ILLINOIS
UNIVERISTY OF ILLINOIS AT URBANA-CHAMPAIGN

Physics
UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

# Introduction to Career as a therapeutic Medical Physicist

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CAREER SEMINAR, UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
SEP 26TH, 2022

Mass General Brigham
Newton-Wellesley Hospital

# Previous related talks

- Dustin Wooten
  https://ws.engr.illinois.edu/sitemanager/getfile.asp?id=2930
- Lonnie Edelheit
  https://ws.engr.illinois.edu/sitemanager/getfile.asp?id=2933
- Gregg Franklin

# Outline

- Overview of the field
  - Scope, focus and subfields
  - Working environment and schedule
  - Some statistics
- Therapeutic and Imaging Modalities involved
- Research areas/topics
- Educational pathways
- My personal experience

# Overview of the field

# Medical Physics is

- an applied branch of physics
- Apply physics concepts and methods to the diagnosis and treatment of human disease

# Medical Physics is

- interdisciplinary field that integrates core knowledge in traditional physics disciplines with specific domain knowledge in:

- the science of healthcare delivery, particularly in ensuring the accuracy and safety of medical diagnostic and therapeutic procedures;
- bioeffects related to exposures to ionizing and non-ionizing electromagnetic radiation, ultrasonic energy, and strong magnetic fields;
- optimization of imaging and therapeutic procedures to maximize benefit and minimize risk to the patient and healthcare provider;
- evaluation and communication of benefits and risks to patients and healthcare providers;
- image science and image analysis;
- data analysis and statistics;
- clinical trial design, implementation and oversight;
- quality assurance and quality improvement processes;
- electrical, mechanical, and biomedical engineering;
- control systems, including computer controlled, mechanical, and electronic systems;
- mathematics;
- computer science;
- computational modeling;
- detector design and fabrication.

LY1

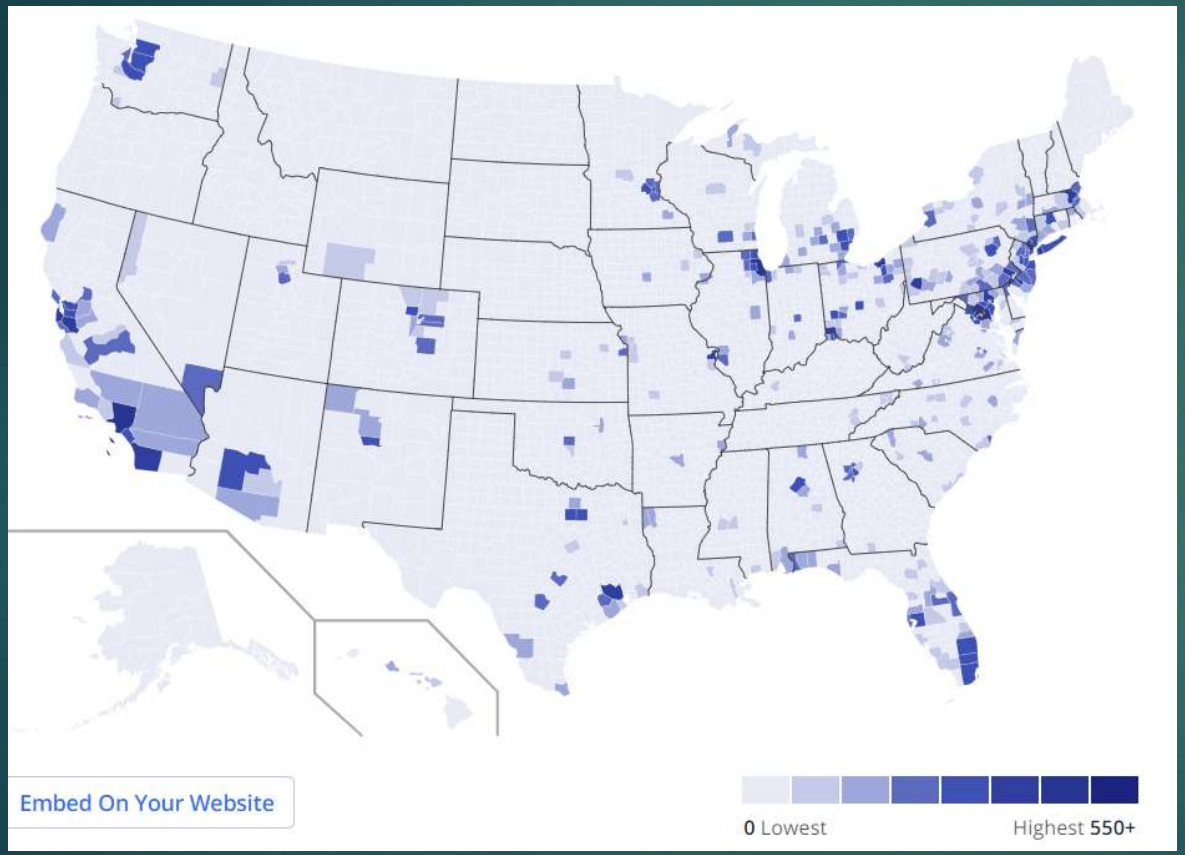
# Subfields

- Medical physicists commonly practice in one of these areas:
  - Therapeutic medical physics.
    - Clinic, Radiation Oncology
  - Diagnostic medical physics.
    - Clinic, Radiology
    - Consulting
  - Nuclear medical physics.
    - Clinic, Nuclear Medicine
  - Medical health physics.
    - Clinic
    - research, industry, education, environmental protection, and enforcement of government regulations
  - Magnetic resonance imaging physics.
    - Clinic, Radiology

## Slide 7

**LY1** Li, Yanjing, 6/24/2022

# Some statistics




- Not very big

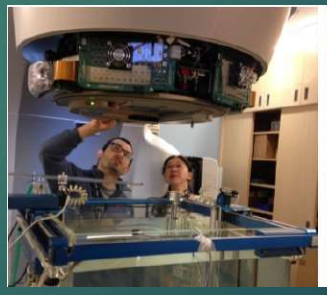
49,555 (APS) vs. 8000 (AAPM)

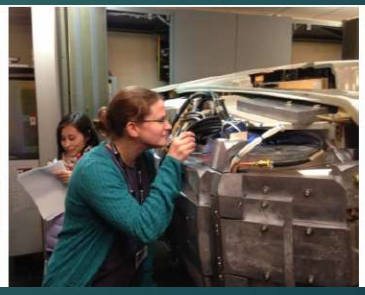
- Jobs mainly located in metropolitan areas
- AAPM member survey (2021)
  - 77% therapeutic
  - 2.8% self employed consultants
  - Women ~25%
  - Average primary salary $207,500

# Clinical medical physicists

- ABR Certification

- Therapeutic medical physicists:
  - Responsible for treatment machines
  - Best design of patient treatments
  - Safety
  - Research & development
  - Clinical implementation of new technology





| Clinic is a must-have | Research is optional - depends on the appointment |
|---|---|

Joost Verburg, PhD

# Intro to Radiation therapy

- Radiation therapy uses carefully targeted and regulated doses of high-energy radiation to kill cancer cells.
- Radiation causes some cancer cells to die immediately after treatment, but most die or become incapacitated as a result of the radiation-induced damage to the cancer cell's chromosomes and DNA.

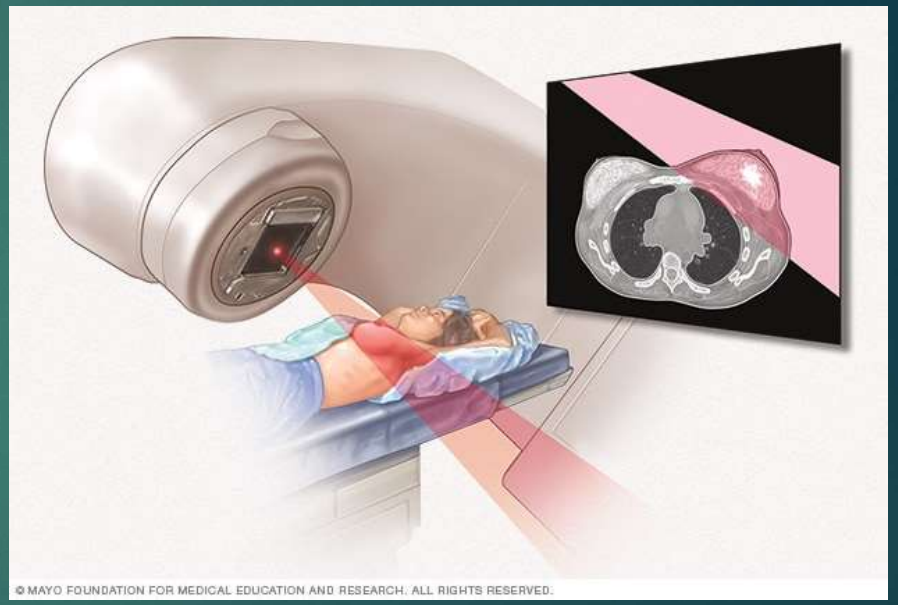



Photo source: Mayo Clinic

# Work environment & schedule

- Work environment
  - Clinic or Industry (consulting Company)
  - Cancer center/Institution (academic) or Private Clinics
  - Big Center or Community hospital
- Schedule
  - Regular clinic hour + After hour
  - Really depends on the clinic & subfields
- People
  - Internal: dosimetrists, physicists, physicians, (patients), nurses, therapists, admin
  - External: engineers, vendors

# Modalities

THERAPY + IMAGING

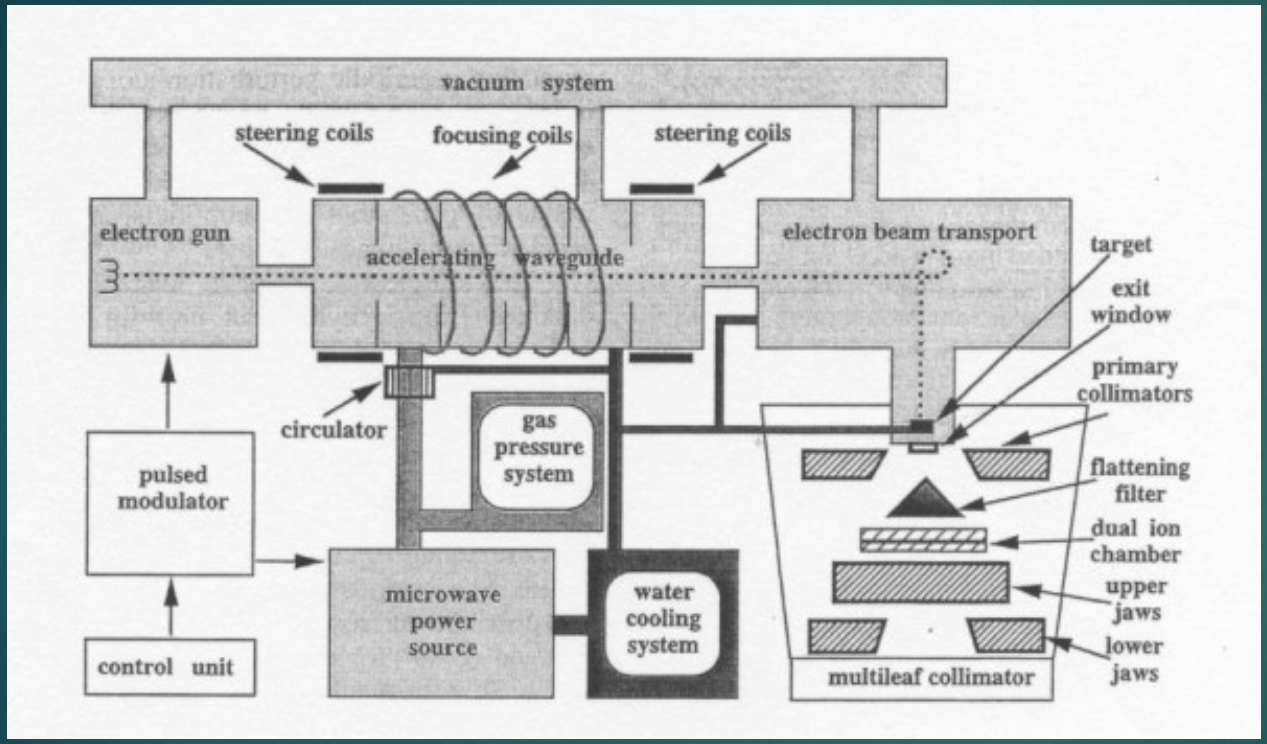
# Therapeutic Medical Physicists

- Hardware (imaging + therapy)
  - CT, MRI, PET
  - External beam
    - Gantry based Linear accelerator
    - Gamma knife, Cyberknife, tomotherapy
  - Brachytherapy
  - MR-Linac
  - Proton
- Software
  - Record and verify system
  - Treatment planning system
  - Quality assurance system
  - …

# Linear accelerator

Photo source: Varian

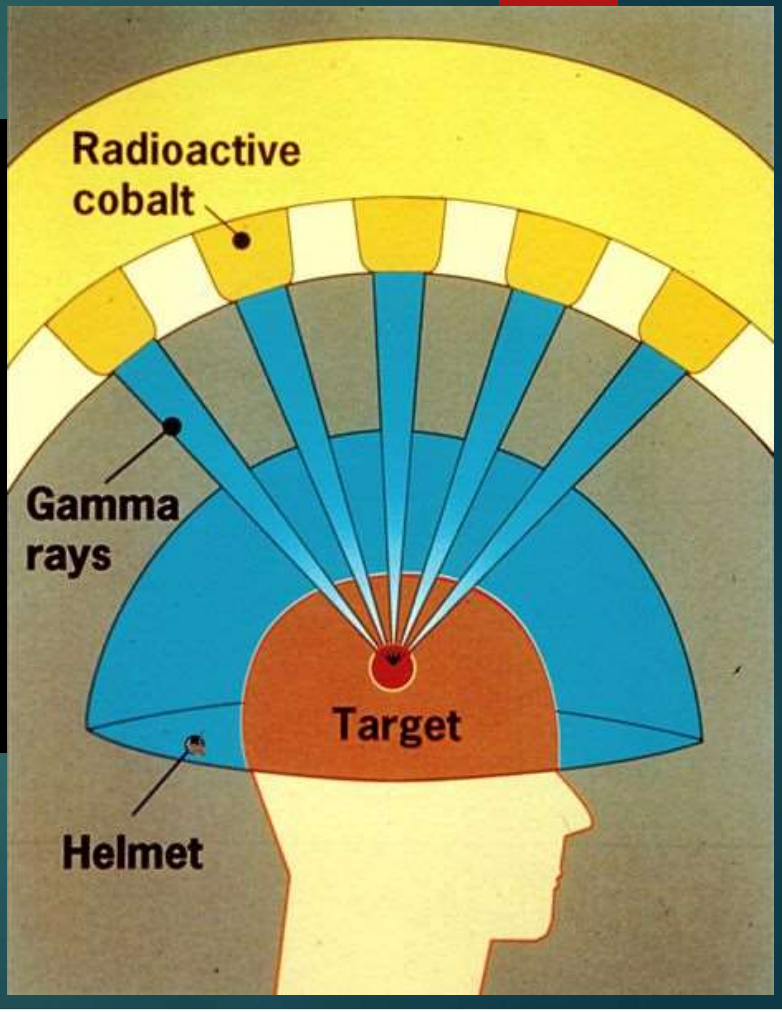
# How it works




Schematic diagram of a typical medical linear accelerator. (reproduced from Van Dyk, J. The modern technology of radiation oncology Madison, WI, USA: Medical Physics Publishing; 1999. p1073.)

# Gamma knife

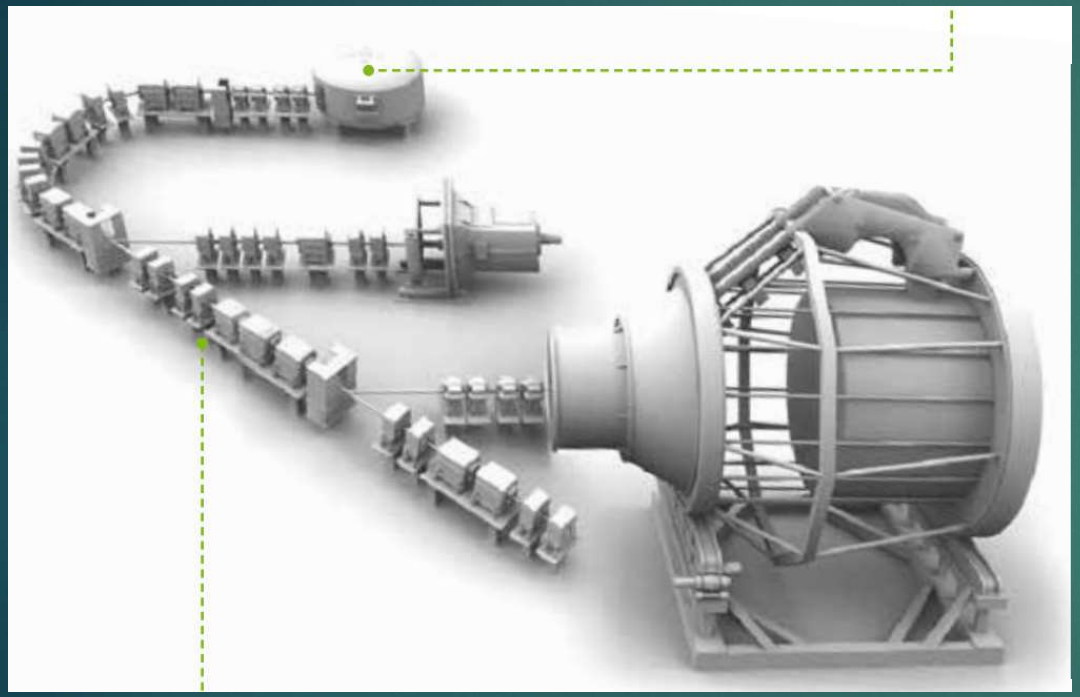
Photo source: Elekta



# Cyberknife


Photo source: Accuray

# Proton therapy



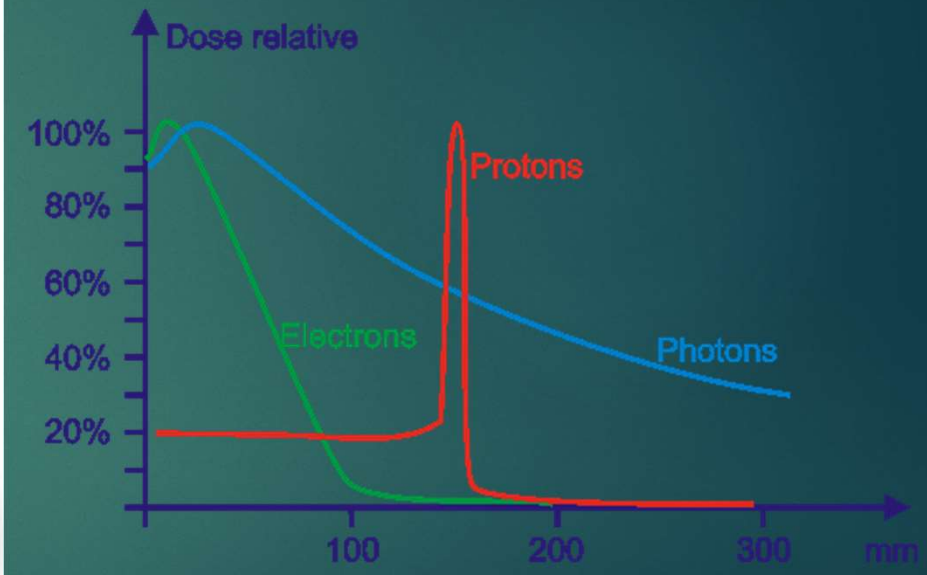
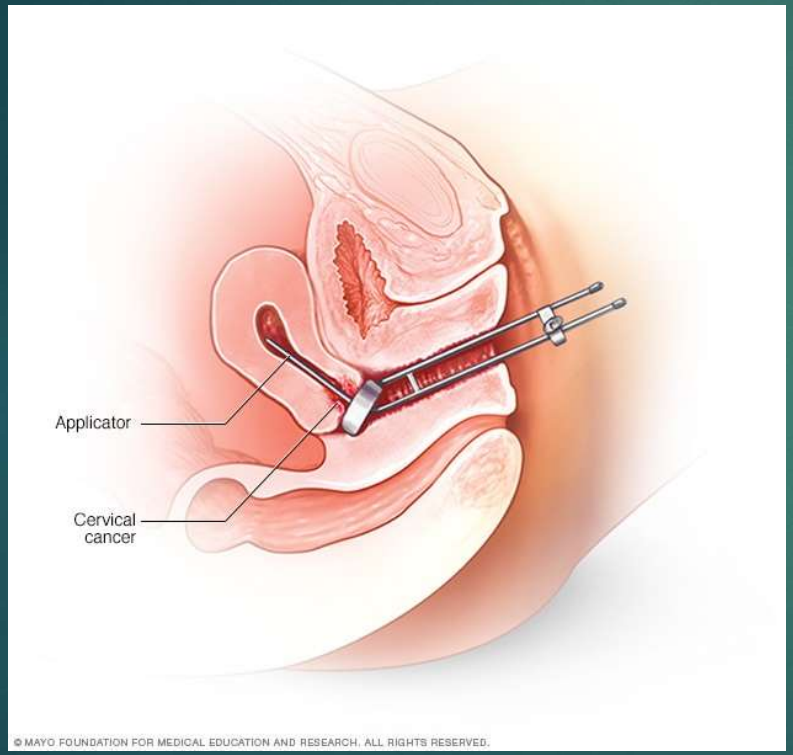




Photo source: IBA

# Brachytherapy



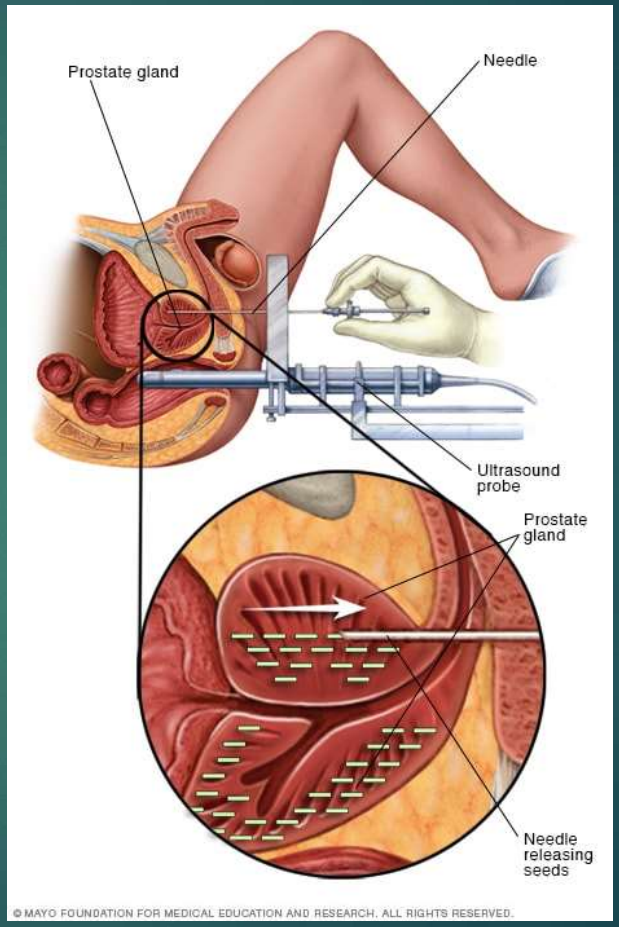
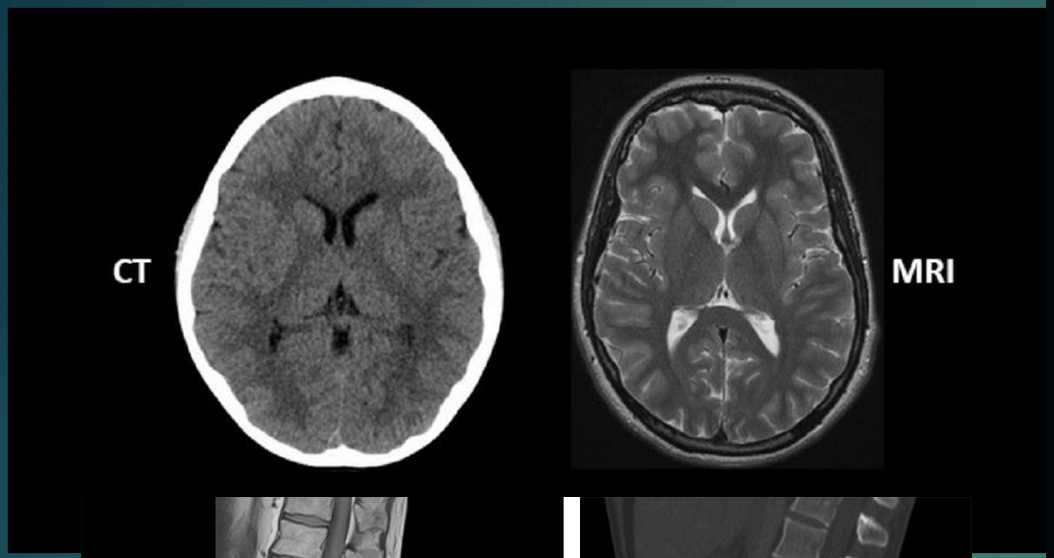
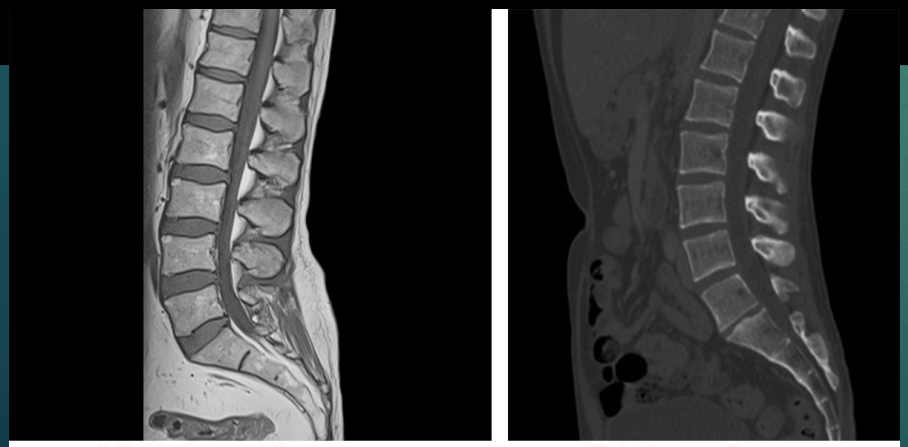




Photo source: Mayo clinic

# MR-Linac



MRI Scan Image



CT Scan Image

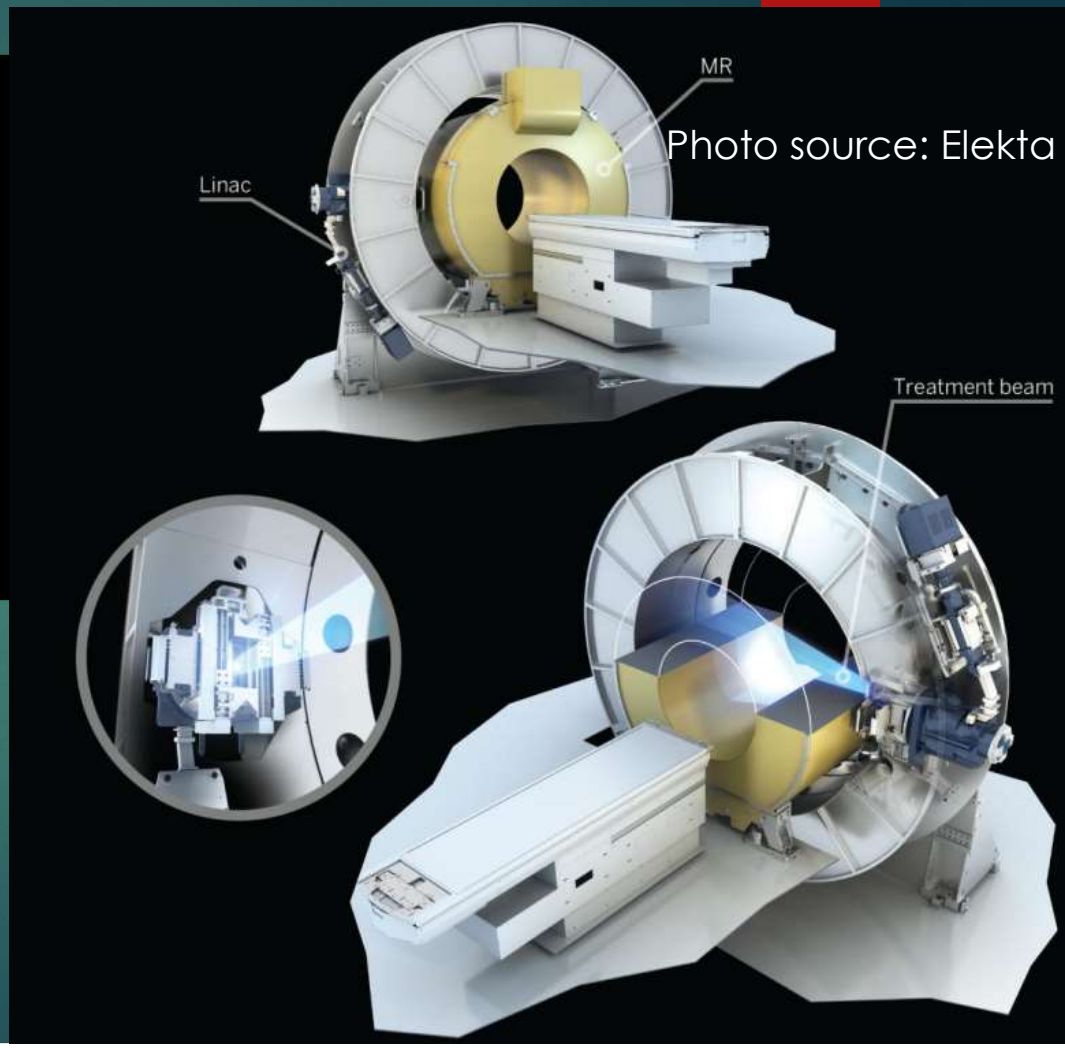



Photo source: Elekta

# Research

# A List of topics

- Biological Modeling
- Drug-Radiation Interaction
- Image Registration
- Monte Carlo
- Motion Management
- Optimization
- Outcome Assessment
- Proton Therapy
- Systems Biology
- Therapy Imaging
- …

**Clinical-driven**
**direct application to patient care**

# Proton

## The Nobel Prize in Physics 1915

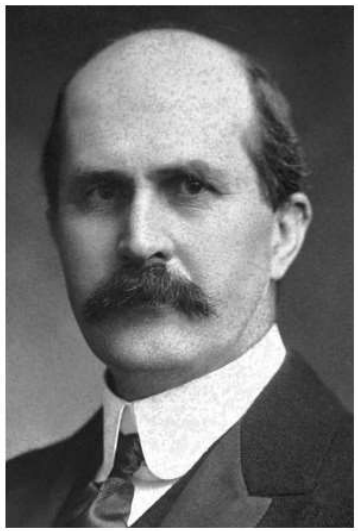


Photo from the Nobel Foundation archive.

Sir William Henry Bragg

Prize share: 1/2

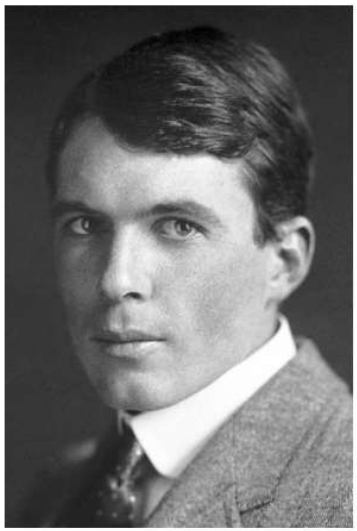


Photo from the Nobel Foundation archive.

William Lawrence Bragg

Prize share: 1/2

- for their services in the analysis of crystal structure by means of X-rays

# CT

## The Nobel Prize in Physiology or Medicine 1979

Photo from the Nobel Foundation archive.

Allan M. Cormack

Prize share: 1/2

Photo from the Nobel Foundation archive.

Godfrey N. Hounsfield

Prize share: 1/2

- for the development of computer assisted tomography

# Nobel prizes related to MR

- 1954
  - Felix Bloch and Edward M. Purcell
  - development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith.
- 1991
  - Richard Robert Ernst
  - the development of the method of high-resolution nuclear magnetic resonance (NMR) spectroscopy.
- 2003
  - Paul Lauterbur and Sir Peter Mansfield
  - discoveries concerning magnetic resonance imaging

# Biology

## The Nobel Prize in Physiology or Medicine 2019

© Nobel Media. Photo: A. Mahmoud

William G. Kaelin Jr

Prize share: 1/3

© Nobel Media. Photo: A. Mahmoud

Sir Peter J. Ratcliffe

Prize share: 1/3

© Nobel Media. Photo: A. Mahmoud

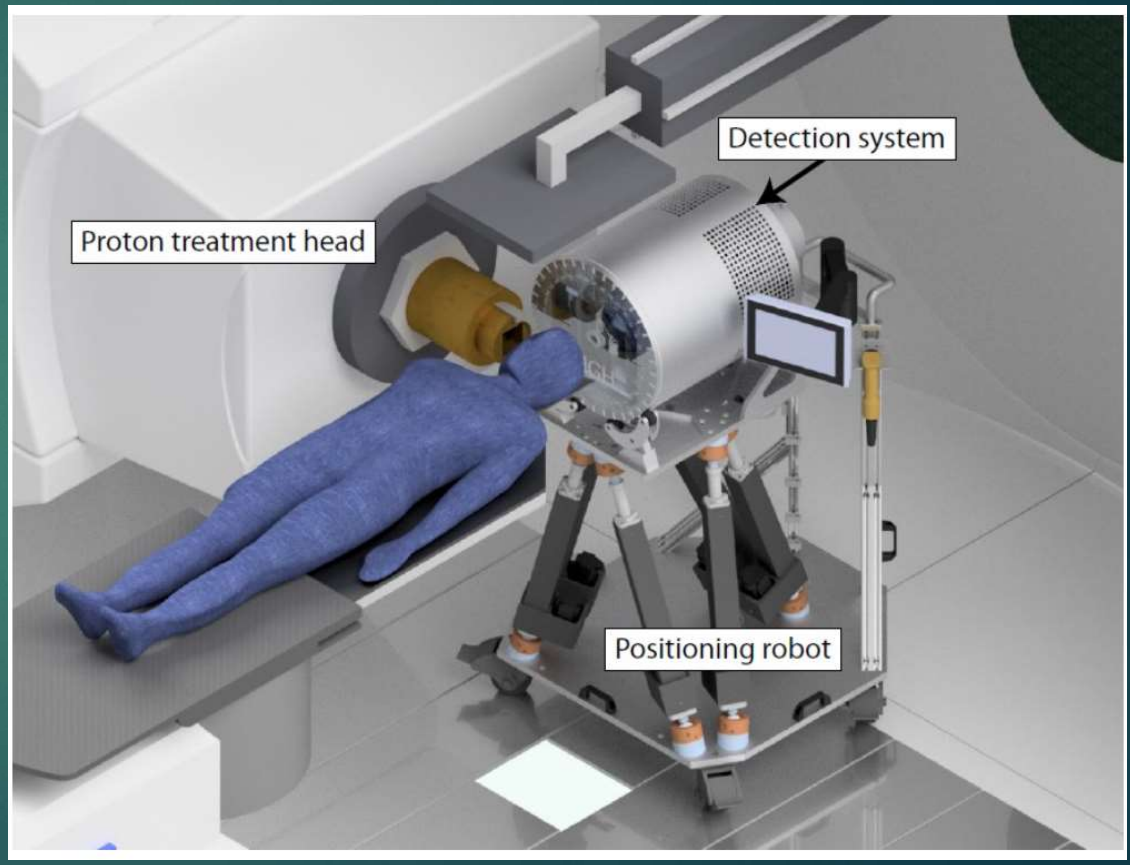
Gregg L. Semenza

Prize share: 1/3

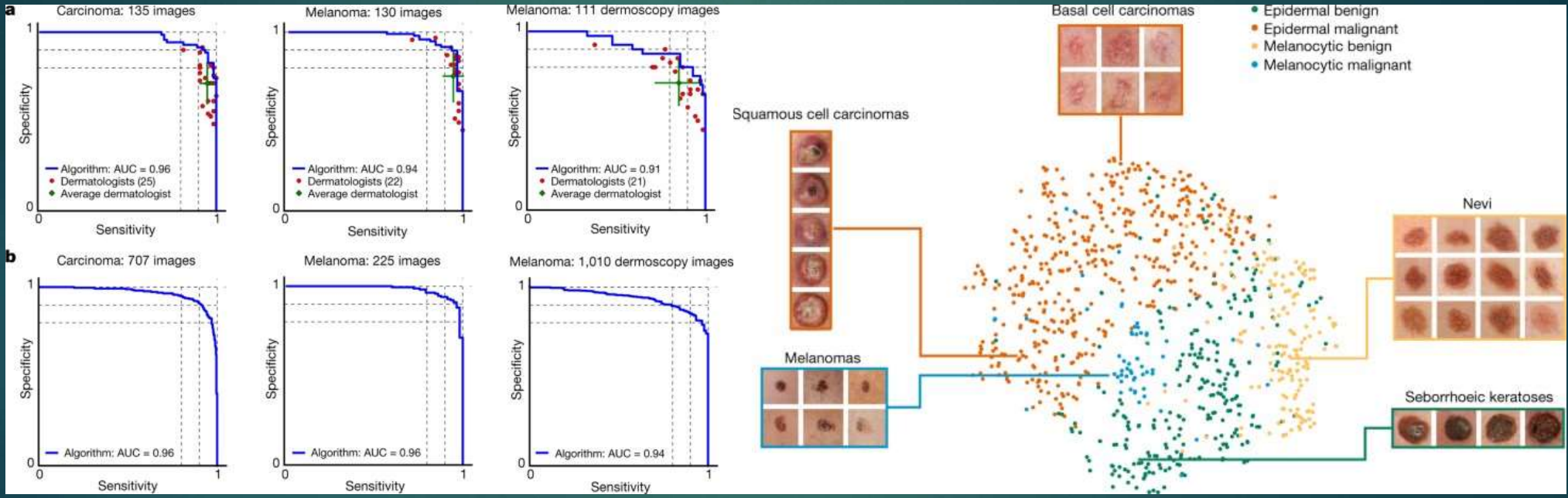
- for their discoveries of how cells sense and adapt to oxygen availability.

# Experimental Prompt gamma

- Clinical needs – where the proton stops?
- Rang uncertainty - multiple Coulomb scattering
- prompt gamma rays – radiation produced by proton interactions with atomic nuclei within the patient.

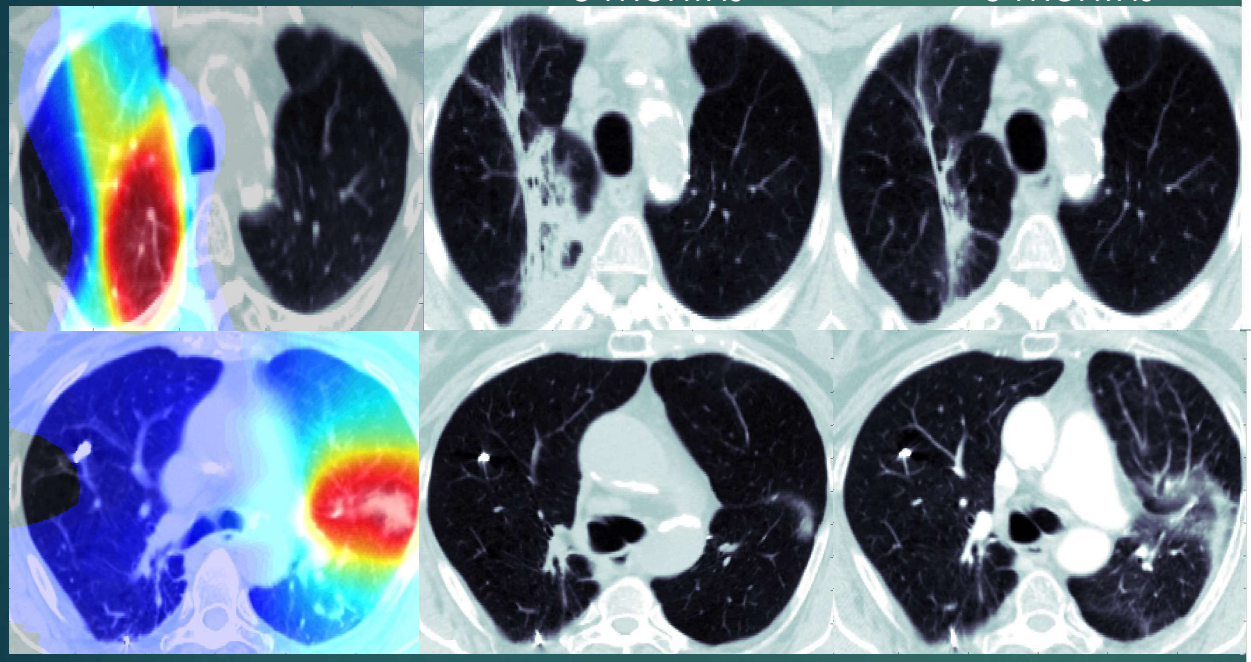


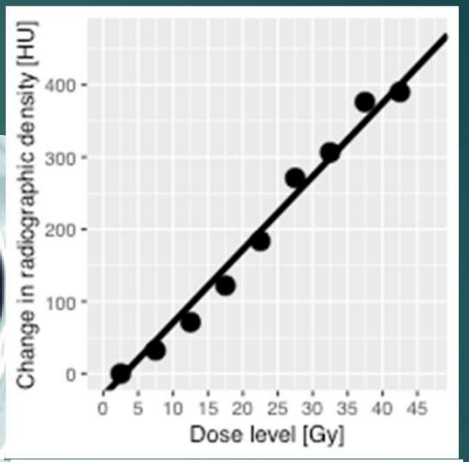
# Skin cancer Classified By CNN

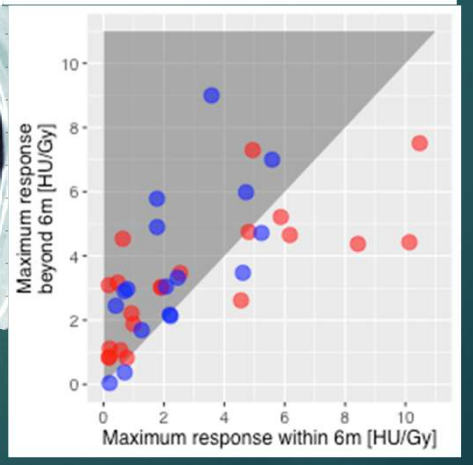



Esteva et al. Nature (2017)

# lung density change after proton vs. photon SBRT



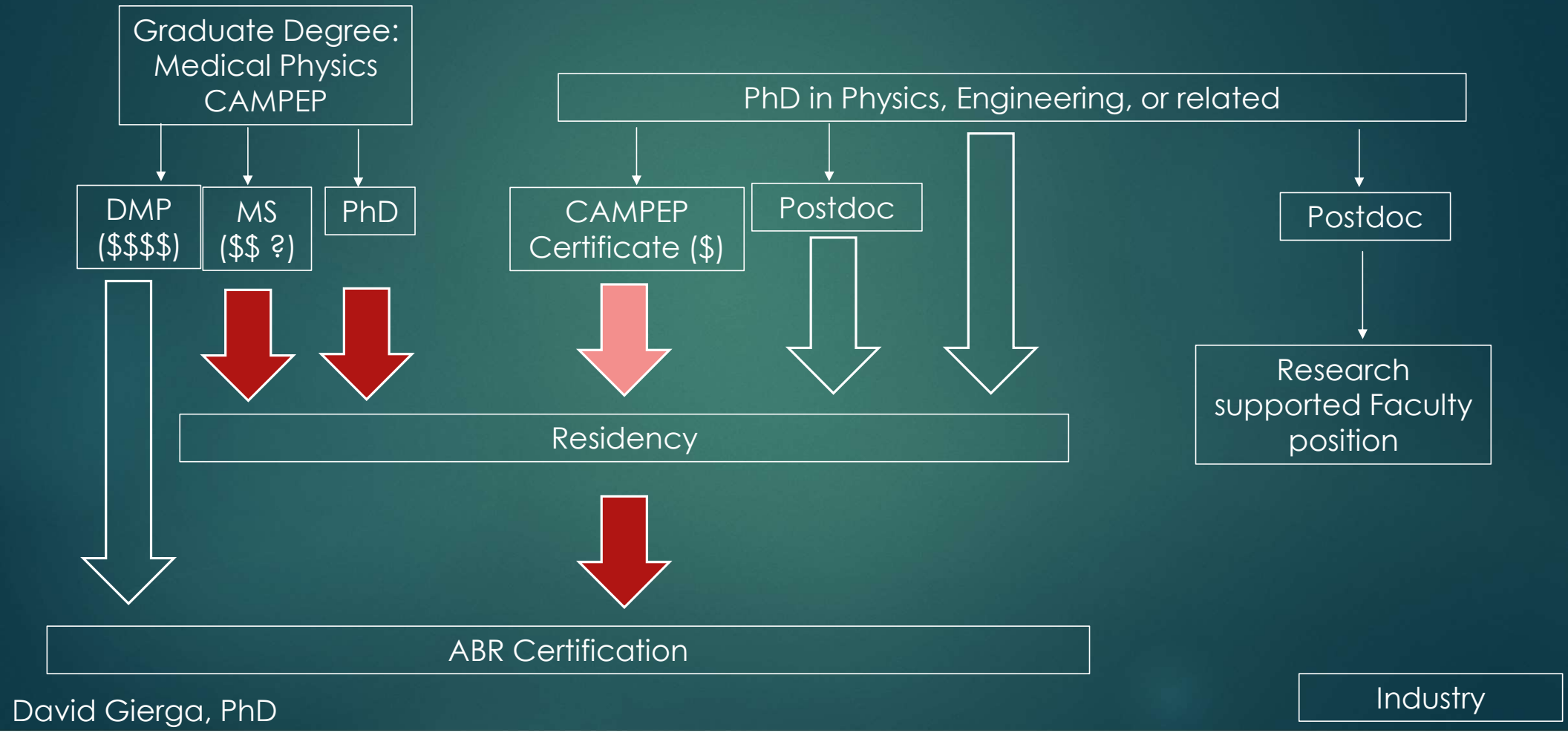




Li et al. Radiotherapy & Oncology (2019)

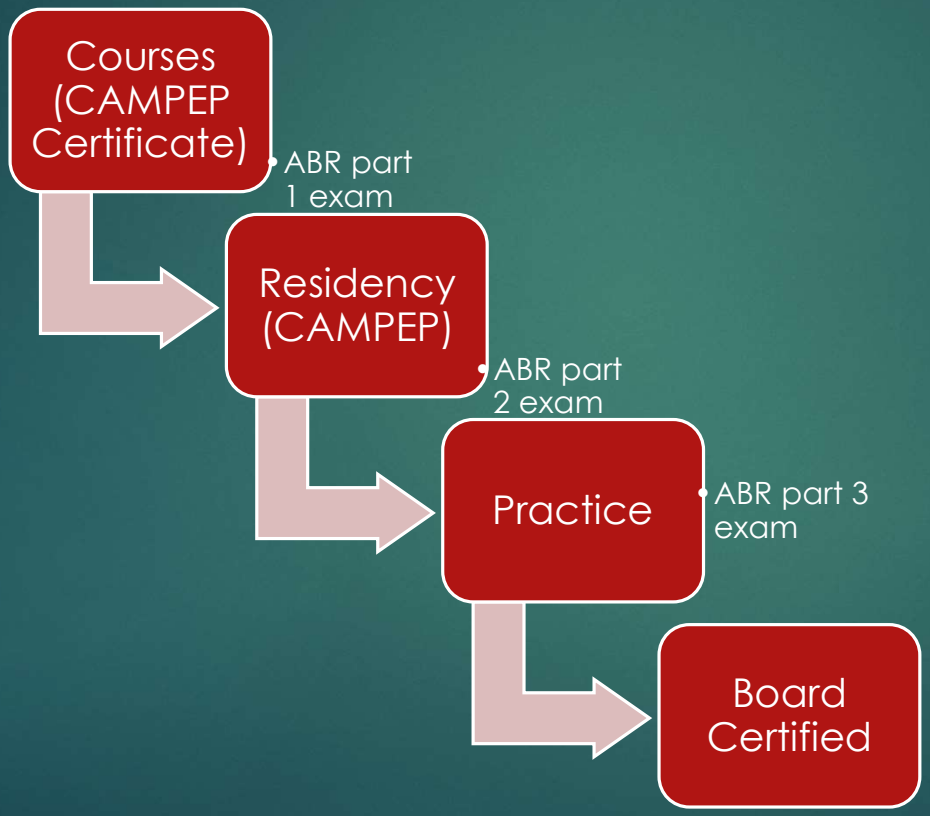
# Educational pathways

# Current Medical Physics Pathways




David Gierga, PhD

# Clinical Physics Pathway Summary




ABR | American Board of Radiology

# Certificate Programs

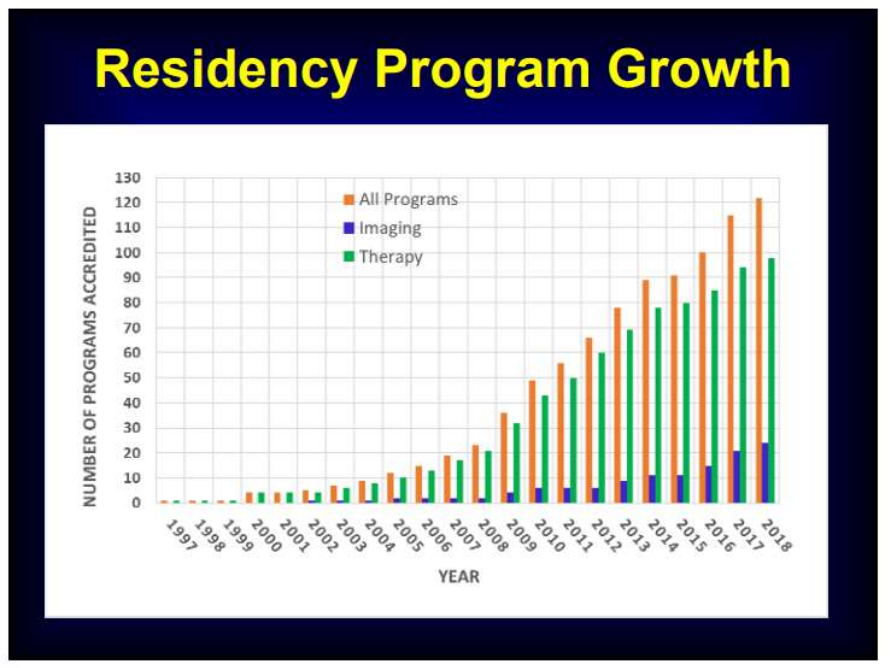
- didactic coursework offered by a CAMPEP-accredited graduate or residency program
- enable individuals with a doctoral degree in physics or a related discipline to meet the didactic requirements needed to enter a CAMPEP-accredited residency program.

CAMPEP website

| Institution | Accreditation | Expiration |
|---|---|---|
| Cleveland State University | 2015 | 2022 |
| Columbia University | 2012 | 2023 |
| Dalhousie University | 2015 | 2024 |
| Dartmouth College | 2021 | 2026 |
| Emory University | 2020 | 2023 |
| Florida Atlantic University | 2017 | 2021 |
| Harvard University | 2016 | 2020 |
| Purdue University | 2017 | 2022 |
| Louisiana State University | 2014 | 2021 |
| Mayo Clinic (MN) | 2019 | 2022 |
| McGill University | 2013 | 2023 |
| Medical College of Wisconsin | 2013 | 2023 |
| Rutgers SUNJ | 2015 | 2024 |
| University of Calgary | 2011 | 2021 |
| University of California Los Angeles | 2013 | 2021 |
| University of Chicago | 2011 | 2023 |
| University of Kentucky | 2015 | 2025 |
| University of Miami | 2014 | 2021 |
| University of Michigan | 2016 | 2021 |
| University of Nevada Las Vegas | 2014 | 2021 |
| University of Pennsylvania | 2012 | 2024 |
| University of Texas Houston | 2012 | 2023 |
| University of Tennessee Knoxville | 2019 | 2022 |
| University of Texas Southwestern | 2018 | 2020 |
| University of Victoria | 2013 | 2023 |
| Virginia Commonwealth University | 2015 | 2020 |
| Washington University in St. Louis | 2013 | 2021 |
| Wayne State University | 2018 | 2026 |
| Western University | 2015 | 2022 |

# Residency Programs

- Full list: https://campep.org/campeplstres.asp
- 153 accredited programs (115 therapy / 38 diagnostic)
- # of residents per year: 140 therapy / 15 diagnostic (2018)




Nesrin Dogan, CAMPEP

**Imaging** **Granted administrative extension of accreditation while under review for reaccreditation.

Allegheny Health Network
Astarita Associates, Inc.
Boston Children's Hospital and Harvard Medical School *
Cleveland Clinic*
Columbia University
Corwin Health Physics, Inc.
Cross Cancer Institute - University of Alberta*
Emory University *
Duke University Medical Center
Henry Ford Health System*
Indiana University School of Medicine
Mayo Clinic***
Medical College of Wisconsin
Medical & Radiation Physics, Inc.
Medical University of South Carolina
Memorial Sloan Kettering
Naval Medical Center Portsmouth
Oregon Health & Science University
Petrone Associates
Radcom Associates*
Southern California Permanente Medical Group*,***
Stony Brook University Medical Center *
The Ohio State University
University Hospitals Cleveland Medical Center
University of Alabama at Birmingham
University of Chicago
University of Florida College of Medicine*
University of New Mexico
University of Oklahoma Health Science Center
University of Pennsylvania
University of Texas McGovern Medical School*
University of Texas M. D. Anderson Cancer Center*
University of Texas Southwestern Medical Center
University of Wisconsin
Upstate Medical Physics
Vancouver Coastal Health Authority*
West Physics***
Yale School of Medicine-Yale New Haven Hospital

# My experience

# Path

- 2018 – 2019, Harvard Medical Physics Certificate Program
  - ABR board part 1, 2019
- 2019 – 2021, Medical Physics Residency Program at Rutgers University
  - ABR board part 2, 2021
- 2021 July -2022 Apr, Saint Vincent Hospital
  - ABR board part 3, Certified 2022
- 2022 Apr – present, Newton Wellesley Hospital

# Certificate Program at Harvard

- To apply
  - https://harvardmedphys.org/certificate-program/
- 6 courses (can be done within a year)
- Tuition fee $28,000
- Clinical exposure
- research opportunities

| Credits | Course |
|---|---|
| 3 | Physics I (Physics and dosimetry) |
| 3 | Physics II (Radiation therapy) |
| 3 | Radiation Biology |
| 3 | Medical Imaging Modalities |
| 3 | Radiation Protection Safety |
| 2 | Anatomy and Physiology |

# Residency Program at Rutgers

- Apply, interview and then match
- 2 years of clinical training
- Work in the clinic while learn from dosimetrist and qualified physicists
- A nice varieties of modalities

| Duration | Rotation |
|---|---|
| 6 mons | Treatment planning |
| 3 mons | Machine and QA |
| 4 mons | Brachytherapy |
| 3 mons | Commissioning and special procedures (TBI, TSET) |
| 2 mons | Medical Imaging |
| 3 mons | SRS (Gamma Knife) |
| 3 mons | Proton therapy |

# Daily work

- Treatment planning
- Quality Assurance
  - Machines and equipment
  - Chart check
  - Patient specific QA
- Introduction and commissioning of new techniques
- Machine issues

# Opportunities & Challenges

- Non-academic
  - Project Management
  - Leadership
- Academic center
  - Research
  - Teaching

- Radiation Safety
  - Accuracy of dose and positioning
  - Accidents happen
- Interaction with people
  - Colleagues (interdisciplinary team)
  - Patients
- Emergency situations
  - Machine issues
  - Clinical decisions

# Acknowledgement


- Nadya Mason
- Lance Cooper
- Lonnie Edelheit
- David Gierga
- John Beatty

# Reference


- AAPM: The American Association of Physicists in Medicine
https://www.aapm.org

- American board of Radiology
https://www.theabr.org/

- Harvard Medical Physics Certificate Program
https://harvardmedphys.org/certificate-program/

- Rutgers University Medical Physics Residency Program
https://rwjms.rutgers.edu/departments/radiation-oncology/educational-programs/medical-physics-residency-program

# Questions

- yli94@mgh.Harvard.edu

# Glossary

- DMP

  A professional doctorate program, typically leading to a degree of Doctor of Medical Physics (DMP) consists of at least two years of didactic education followed by at least two years of clinical education.

- CAMPEP (Commission on Accreditation of Medical Physics Education Programs)

  is a nonprofit organization, independent of its Sponsoring Organizations, whose objectives are the review and accreditation of educational programs in medical physics.

- ABR (American Board of Radiology)

  is an independent, not-for-profit organization and is one of 24 national medical specialty boards that make up the American Board of Medical Specialties (ABMS). We were founded to protect the public by assessing and certifying doctors who meet specific educational, training, and professional requirements.

- Residency

  This Residency Program training involves full participation of the physics resident in the clinical routine, under the supervision of experienced radiation oncology physicists.