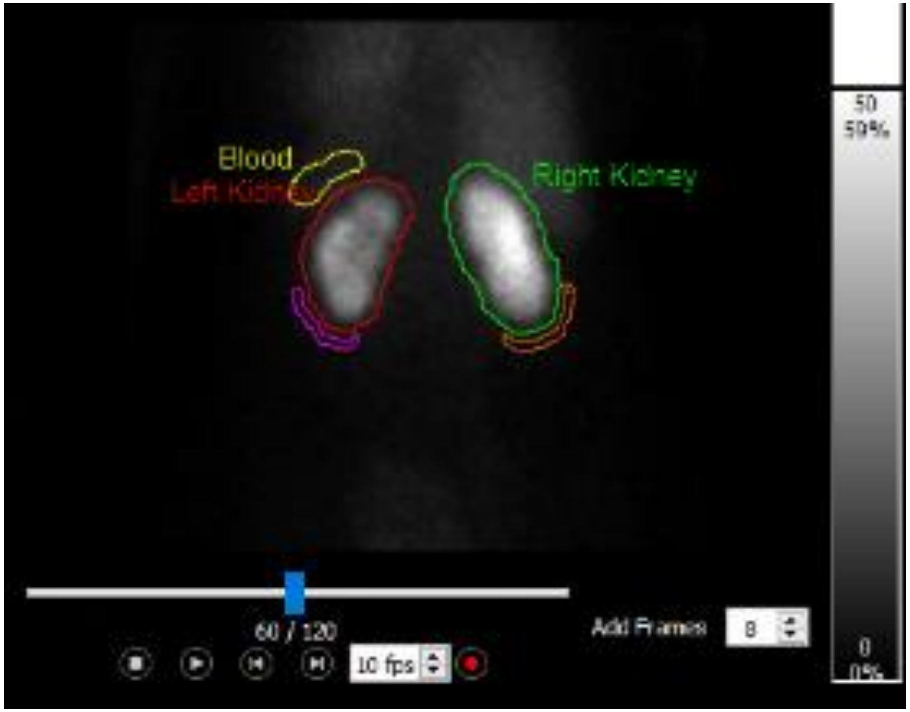
Posterior
Left

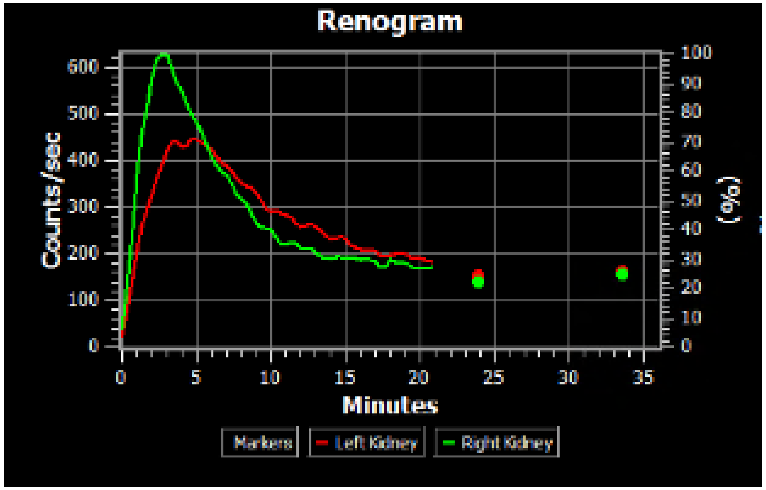
Other examples

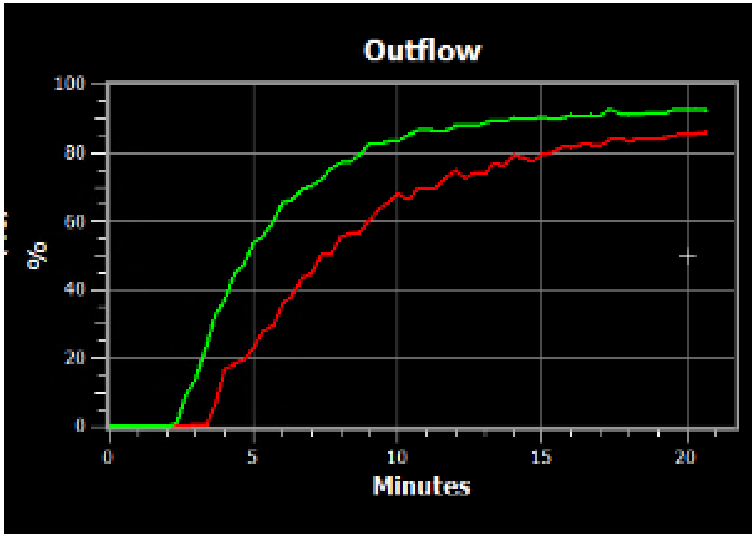
- The same principles can be used to look at a large variety of conditions

Renogram

Renogram







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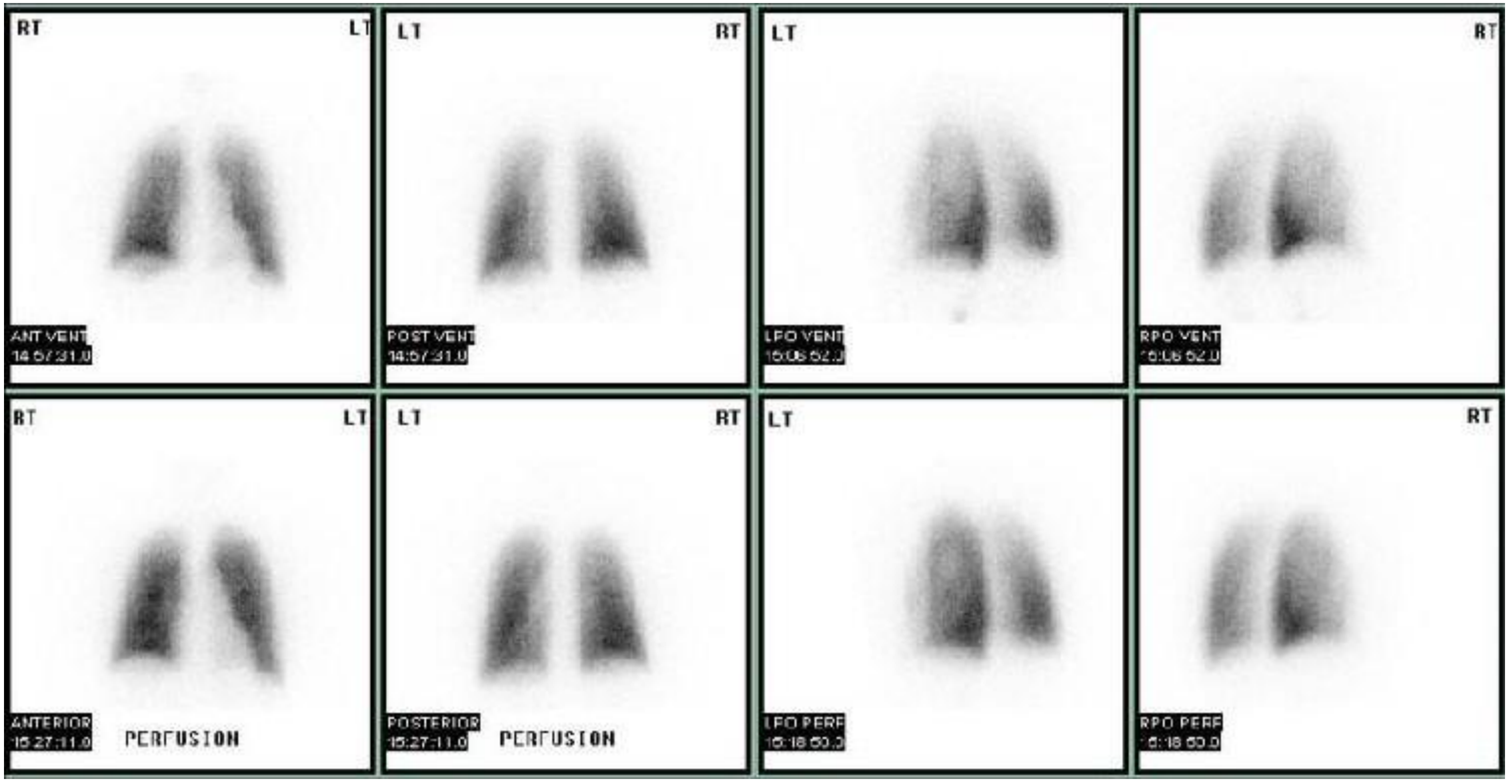
Lungs


RT
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ANT VENT
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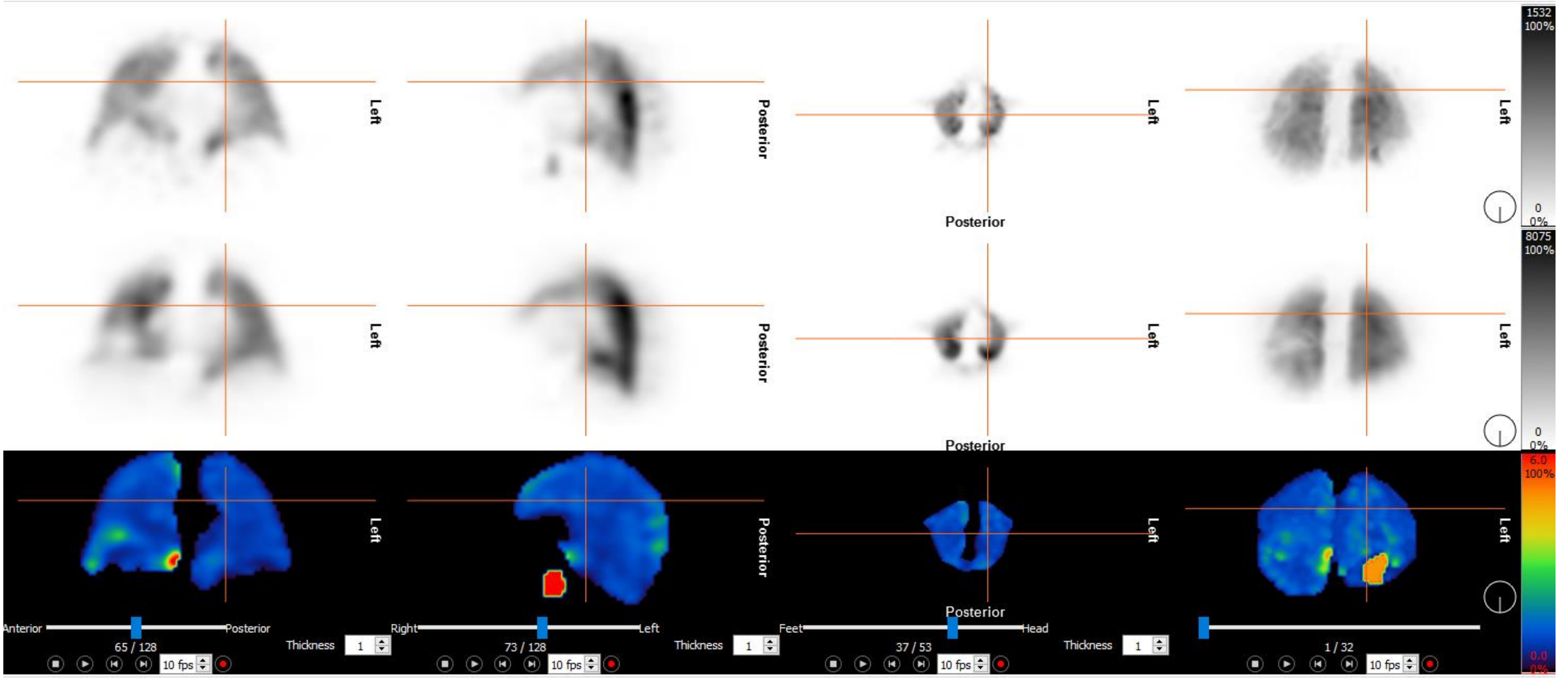
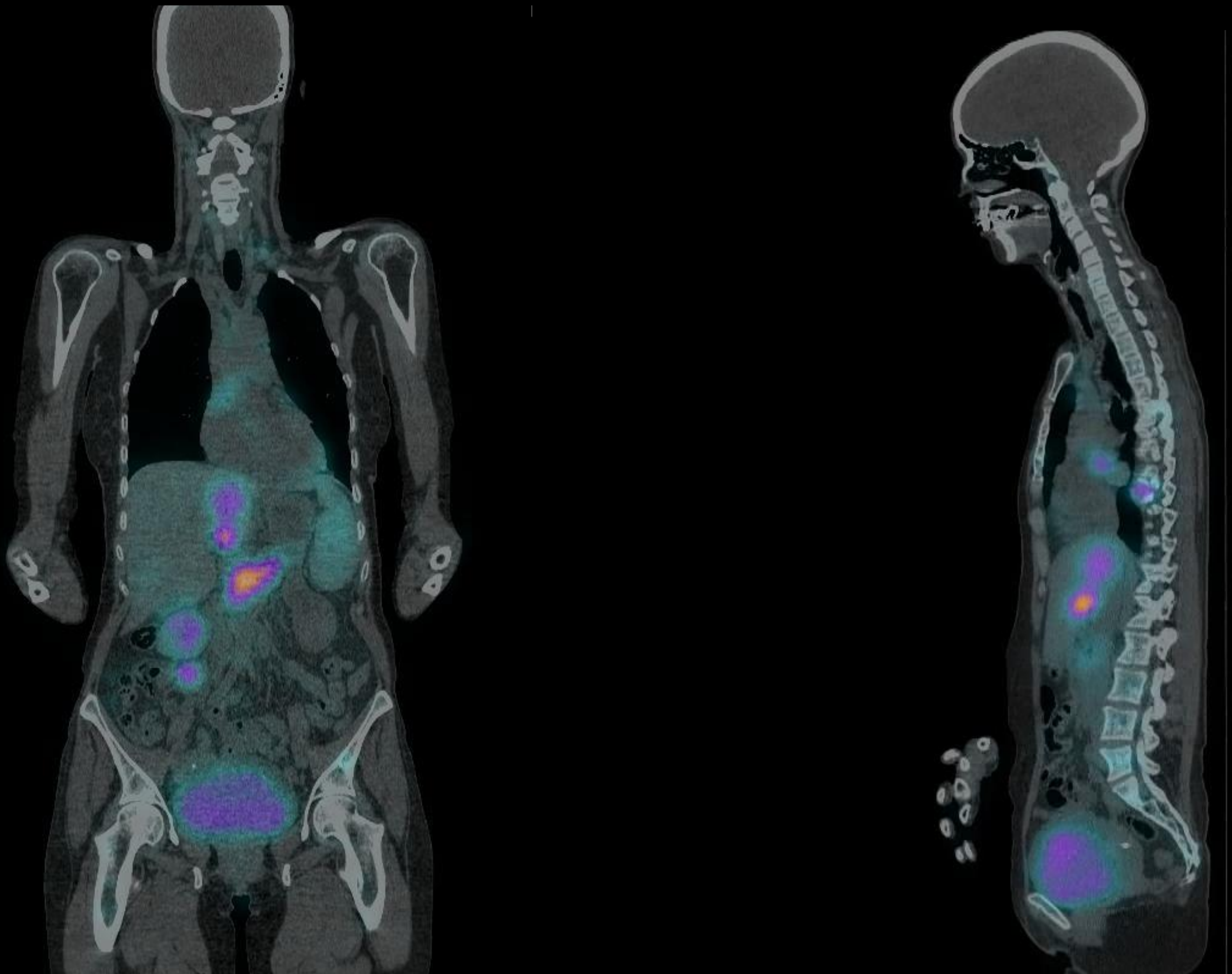
Lungs


Left
Posterior
Left
Posterior
Left
1532
100%
0
0%
8075
100%
6.0
0.0
Anterior
Posterior
65 / 128
Thickness 1
Right
Left
73 / 128
Feet
Head
37 / 53
1 / 32
10 fps

Our favourite radionuclide

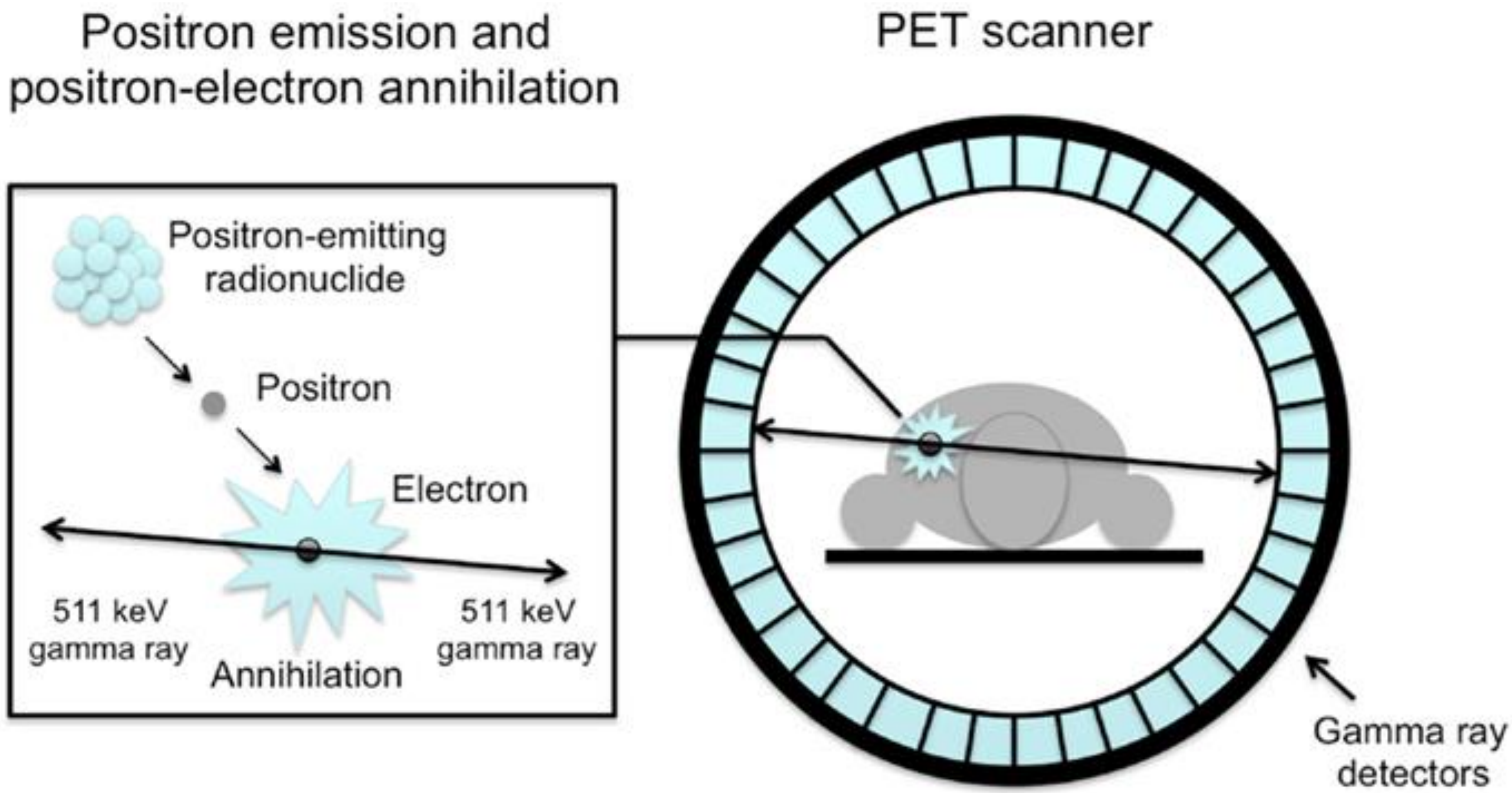
- ^{99m}Technetium is a great radionuclide for nuclear medicine
  - Half life 6 hours
  - High branching ratio gamma ray emission, at 140 keV
  - Simple chemistry
  - Generator system improves availability
- We do use other radionuclides too



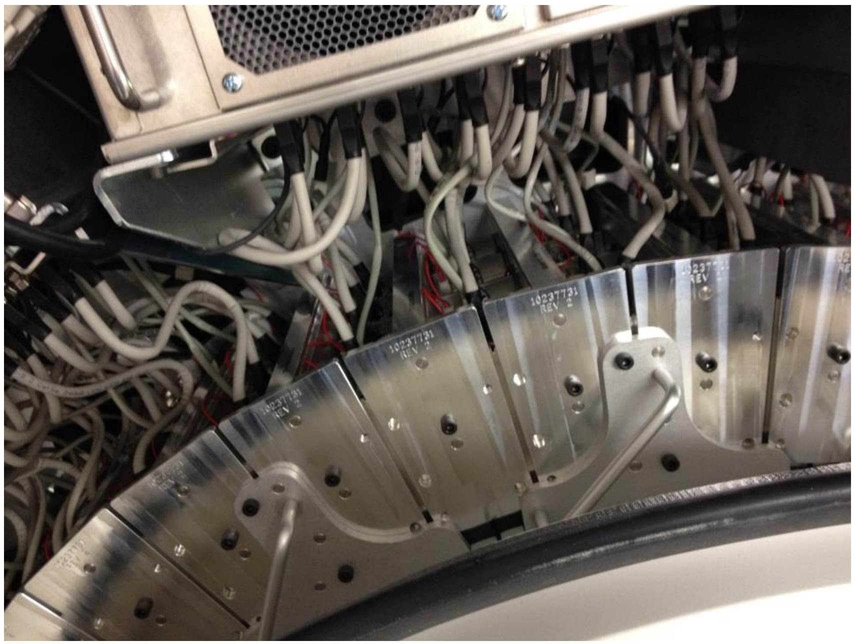
Positron Emission Tomography

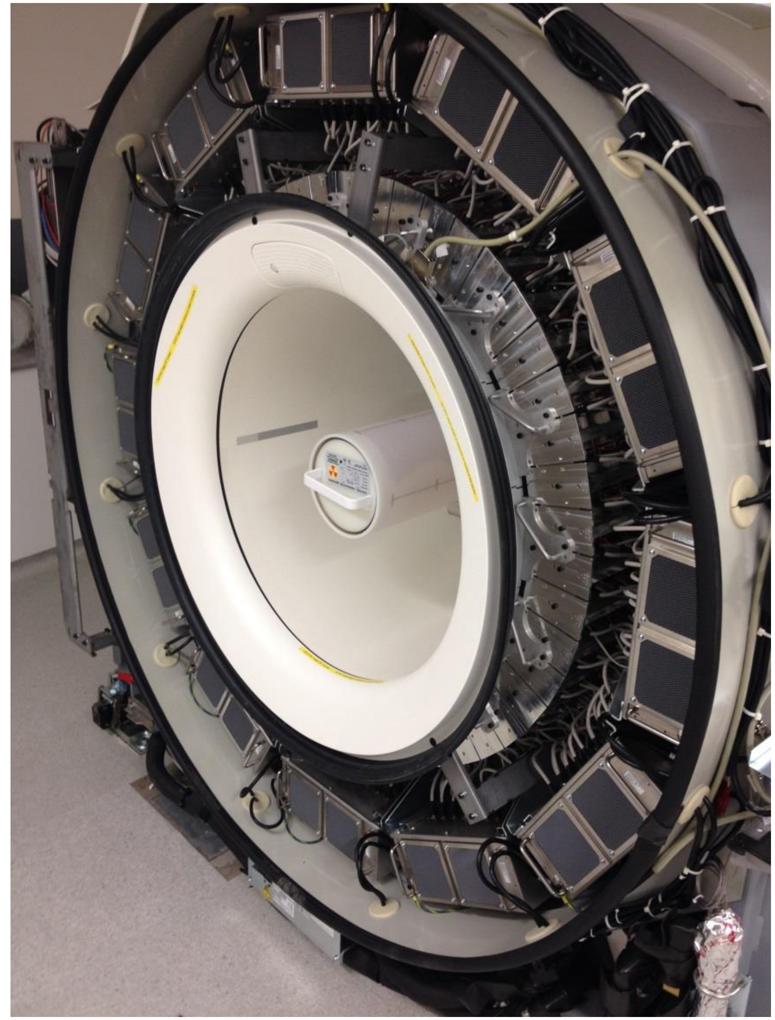
- Similar principle, but use positron emitting radionuclides.
- When each positron annihilates in the patient, two photons are emitted at ~180 degrees
- Detect both >annihilation occurred on the line between them

Positron Emission Tomography



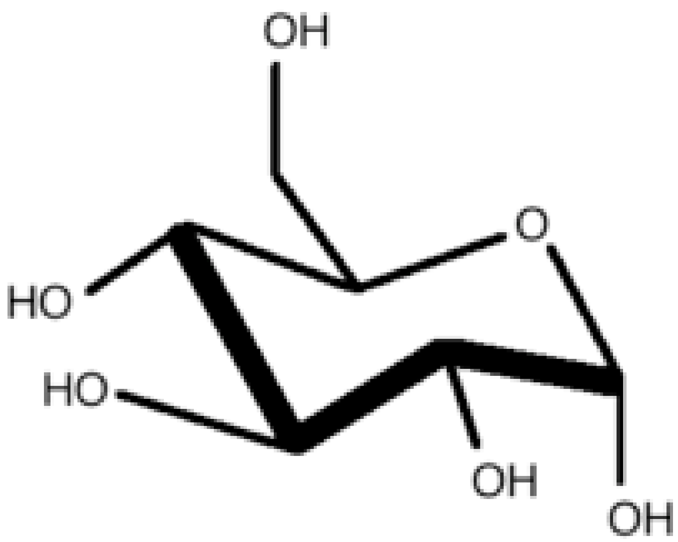
Instrumentation



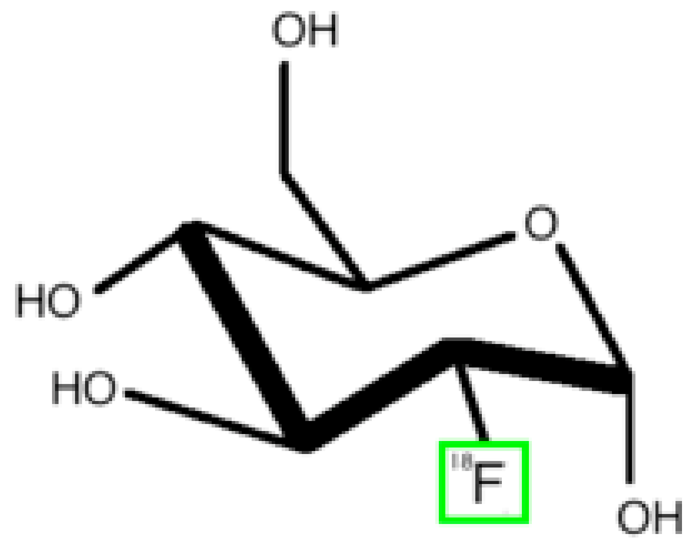


PET tracers: typically cyclotron produced

Positron Emission Tomography

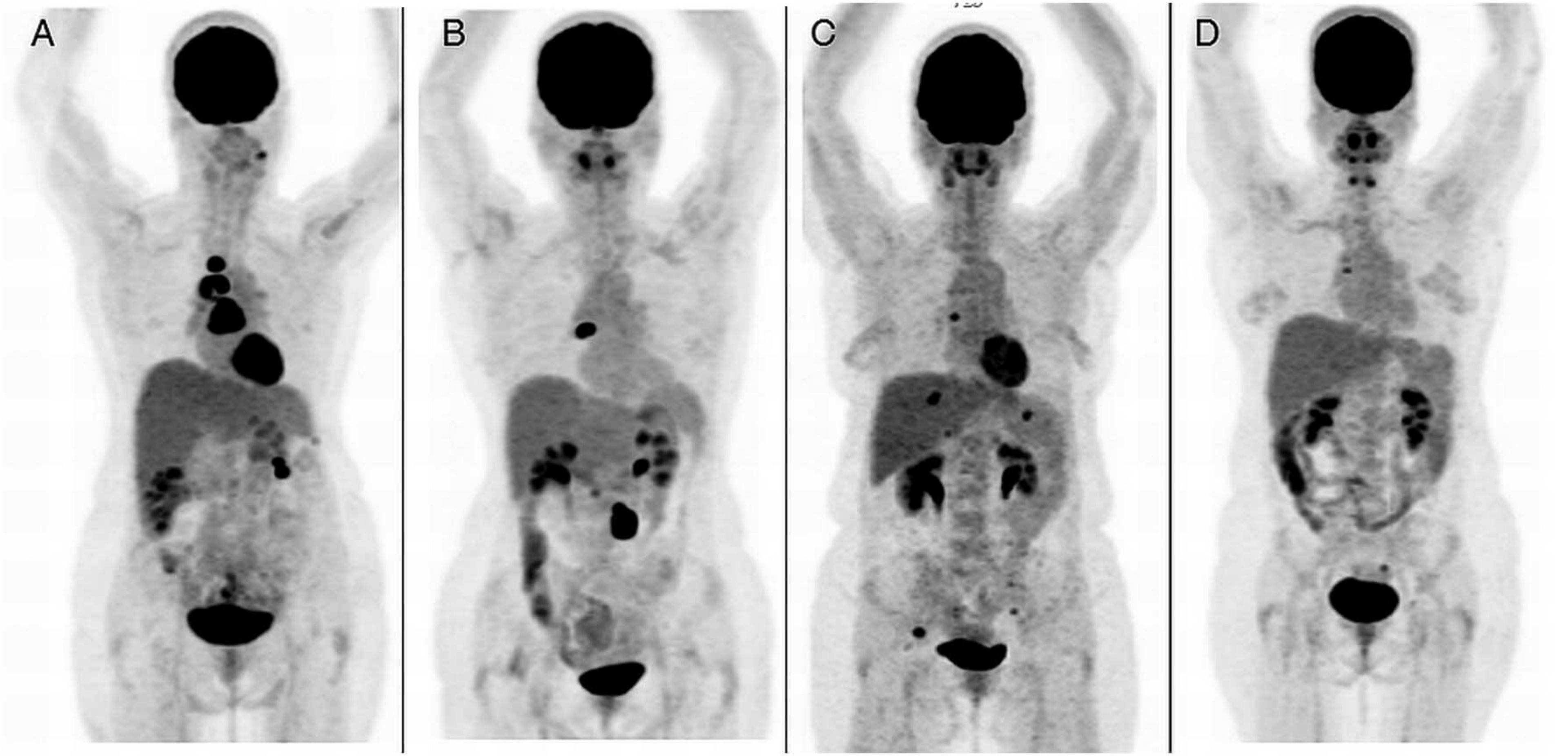


Glucose



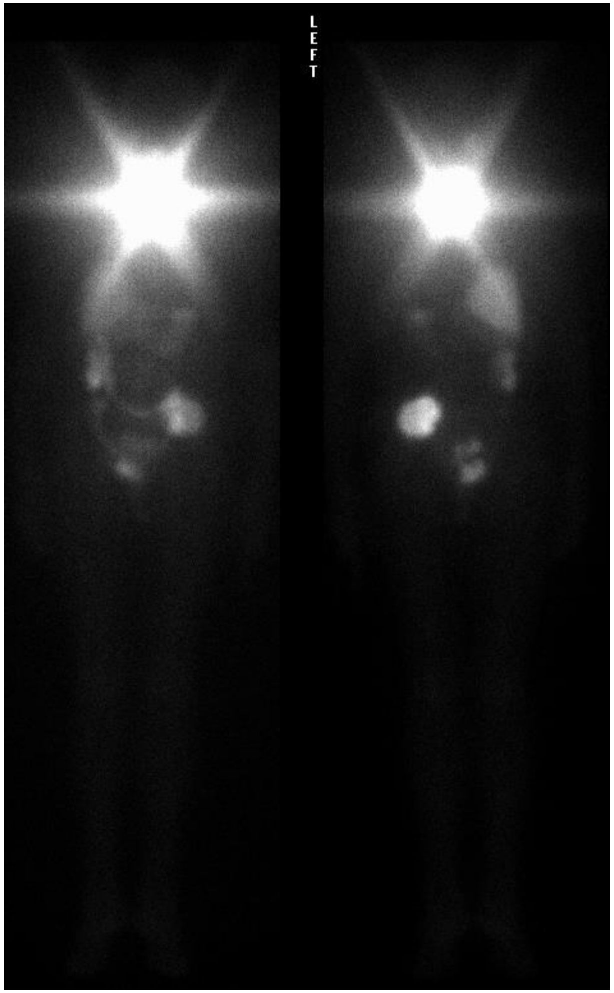
2-deoxy-2-[^{18}F]-D-glucose

Positron Emission Tomography



Nuclear Medicine in therapy

- ^{131}Iodine for thyroid cancer
- ^{177}Lu-DOTATATE for neuroendocrine tumours
- Several others



But what does a Physicist actually *do*?

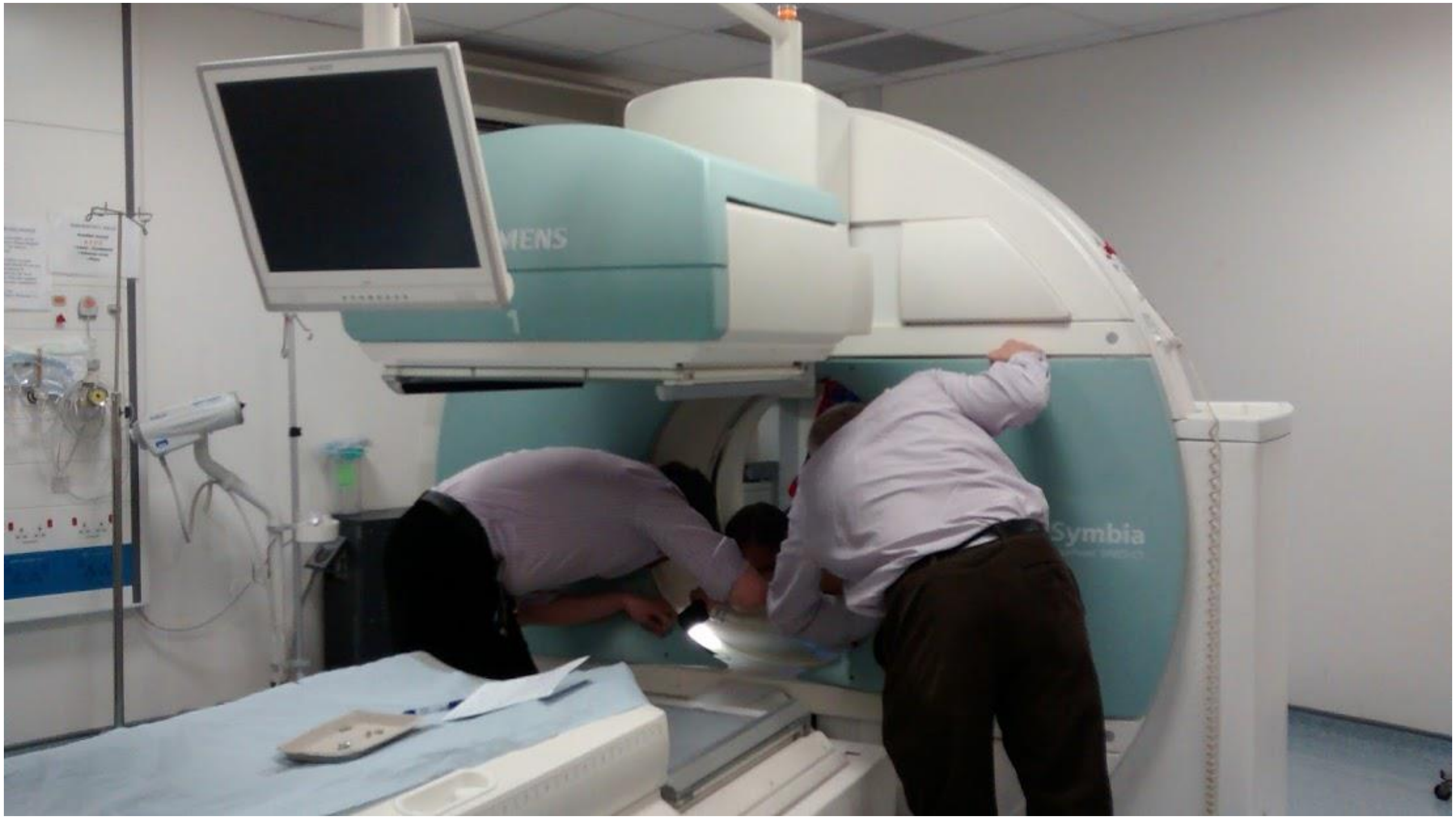
Providing a Service

- Talk to patients about radiation
  - Radiation risk
  - Radiation protection considerations
  - Contact restrictions (therapies)
- Verify imaging and testing
- Manage equipment
- Radiation Protection
- Research

Managing Equipment

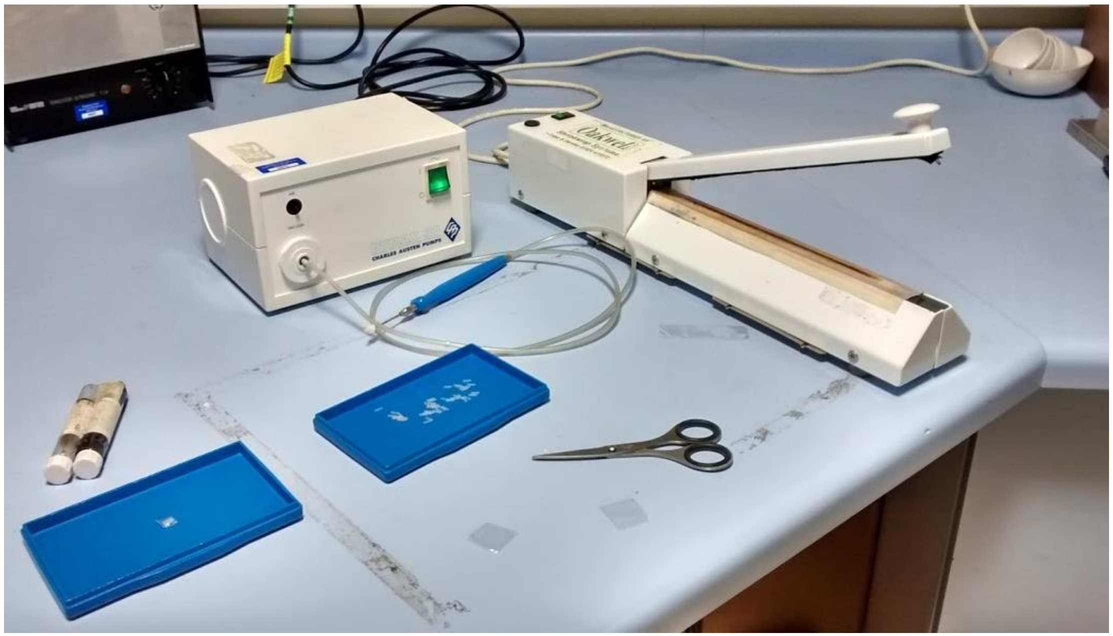
- Procurement
- Commissioning
- Optimising the use of new technology
- Quality Assurance
- Troubleshooting

Managing Equipment



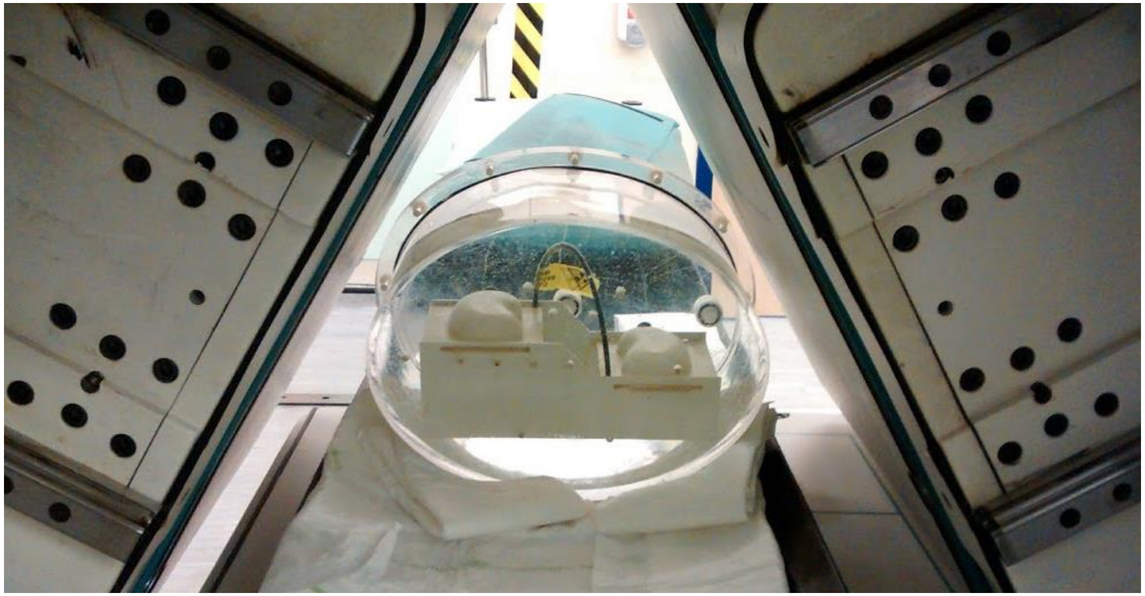
Cameras, technical equipment, workstations and software all need attention

Radiation Protection



- Risk Assessments
- Local Rules
- How to manage care of radioactive patients in a safe way
- Monitoring of staff and patient doses
- Dosimetry following incidents

Research and Innovation



- Adapting techniques for unusual cases/ local needs
- Optimising image quality/ patient dose
- Improving accuracy
- New techniques
- New equipment

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Paths into medical physics

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My path into medical physics

- 2009-2012 BSc Physics
- 2012: Health Care Assistant
- 2013-2014 Lab technician in Vascular Ultrasound
- 2014-2017: Scientist Training Programme (including MSc Medical Physics)
- 2017-present: Nuclear Medicine Physicist

The Scientist Training Programme

- 3 year graduate training scheme
- MSc + hospital training
- Rotate through four areas of medical physics
  - Imaging with ionising radiation
  - Imaging with non-ionising radiation
  - Radiation Safety
  - Radiotherapy
- Then specialise for last 18 months
- At completion, can apply to be a HCPC registered 'Clinical Scientist'

The Scientist Training Programme

- Paid NHS Band 6 throughout training (starting salary £31,365, +20% if your work is based in London)
- MSc tuition costs also covered
- Entry can be competitive
- 2:1 or 1st, (2:2 may be considered if you also have a relevant higher degree)
- Application process opens January 2021 for September 2021 start

The Scientist Training Programme

- Further information:

https://nshcs.hee.nhs.uk/programmes/stp/

https://www.healthcareers.nhs.uk/career-planning/study-and-training/graduate-training-opportunities/nhs-scientist-training-programme

Alternative routes

- If already employed by an NHS trust willing to train you:
  - Can apply to the STP ‘in service’, or
  - Can submit a portfolio of evidence to show you have the required competencies (“route 2”)
  - These options are sometimes used by candidates already holding a PhD

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Thank you for listening
Any questions?

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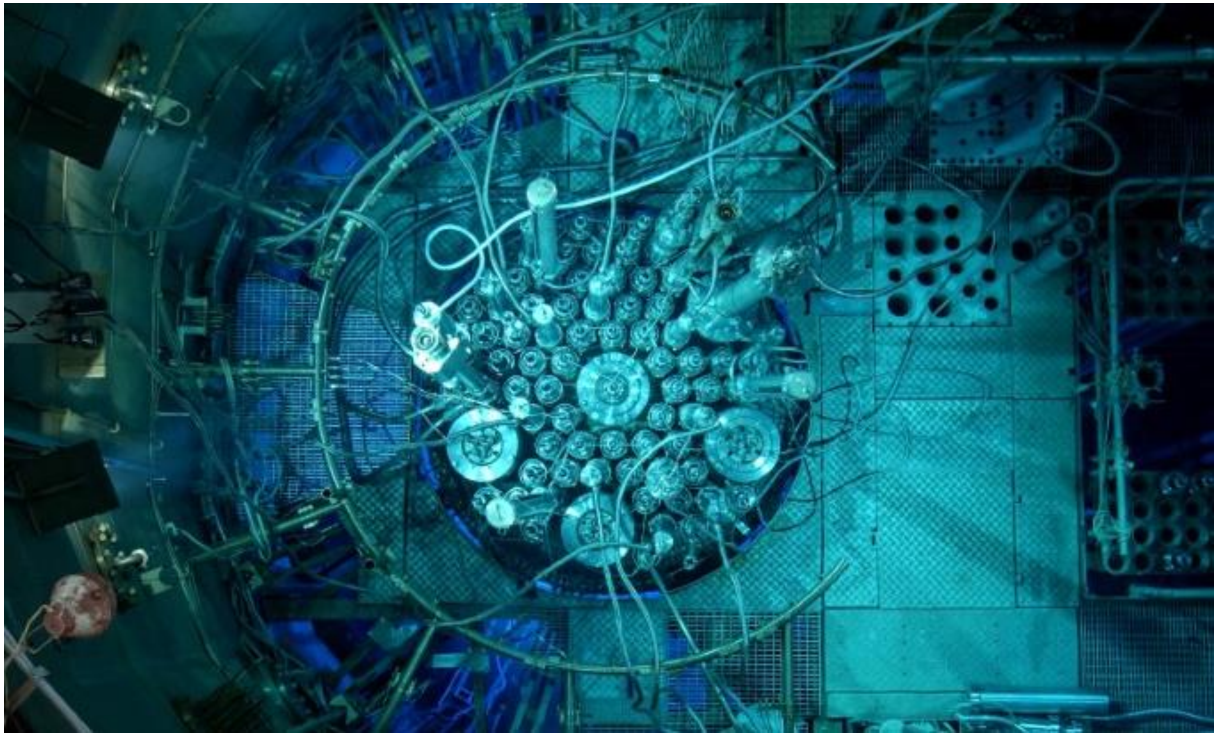
Bonus slides
(in case of questions)

Radioisotope production

- ^{99}Molybdenum produced inside a specialist nuclear reactor



Radioisotope production

- Extracted and processed, formed into a ‘generator’ which hospitals buy
- The ^{99}Molybdenum decays into ^{99m}Technetium, with a half-life of 2.7 days
- ^{99m}Technetium is chemically extracted from the generator, on the hospital site