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Physics and medicine: a historical perspective

Stephen F Keevil

Nowadays, the term medical physics usually refers to the work of physicists employed in hospitals, who are concerned mainly with medical applications of radiation, diagnostic imaging, and clinical measurement. This involvement in clinical work began barely 100 years ago, but the relation between physics and medicine has a much longer history. In this report, I have traced this history from the earliest recorded period, when physical agents such as heat and light began to be used to diagnose and treat disease. Later, great polymaths such as Leonardo da Vinci and Alhazen used physical principles to begin the quest to understand the function of the body. After the scientific revolution in the 17th century, early medical physicists developed a purely mechanistic approach to physiology, whereas others applied ideas derived from physics in an effort to comprehend the nature of life itself. These early investigations led directly to the development of specialties such as electrophysiology, biomechanics, and ophthalmology. Physics-based medical technology developed rapidly during the 19th century, but it was the revolutionary discoveries about radiation and radioactivity at the end of the century that ushered in a new era of radiation-based medical diagnosis and treatment, thereby giving rise to the modern medical physics profession. Subsequent developments in imaging in particular have revolutionised the practice of medicine. We now stand on the brink of a new revolution in post-genomic personalised medicine, with physics-based techniques again at the forefront. As before, these techniques are often the unpredictable fruits of earlier investment in basic physics research.

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This is the first in a Series of five papers about physics and medicine

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Introduction

Medical physics, as we usually understand the term, emerged as a distinct scientific discipline early in the 20th century in response to the growing use of ionising radiation in diagnosis and treatment. Establishment of the first posts for hospital-based physicists during this period laid the foundations for a new health-care profession, which continues to play an important part in the development and safe and effective implementation of physics-based technology. However, the relation between physics and medicine has a much longer and richer history than this conventional picture suggests. In fact, medical physics could be anywhere between 100 and 5000 years old, depending on how broadly it is defined.

In this report, the first in *The Lancet* Series, I have taken a broad view of how this relation has evolved, sometimes intentionally but perhaps more often by chance, across several centuries. It ends with a glimpse into the future, exploring how medical physics as a profession and a scientific discipline might develop as new areas of physics begin to be used by clinicians in the post-genomic world.

Antiquity and the middle ages

Physical techniques have been used in medicine from the earliest times. The Edwin Smith Surgical Papyrus, written in Egypt between 3000 and 2500 BC, is the oldest known medical document. It contains a remarkable description of the treatment of breast abscesses by cauterisation with a fire drill.[1] A little later, the iconic Greek physician Hippocrates (circa 460–377 BC) described the first recorded method for measurement of body temperature.[2] Hippocrates' technique was actually a form of thermal imaging akin to thermography (figure 1), and so arguably is the earliest example of diagnostic imaging. By 200 AD, priests on the Greek island of Samothrace were selling magnetic rings to treat arthritis,[3] another approach that has parallels nowadays, despite the absence of a convincing evidence base.[4]

Some of the greatest thinkers of the medieval period worked at the interface between medicine and physics. The Iraqi polymath Ibn al-Haytham (circa 965–1039), usually known by the Latinised name Alhazen, revolutionised the development of science and the scientific method in Europe and the Islamic world. Alhazen made particularly important contributions to optics, including a description of the physics of vision, and the first experimental demonstration that sight is caused by rays of light entering the eye rather than by

Key messages

- The relation between physics and medicine dates back to the earliest recorded period of medical history.
- Across the centuries, application of physics laid the foundations for scientific exploration of the functions of the body.
- Disciplines such as electrophysiology, biomechanics, and ophthalmology are the direct result of the application of physics to medical and physiological questions.
- Early in the 20th century, increasing use of radiation in medicine led to a demand for physicists who could apply their expertise directly to the clinical care of patients, and the modern medical physics profession began.
- Many advances in medicine, such as MRI and modern radiotherapy, are unpredictable spin-offs from fundamental physics research, and were only possible because of past investment in basic science.
- As we stand on the brink of a revolution in post-genomic personalised medicine, once again physicists have the opportunity to play leading parts in the safe and effective use of new physics-based techniques for diagnosis and treatment.

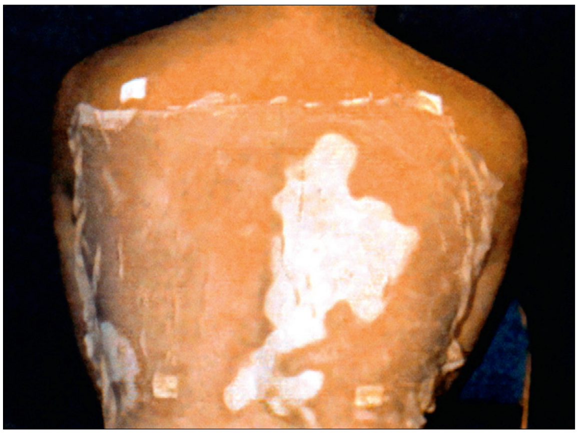

Figure 1: **Reproduction of Hippocratic thermography**
This image was taken 8 min after a cloth soaked in potter's earth was applied to the volunteer's back. The rate at which the cloth dries is related to the temperature of the skin underneath. The region on the right-hand side had previously been heated with a compress. Reproduced from Ostuka and Togawa,[2] by permission of IOP Publishing.

light emanating from the eye to probe objects as some had thought previously.[5]

Although Alhazen has been called the world's first true scientist,[6] Leonardo da Vinci (1452–1519) has been described as the first medical physicist because of his detailed studies of the mechanics of the human body.[7] Although this work was more closely related to clinical engineering than to medical physics, the boundary between these disciplines is, at best, indistinct. His work on optics and his discovery of the principle of the contact lens fall squarely into the domain of physics,[8] so perhaps we can add father of medical physics to the many epithets applied to Leonardo.

Medical physics as iatrophysics

The scientific revolution in the 17th century led to changes in the philosophy and practice of science although scholarly opinions differ as to whether these changes were truly revolutionary,[9] or merely the logical outworking of ideas originating in the medieval period and earlier.[10] However, whether by radical or gradual change, by the end of the period, scientific method had been established, science and reason had supplanted religion as the principal source of knowledge about the natural world, and the main scientific disciplines had been established as spheres of study distinct both from each other and from philosophy.

The recognition early in this period that material objects obey rational physical laws led to the development of mechanistic philosophy: the belief that nature could be exhaustively described in purely mechanistic terms. The case for extension of this new dogma to living creatures seemed to be supported by discoveries about the role of the heart as a pump by Andreas Vesalius (1514–64) and the circulation of the blood by William Harvey (1578–1657), and later by the work of Anton van Leeuwenhoek (1632–1723) whose microscope opened up new vistas of biological structure.[11]

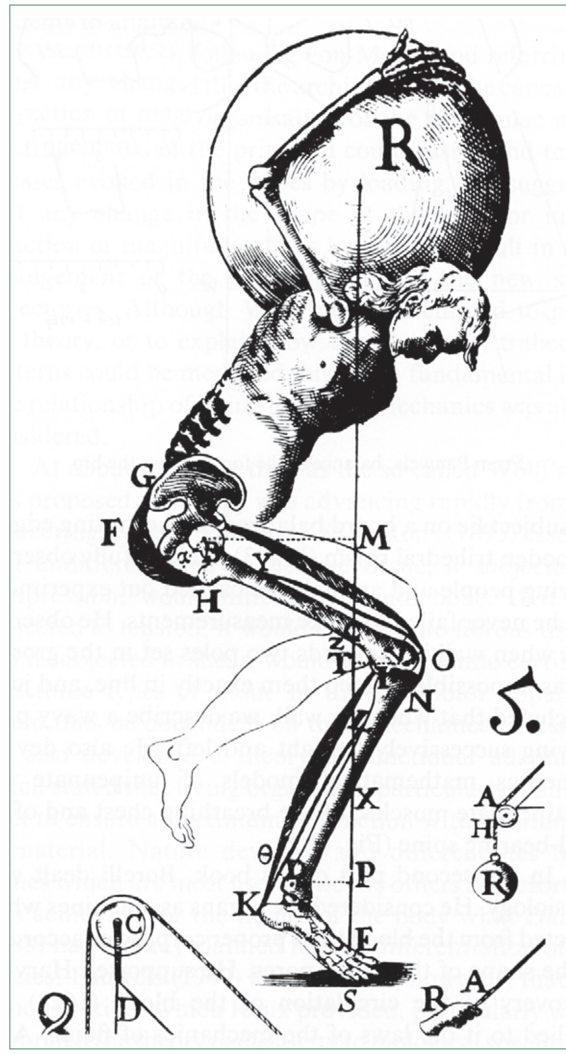

Figure 2: **Giovanni Borelli's representation of the body as a mechanism**
Reproduced from Maguet.[12]

René Descartes (1596–1650), in his revolutionary *Traité de l'homme et de la formation du foetus* (published posthumously in 1675), described creatures as mechanisms, no different from other material objects. In the case of human beings, the bodily mechanism was directed by a rational soul located in the pineal gland.[12] But it was a simple step for later materialist philosophers, such as Thomas Hobbes (1588–1679), to dispense with the soul and so apparently reduce human beings and other animals to the status of automata.[11] In the 17th century, the term for this school of thought was iatrophysics (Greek ιατρός for a physician or surgeon), which is often translated as medical physics. But iatrophysics was a very different enterprise from medical physics as we now understand it; iatrophysics was concerned with fundamental questions about the function of the body and the nature of life, rather than the practicalities of medical diagnosis and treatment.

Iatrophysics provided useful insights into bodily function, leading to the development of biomechanics through the work of Giovanni Borelli (1608–1679) (figure 2).[12] However, iatrophysics failed to explain many phenomena, most profoundly vitality itself. Creatures were thought to possess a vital force animating the bodily mechanism, but the nature of this force remained a mystery. Here, too, physics was to provide at least a partial answer in the 18th century, with the work of Luigi Galvani (1737–98) and Alessandro Volta (1745–1827) demonstrating that electricity generates muscular activity and, in the process, founding the science of electrophysiology.[11]

These attempts to identify the origin of vitality led to an interesting diversion in which the *The Lancet* was to play an important part.[3] The 16th century alchemist Theophrastus Bombast von Hohenheim (1493–1541), usually known as Paracelsus, taught that the body contained a magnetic vital fluid, and that disease could be treated by application of magnets to correct abnormalities in this fluid's distribution. Research into Paracelsus' so-called animal magnetism continued into the 18th century with Franz Anton Mesmer (1734–1815). Mesmer seemed to effect astonishing cures by giving patients hysterical convulsions, allegedly related to animal magnetism, but actually induced by the power of suggestion with which his name became synonymous. Mesmer was eventually discredited and exiled from both Vienna and Paris, but, as late as 1837, John Elliotson (1791–1868) was undertaking surgery on patients anaesthetised with mesmeric sleep (hypnotism) at University College Hospital in London, UK. Two of Elliotson's patients claimed to be able to see inside the bodies of other patients when in this trance-like state, and Elliotson began to use this so-called magnetic imaging to make diagnoses. In 1838, *The Lancet* arranged trials of Elliotson's claims, with the result that he was discredited and the authority of the fledgling journal greatly increased.[13]

Physics-based medical technology in the 19th century

Modern clinical practice and research are heavily dependent on technology, and hospitals are equipped with physics-based devices for clinical measurement, diagnosis, and treatment. Invention of the microscope early in the 17th century, and the pioneering work of Santorio Sanctorius (1561–1636) on clinical measurement of temperature, pulse rate, and body mass, are early examples of the development of such techniques.[11] The pace quickened in the 19th century, with extensive investigation of mechanical, thermal, electrical, optical, and acoustical processes in the body. Some of the most eminent scientific figures of the time contributed. Thomas Young (1773–1829), famous for his work on capillary action, interference, and the wave theory of light, also made important contributions to the physiology of vision, as did Hermann von Helmholtz (1821–94), who invented the ophthalmoscope and is regarded by some researchers as the founder of ophthalmology.[7] In 1856, Adolph Fick (1829–1901), renowned for work on diffusion, published *Medizinische Physik*, which included new physiological measurement techniques, an account of the physics of the lungs, and application of thermodynamics to the heat economy of the body.[14] Initially, much of this basic research had little effect on medical practice, but some practical developments had lasting importance, including the invention of the most iconic of medical instruments, the stethoscope, by René Laennec (1781–1826) in 1816.[11] Many other examples of medical physics in the 19th century are provided by Duck,[15] particularly in the specialty of electrophysiology.

Figure 3: **Radiograph of Frau Röntgen's hand**
Circulated to colleagues by Wilhlem Röntgen on Jan 1, 1896. Reproduced from German Roentgen-Museum, Remscheid.

The role of physicists in medical education also began to develop during this period, with Michael Faraday (1791–1867) giving lectures at St George's Hospital in London as early as 1835.[15] From the late 19th century onwards, basic physics was a compulsory element in undergraduate medical education in the UK, in recognition of the growing importance of physics in medical practice.[16] This system remained in place for many years, although later students with a GCE A-level pass in physics were exempt.[17] The requirement was eventually dropped altogether in the 1980s, although physics remains part of the medical degree syllabus

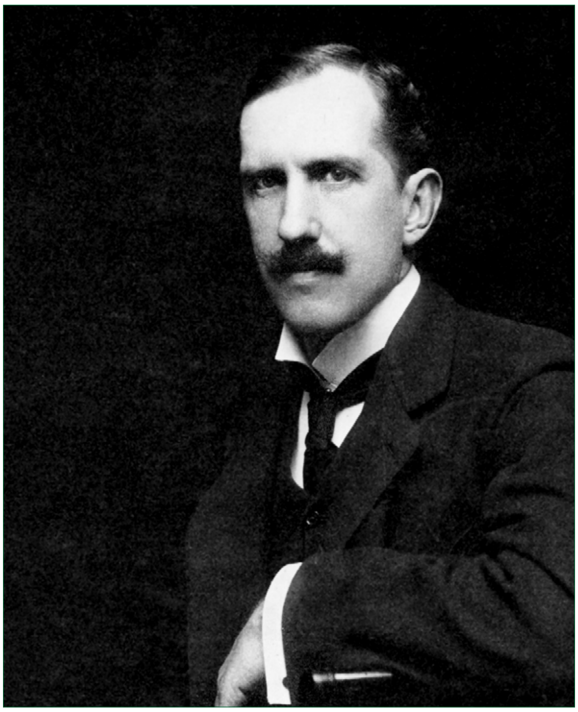

Figure 4: **Major Charles Edmund Stanley Phillips, arguably the first true medical physicist**
Reproduced from the British Institute of Radiology Archive.

elsewhere in Europe.[18] To provide this teaching, academic physics departments were established in medical schools—a professor of medical physics was appointed in Paris as early as the first half of the 19th century[15]—but some years passed before physicists became directly involved in the delivery of clinical services. Then, in the early evening of Nov 8, 1895, Wilhelm Röntgen (1845–1923) discovered "a new kind of ray"[19] and everything changed.

Medical physics in the 20th century

The closing years of the 19th century were a productive period for physics. Within 4 years, Röntgen discovered x-rays, Henri Becquerel (1852–1908) discovered radioactivity, and Pierre and Marie Curie (1859–1906 and 1867–1934, respectively) discovered radium and isolated radioactive isotopes. None of these scientists was a medical physicist in the modern sense, and their investigations were not inspired by the prospect of medical applications. But when Röntgen circulated radiographs of his wife's hand to scientific colleagues in January, 1896 (figure 3), the medical potential was immediately apparent.[20]

The speed with which basic research findings could affect clinical practice more than 100 years ago far outstrips present efforts at translational medicine. In March, 1896, radiography was used on the battlefield for the first time.[20] By April, 1896, medical imaging had its first scientific journal, *Archives of Clinical Skiagraphy* (an early term for radiography, from Greek σκία for a shadow), with the first issue already heavily illustrated with clinical examples.[21] In 1897, the world's first radiological society, the Röntgen Society, was formed in London, admitting medical practitioners and physicists as members on an equal footing;[16] this society is now the British Institute of Radiology. X-rays were rapidly brought into therapeutic use; the first person who attempted to do so is uncertain, but a strong candidate is Victor Despeignes (1866–1937), who (unsuccessfully) treated stomach cancer in July, 1896.[22] Initially, only very low energy x-rays were available, limiting successful treatment to superficial lesions until the advent of 200 kV equipment for deep therapy in 1922.[23]

The harmful effects of radiation became apparent very early on. In 1898, the Röntgen Society established a Committee on X-ray Injuries, inititating the discipline of radiation protection.[20] Recognition of the biological effects of radioisotopes was soon to give rise, quite serendipitously, to another important area of clinical application. In 1901, Becquerel reported receiving a radiation burn from a piece of radium.[24] This finding paved the way for brachytherapy—placement of radioactive sources on the surface of the body, in body cavities, or interstitially in the form of needles—with radium, and, later, encapsulated radon gas, and the first trials were published within a year of Becquerel's report.[25] Radium teletherapy, providing external beams of radiation that give deeper penetration than with x-rays, was attempted as early as 1913,[23] but was limited by the very poor availability of the isotope. Meanwhile, Clarence Dally (1865–1904)—an assistant to Thomas Edison (1847–1931), who was a pioneer in the development of x-ray tubes and intensifying screens—became the first so-called x-ray matryr when he died of mediastinal cancer.[20]

By 1910, the main applications of ionising radiation in medicine—x-ray imaging and radiotherapy by use of x-rays and radium—were firmly established. Rapid technological developments in image quality and treatment standardisation followed. Landmarks included the development of more reliable x-ray tubes by William Coolidge (1873–1975) and standardisation of radiation measurement by Rolf Sievert (1896–1966),[20] whose crucial contributions were recognised in the naming of the SI unit of equivalent dose. Although physicists were central to these developments, they still did not directly participate in clinical work. A notable exception is Charles Phillips (1871–1945),[20,26] a gentleman scientist without formal qualifications, who was honorary physicist to the Royal Cancer Hospital in London (forerunner of the Royal Marsden) from about 1892 until his retirement in 1927, and is often regarded as the first true medical physicist (figure 4). But in 1913, Sidney Russ (1879–1963) became the first physicist formally appointed by a British hospital, the Middlesex Hospital in London[27] (a slightly earlier appointment had been made in Munich in 1912).[28] Russ made important contributions to radiation protection and dosimetry, and developed one of the first collimated radium teletherapy machines.[23] Other major hospitals in the UK began to draw on the expertise of physicists attached to their medical schools to support clinical activities, for example Frank Hopwood (1884–1954) at St Bartholomew's Hopsital, London, and Gilbert Stead (1888–1979) at Guy's Hospital, London.[27] By 1932, between ten and 12 medical physicists were based in hospitals in the UK,[16] growing to 35–40 by World War 2.[29]

Nuclear medicine was the last piece in the jigsaw of medical radiation physics to fall into place. Setting aside early unsuccessful attempts to use radium and radon,[20] imaging with radioactive tracers is perhaps one of the more benign consequences of the Manhattan Project. Although artificial production of radioisotopes had been achieved in 1934,[30] wartime developments in nuclear physics technology were needed for isotopes to be produced in sufficient quantities for practical use in medicine. The first radioisotope to be used clinically was ^{131}I,[31] which was produced from the Berkeley cyclotron (Berkeley CA, USA), in 1939 and was used for thyroid investigations. These early studies used autoradiography and crude external counting techniques rather than imaging. The same isotope was soon used for treatment of hyperthyroidism and thyroid cancer.[32–34] A wide range of other artificial isotopes became available subsequently, and preparation in appropriate chemical forms allowed studies of a range of organs. However, after an imaging demonstration in 1964,[35] ^{99m}Tc rapidly became the most widely used radioisotope because of its convenient physical and chemical properties.

In 1950, the Dutch neuroradiologist Bernard George Ziedses des Plantes (1902–93) described a means of moving a Geiger-Müller tube over a patient's thyroid, thus mapping out the distribution of radioactivity.[36] This report came a year before the generally acknowledged description of the rectilinear scanner by William Valentine Mayneord (1902–88; figure 5).[37,38] With these developments, nuclear medicine became a fully fledged functional imaging technique. Mayneord, who spent most of his career at the Royal Marsden Hospital in London, made numerous important contributions to radiation dosimetry, radiobiology, and nuclear medicine.[27] He disliked the term medical physics, believing that physics is "one entity, fundamental and indivisible",[26] and hence preferred to refer to the discipline as "physics applied to medicine."[26] The rectilinear scanner was superseded by Hal Anger's (1920–2005) gamma camera in the 1960s.[39] Nuclear tomographic imaging, also known as single photon emission CT, was developed in the 1960s,[40] only to be eclipsed by x-ray CT before undergoing something of a renaissance from the 1980s onwards. Imaging by detection of annihilation photons after positron emission by a radionuclide was first reported in 1951.[41] This work led to the development of clinical PET systems,[42] capitalising on advances in the synthesis of positron emitting radionuclides and on detector technology originating in nuclear and particle physics.

A period of great innovation in radiotherapy occurred after, and to a large extent because of, World War 2. Developments in accelerator technology for basic nuclear physics led to implementation of megavoltage x-ray therapy at the Massachusetts General Hospital in Boston (MA, USA) and at St Bartholomew's Hospital in London in the late 1930s (figure 6).[23] In 1949, the Canadian physicist Harold Johns (1915–98) pioneered the use of betatron accelerators, again developed in the context of nuclear and particle physics, to deliver 20–22 MV x-ray therapy.[23] Furthermore, artificial radioisotopes, which initiated nuclear medicine, also had beneficial spin-offs in radiotherapy. In the late 1940s, work by the dual-qualified physicist and physician Joseph Mitchell (1909–87) in Cambridge, UK, and by Mayneord, led to the adoption of ^{60}Co produced in a nuclear reactor as an alternative source of high-energy γ rays for teletherapy, with a higher dose rate than could be achieved with radium.[43] Telecobalt therapy was first used clinically in Saskatoon, SK, Canada,

Figure 5: **William Valentine Mayneord's rectilinear scanner**
Reproduced from Maynerord and colleagues,[37] by permission of *Nature* Publishing Group.

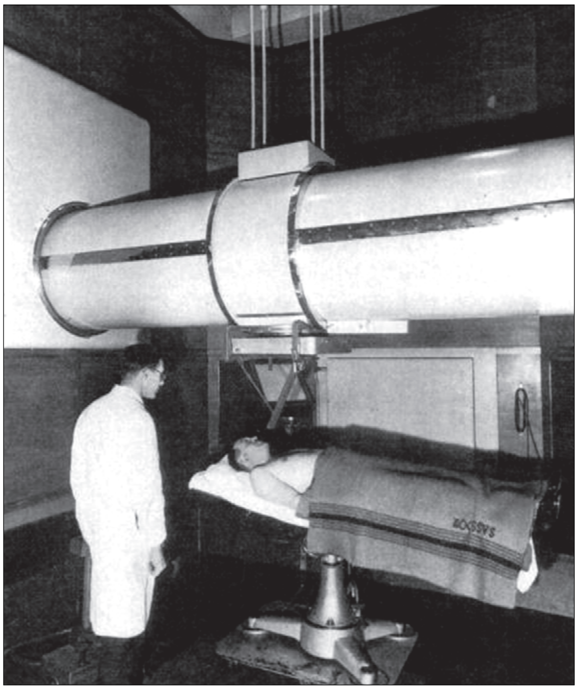

Figure 6: **One of the world's first megavoltage radiotherapy units at St Bartholomew's Hospital, London, UK, in 1937**
Reproduced from Laughlin,[45] by permission of the British Institute of Radiology.

Figure 7: **Godfrey Hounsfield's first x-ray CT scanner**
Reproduced from Hounsfiled,[51] by permission of the British Institute of Radiology.

with a machine designed by Johns.[44] Production of an increased range of radioisotopes with improved characteristics for brachytherapy also became possible.[45] Electron linear accelerators (linacs) for delivery of megavoltage x-rays, a spin-off from war-time research on radar, were in use at Hammersmith Hospital in London by 1953.[23] A comprehensive account of the early history of medical linacs has been published elsewhere.[46] Nowadays, these machines are the mainstay of teletherapy, delivering both x-rays and electrons for superficial treatment, with new approaches such as intensity modulated radiotherapy and image guided radiotherapy allowing ever more precise delivery of radiation to tumours.[47] However, the advantages of therapy with heavier charged particles were recognised by the American particle physics pioneer Robert R Wilson (1914–2000) as early as 1946,[48] and this approach has become important in the treatment of some types of cancer.[49]

Three other major imaging milestones remain to be discussed. Ultrasound imaging was introduced in the 1930s for non-destructive testing, and again underwent tremendous technological development during World War 2, particularly as a result of developments in electronics. Medical applications followed in the 1950s.[50] In 1973, Godfrey Hounsfield (1919–2004) described what would become the first x-ray CT scanner (figure 7),[51] although others had previously reported similar approaches independently.[52] The revolution that CT brought about in medical imaging has been surpassed only by MRI. MRI was invented by the American chemist Paul Lauterbur (1929–2007) and the British physicist Peter Mansfield (born 1933).[53,54] It is based on nuclear magnetic resonance (NMR), which was developed in the context of nuclear physics by Felix Bloch (1905–83) and Edward Purcell (1912–97), and makes use of magnetic fields rather than ionising radiation. It is a very powerful and flexible technique, capable of imaging physiological and mechanical function and structure. With advances in functional MRI of the brain, medical physics is perhaps bringing us closer to an understanding of consciousness, such an elusive notion for the iatrophysicists of past centuries.[55] Modern MRI was made possible by the advent of superconducting magnets, again a development rooted in basic physics. A major focus today is multimodality imaging, bringing together the complementary capabilities of PET and CT[56] or, more recently, PET and MRI[57] in one imaging system.

The duties of the first hospital physicists were related mainly to radiation protection and radiotherapy. As new clinical applications of radiation and new imaging techniques developed, the profession grew in numbers and broadened its horizons. For example, other regions of the electromagnetic spectrum began to be used for clinical imaging and treatment. Reference has already been made to claims that Hippocrates described the first thermal imaging technique in the 4th century BC.[2] Modern infrared thermography dates back only as far as 1957,[58] although the idea had been described more than a century earlier by John Herschel (1792–1871), son of the famous astronomer and discoverer of infrared radiation.[59] Therapeutic use of ultraviolet radiation was known to the ancient Greeks, with the ubiquitous Hippocrates prescribing heliotherapy (sunbathing) for medical and psychological reasons.[60] After falling into disuse, the technique was rediscovered in medieval Persia, and described by Avicenna (circa 980–1037).[60] Scientific understanding of the therapeutic (and potentially harmful) effects of ultraviolet radiation followed in the 18th and 19th centuries, allowing more systematic clinical exploitation. Another crucial development in the history of physics and medicine was the invention of the laser. In an example of rapid translation reminiscent of Röntgen's work, medical applications were developed within a year of construction of the first functioning laser in 1960.[61] Early applications in ophthalmology and dermatology were followed by more gradual adoption of lasers in other surgical specialties and in photodynamic therapy.[61]

Developments in electronics and computer technology during the 20th century revolutionised many areas of clinical measurement, notably audiology and ophthalmology, but also physiological measurement in a host of other body systems. As in the 19th century, physicists tended to supply instruments for use by others in these disciplines rather than directly participating in clinical service delivery themselves.

The contributions of physics to medicine have often been at the forefront of science, and have been recognised by the award of several Nobel Prizes both to researchers who investigated the underlying basic science and to those who translated science into clinically useful technology. Röntgen won the first ever Nobel Prize for physics in 1901, followed by Becquerel, both of the Curies, and Bloch and Purcell. The Nobel Prize for physiology or medicine was awarded to Hounsfield and the South African physicist Allan Cormack (1924–98) for their work on CT and to Lauterbur and Mansfield for MRI. Special mention should be made in this context of Joseph Rotblat (1908–2005), the only scientist to resign from the Manhatten Project on the grounds of conscience. Rotblat went on to be professor of physics at St Bartholomew's Hospital Medical College in

London, but is better known for his disarmament work, for which he was awarded the Nobel Peace Prize in 1995.[62]

Postgraduate education at Master of Science level for medical physicists was established in the UK in the 1970s to support increasing specialist training needs. About 2000 medical physicists now work for the UK National Health Service. They are fully fledged health-care professionals, registered as clinical scientists with the Health Professions Council, with formal requirements to undertake preregistration training and continuing professional development. These needs are served by a dedicated professional body and learned society, the Institute of Physics and Engineering in Medicine. Similar organisations exist in other countries, such as the American Association of Physicists in Medicine and the Deutsche Gesellschaft für Medizinische Physik. At international level, there are regional organisations such as the European Federation of Organisations for Medical Physics, and medical physicists worldwide are brought together in the International Organisation for Medical Physics, which in turn joins with the International Federation for Medical and Biological Engineering to form the International Union for Physical and Engineering Sciences in Medicine, a full member of the International Council for Science.

Physics and medicine in the post-genomic world

While a distinctive medical physics profession developed around radiation and imaging in the 20th century, the contributions of physics to other areas of biological science continued at an ever-accelerating rate. Elucidation of the structure of DNA with x-ray diffraction is an unparalleled example. The scope of this report precludes discussion of the many contributions that physics has made to the development of molecular biology. As these biological techniques begin to be translated into medical applications, we seem to be on the verge of a new era of personalised molecular diagnostics and therapeutics, with physics often at the forefront of these new technologies. For example, optical techniques such as fluorescence imaging and optical coherence tomography are showing great promise in a range of oncological applications, sometimes as part of multimodality systems in combination with MRI or CT.[63] Clinical trials are beginning to establish the role of some of these techniques in early prediction of the response of individual patients to cancer treatment,[64] and results suggest an important role for intraoperative optical imaging.[65] These techniques will develop in parallel with continued use of existing technologies such as CT, MRI, and PET, particularly for functional and molecular imaging, and other new methods such as terahertz imaging.[66] Simultaneously, totally novel medical applications of physics continue to emerge. Examples presented at the 2010 SET (science, engineering and technology) for Britain event in the UK Houses of Parliament included a new imaging technique with surface plasmon resonance,[67] application of statistical physics to epidemiology,[68] and investigation of neural network topology.[69]

Conclusions

In this report, I have presented a broad and necessarily selective history of the contribution that physics has made to medicine. Even from this brief account, the importance and diversity of this contribution is clear. From Alhazen, Leonardo, and the iatrophysicists onwards, physics has been applied to the measurement and understanding of physiological function. In the process, new disciplines such as ophthalmology, biomechanics, and electrophysiology were established. Other scientists focused on development of technologies for diagnosis and treatment. A unique situation arose early in the 20th century, when introduction of ionising radiation into medicine necessitated continuing input from physicists in the clinical setting. Consequently, medical physics was established as a distinct profession, which was able to diversify as new imaging and physiological measurement techniques emerged. Nowadays, as new physics-based techniques are translated from biology into medicine, medical physicists have another opportunity to play a key part to ensure safe and effective clinical implementation.

There is a final, very important, point to be made. Many physics-based medical innovations, such as CT and PET, have resulted from focused research with clinical applications in mind from the outset. But frequently major developments have been wholly unpredictable spin-offs from basic science research. Röntgen's discovery of x-rays is the obvious example, but translation into clinical practice has not always been as rapid or as straightforward. MRI followed some 30 years after Bloch and Purcell's discovery of NMR, and much of modern radiotherapy and nuclear medicine would not be possible without basic nuclear and particle physics research undertaken for entirely different purposes. These are important considerations when the value of investment in basic science research is called into question, as it is now in the UK. Who can say what medical benefits might arise during the next century as a result of projects such as the Large Hadron Collider?

Conflicts of interest

I am president-elect of the Institute of Physics and Engineering in Medicine, which is the primary professional organisation for medical physicists in the UK.

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