Physics of medical imaging and radiotherapy

BSc/MSci Physics level 3
7.5 ECTS course in term 2

Prof Chris Dunsby
christopher.dunsby@imperial.ac.uk

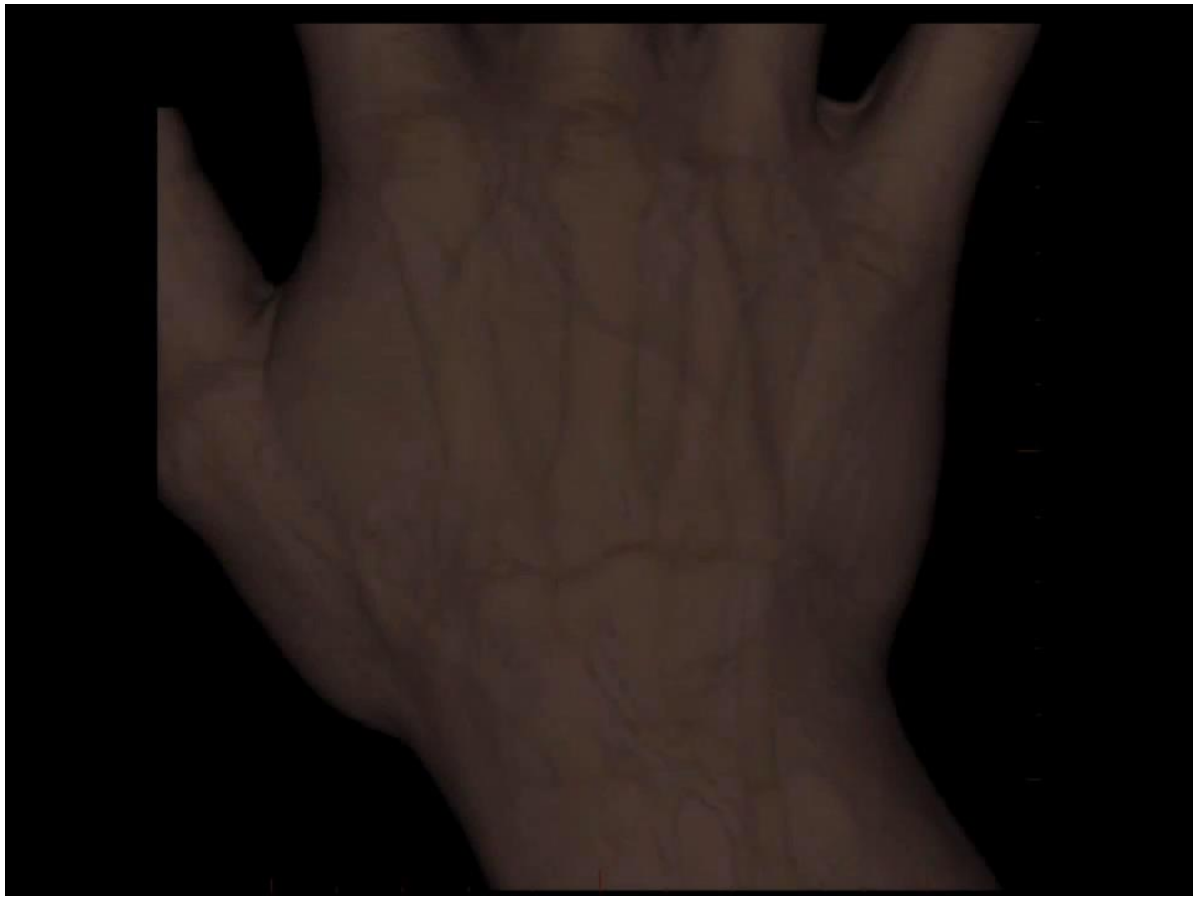
Prof Ken Long
k.long@imperial.ac.uk

Dr James McGinty
james.mcginty@imperial.ac.uk

Prof Uwe Oelfke
uwe.oelfke@icr.ac.uk

- The discovery of X-rays (Röntgen 1895) kick-started the field of medical imaging

- Developments in understanding and technology has led to far superior image quality



- and has been extended to full 3D tomography

Key developments in medical imaging

1895 – First x-ray image by Röntgen (NP 1901)

1896 – Becquerel finds radiation from uranium (NP 1903)

1898 – Marie and Pierre Curie find radiation from polonium and radium (NP 1903)

1910 – Krause, Bachem and Günther use barium sulphate as contrast agent

1926 – Forssmann places catheter in own heart and takes x-ray image (NP 1956)

1946 – Purcell and Block demonstrate Nuclear Magnetic Resonance (NP 1952)

1956 – Anger: first gamma camera

1958 – Donald: ultrasound of unborn child

1971 – Hounsfield: first x-ray Computed Tomography (CT) scanner (NP 1979)

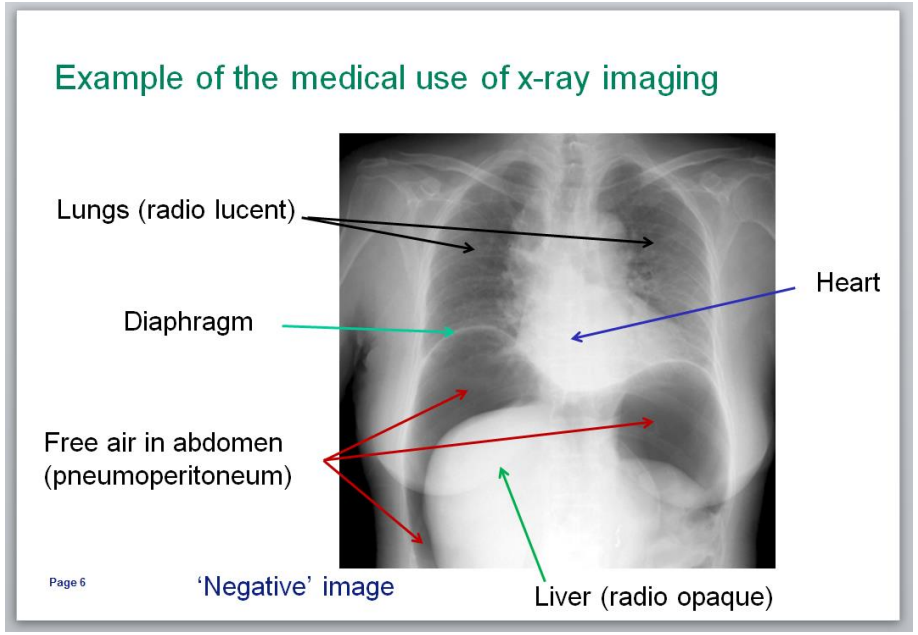
1973 – Lauterbur: first Magnetic Resonance Imaging (MRI) (NP 2003)
→ Mansfield

1975 – Pogossian: Positron Emission Tomography (PET) scanner

Aims:

- insight into the state of the art of medical imaging technology
- to introduce the physical principles behind:
  - interaction of radiation with biological tissue
  - generation & detection of radiation
  - signal and image processing
  - radiation used for therapy

Don’t worry, you will not be expected to learn biological/medical terms.



Course Structure:

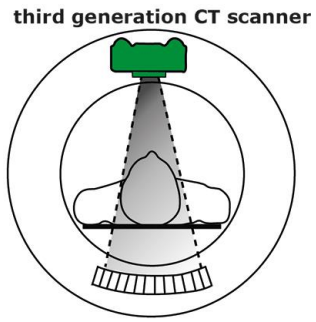
- Overall
  - 19 lectures/seminars covering core examinable material
  - Assessed by a summer examination
  - 55% contribution to course mark
- You will get
  - Lectures; number varies, but, usually between 1 and 3 per week
  - Additional study material
  - 1st in-person seminar
    - Introduction to Projects and Problem Sheet exercise
  - In-person seminars 2 & 3
    - Work on “Problem Sheet” exercise
  - 4th in-person seminar
    - Peer-assessment of “Problem Sheet” exercise – more details in a bit…

Lectures 2—6: X-ray imaging and tomography

Dr James McGinty
james.mcginty@imperial.ac.uk

X-ray

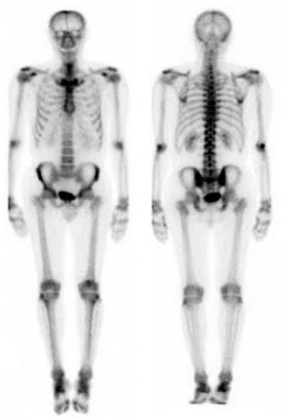
X-ray CT



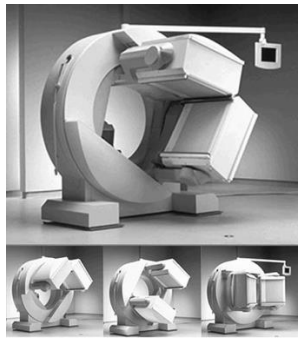
Lectures 7-9: Nuclear imaging

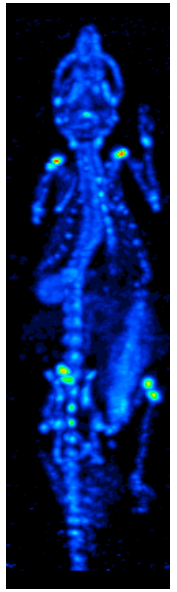
Chris Dunsby
christopher.dunsby@imperial.ac.uk

Gamma camera

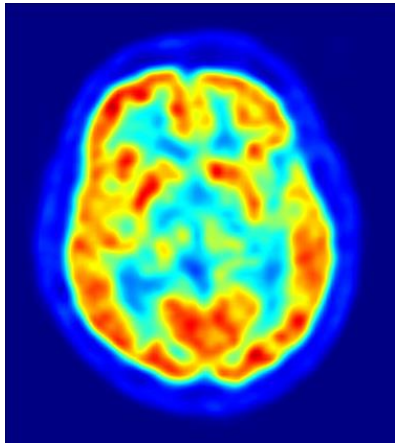


SPECT



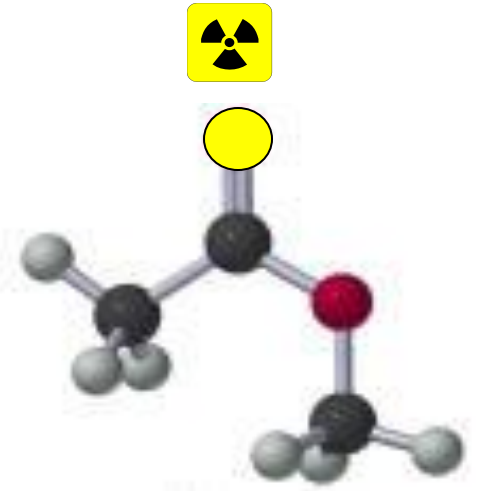


PET



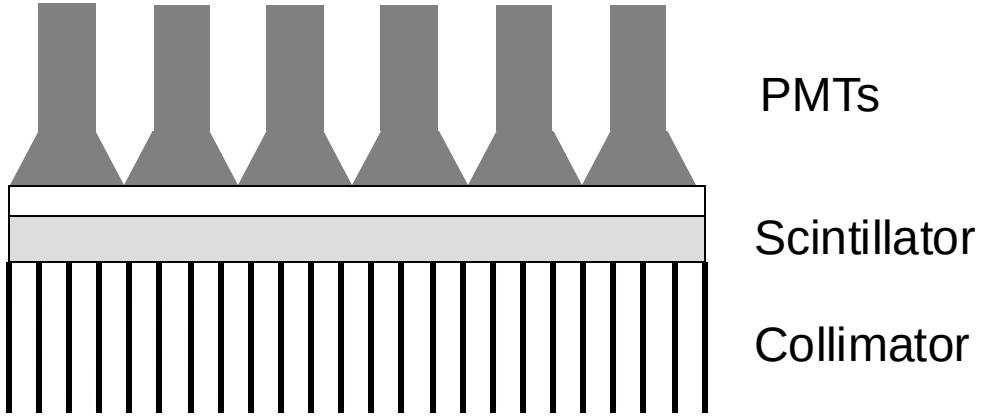
Radiopharmaceutical

- compound tagged with a radionuclide
- accumulation, or rate of uptake or clearance of radiopharmaceutical should be related to a physiologic, biochemical or molecular process, target or function
- radionuclide should produce emissions that can be detected outside the body (primarily gamma rays or annihilation photons)
- radiopharmaceutical introduced in very tiny amounts (~nanograms)



Lectures 7-9: Nuclear imaging

Gamma camera



PET: annihilation coincidence detection

Front view:

Coincidence?

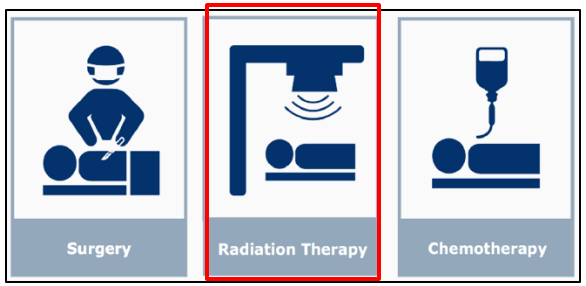
Electronics, processing & display

Side view:

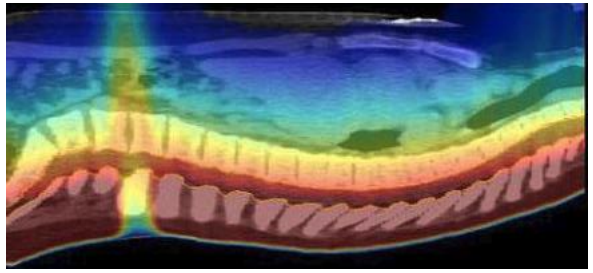
Detectors

Lectures 10—12: Radiotherapy

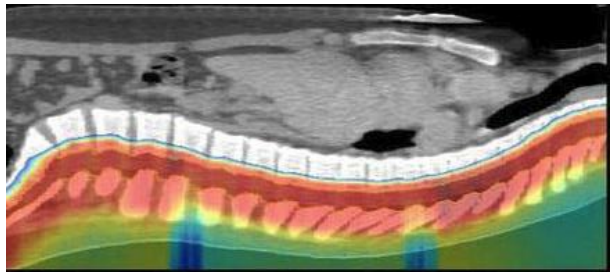
Prof Uwe Oelfke
ICR/RMH
uoelfke@ic.ac.uk &
uwe.oelfke@icr.ac.uk



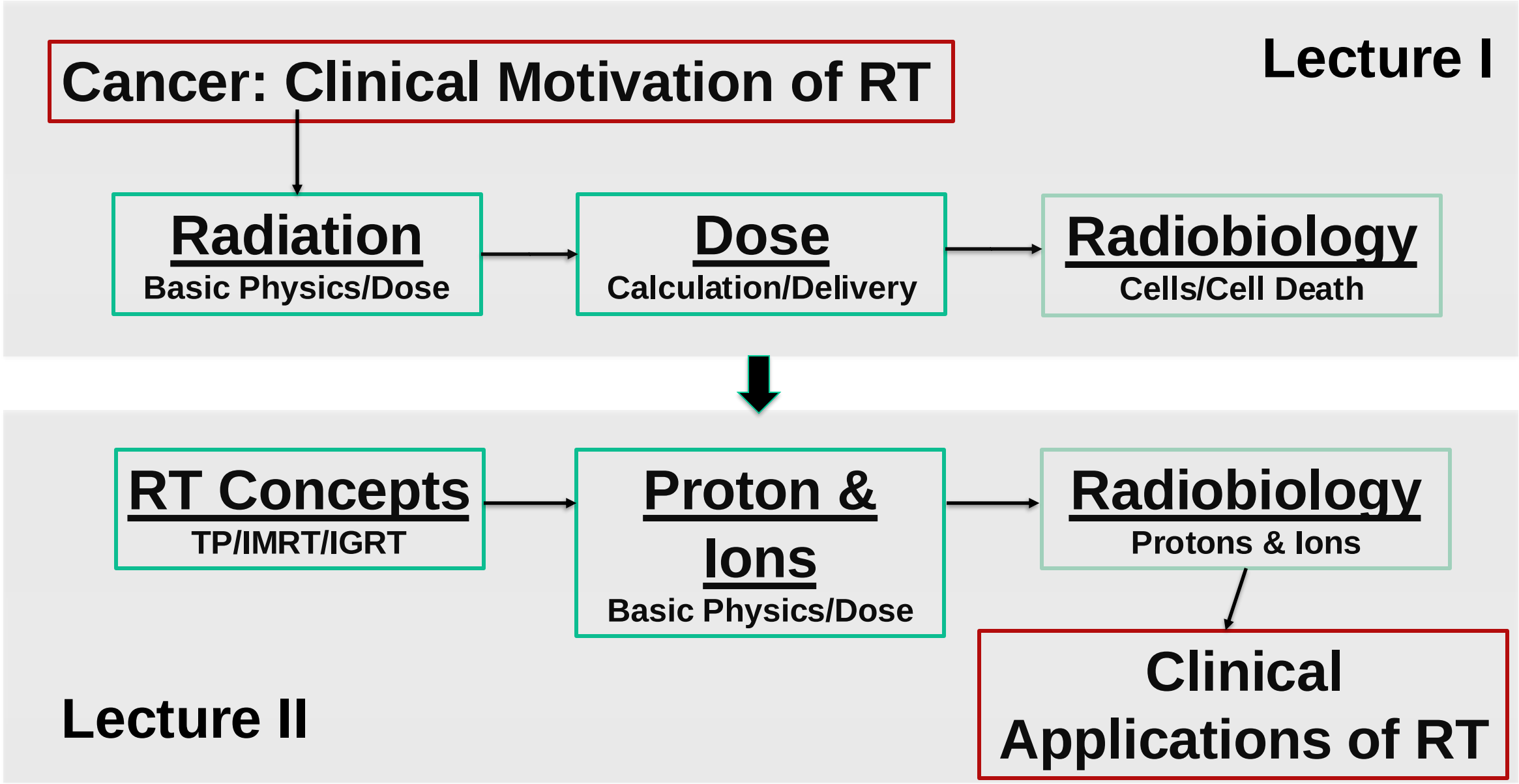
X-ray/photon therapy



Proton-beam therapy



Radiotherapy overview

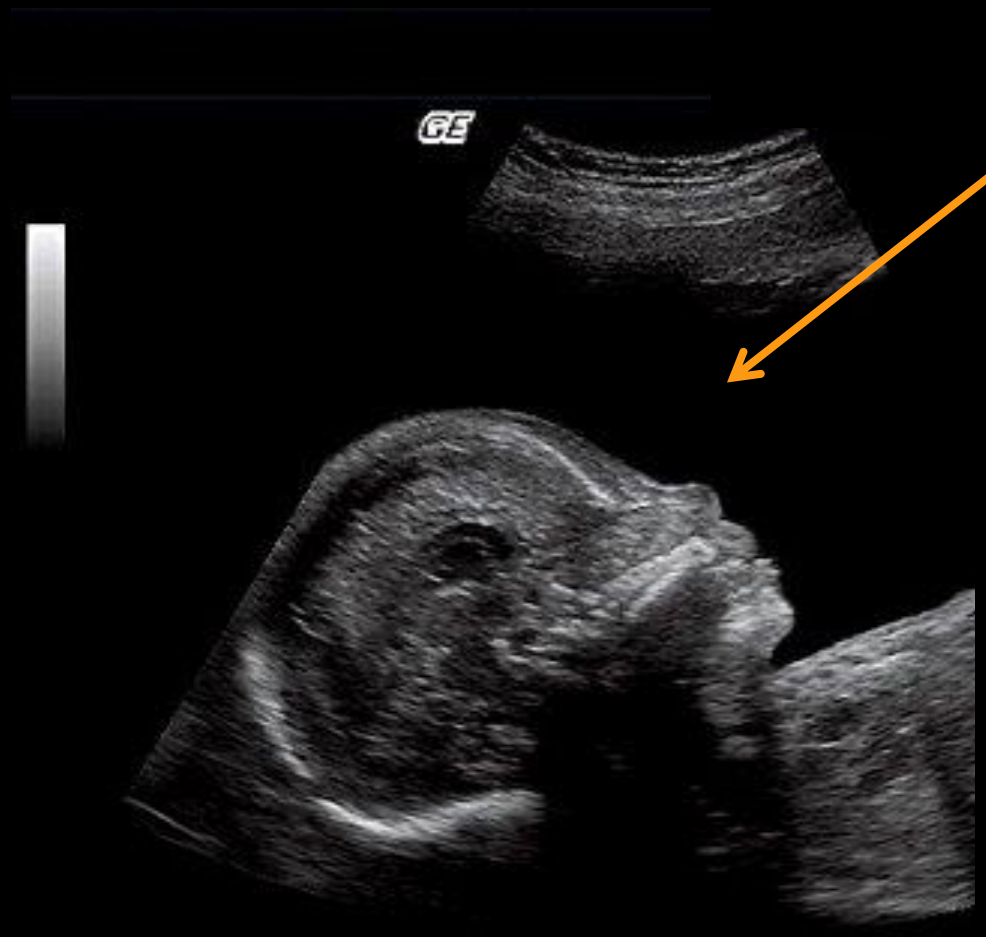


Lectures 13-15: Ultrasound Imaging

Prof Chris Dunsby
christopher.dunsby@imperial.ac.uk

Ultrasound

Safe, gentle, cheap



2D Cross-sectional image

3D surface-rendered image

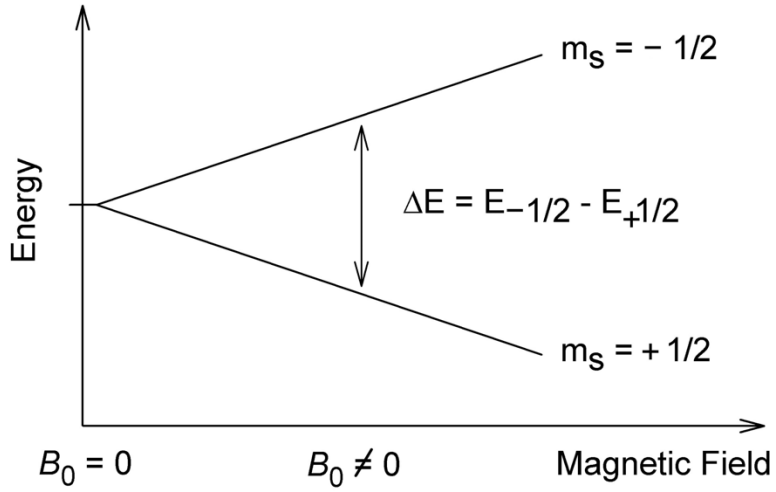
Overview of ultrasound imaging lectures

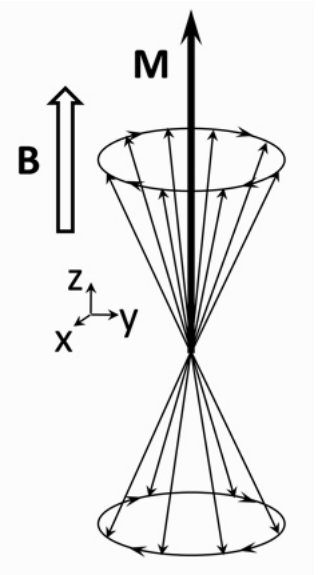
- Physics of ultrasound
  - ultrasound waves
  - wave propagation
  - interaction with biological media
- Engineering
  - hardware and software components for ultrasound imaging
  - design criteria – resolution
  - compromises

Lectures 16—19 and Seminar 6: MRI

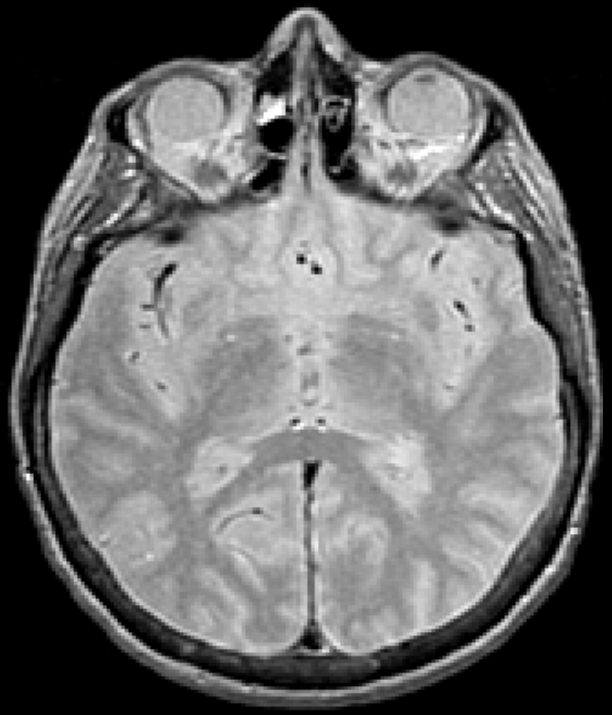
Prof Ken Long
k.long@imperial.ac.uk

MRI

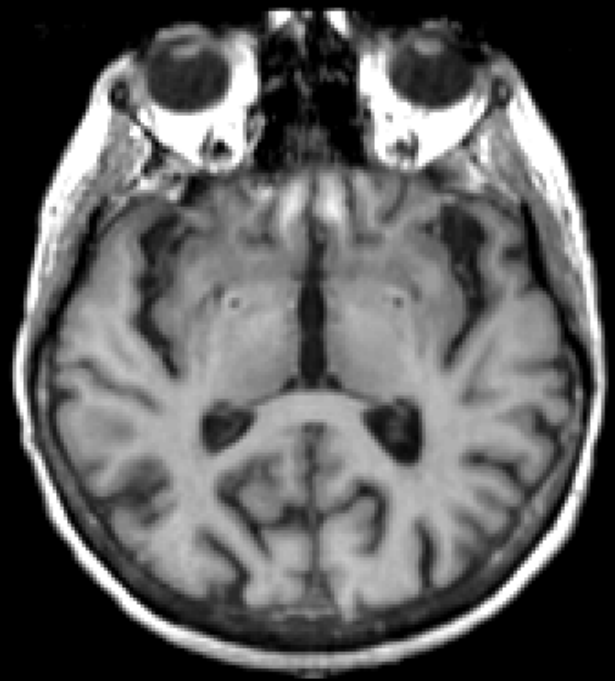




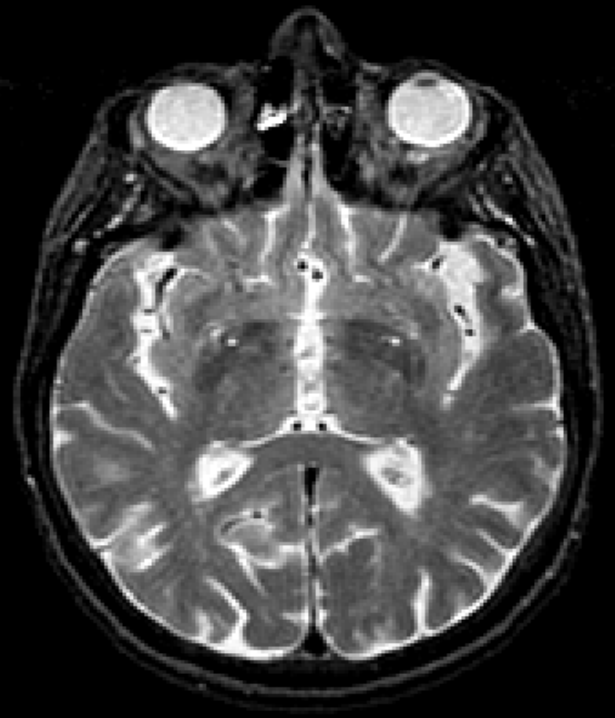
MRI - multi contrast



Proton Density Weighted



T1 Weighted



T2 Weighted

Course Structure: Weeks 7-11

- Problem Sheet Question and Answer exercise
  - Worth 10% of the final mark
  - Topic will be linked to that of the Project, see following slides
  - Work in a group of ~4
  - Group members will be the same as for Project
- Working in your group you:
  - Will prepare a problem sheet-style (NOT an exam-style) question with answers
  - Will have time to work on your PS Q&A in class (15:00 25/02/25, 17:00 28/02/25)
  - Should aim to spend further time on this exercise outside class
  - Should aim that someone else in the class should take ~40 mins to complete it
  - Will assess the problem sheet-style question and answers prepared by 3 other groups
  - Will have time in class for discussing the other group's Q&As (3pm 10/03/25)
  - Assign a single mark (out of 10) from your group for each of the other 3 groups' questions
  - This will then be combined with a mark (out of 10) from a member of academic staff to give the overall mark for the exercise (out of 20)

Course Structure: Weeks 7-11

- Group project on an advanced topic
  - We will release the list of potential projects at end of week 7
  - At start of week 7, you will be asked to give your ranked preference for the projects on offer
  - We will tell you your group and assigned project topic at the PS Q&A session at end of week 8
  - Working with your group, you need to prepare a report
  - It is up to you to arrange meetings with your project supervisor
- The Report – deadline 5pm 2nd May
  - 35% of final mark
  - Max. 5 pages and max. 1500 words per group member (so max. 20 pages and max 6000 words for group of 4)
  - Marked by member of academic staff
- Report peer questionnaire
  - "For the report, each group member will return a survey on the relative contributions of all group members. If the contribution of any group member ***differs from the average by more than 20%***, then ***each group member's mark will be scaled*** by the average of the relative contributions returned by the other group members."