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Invited paper

The origins of medical physics

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ABSTRACT

The historical origins of medical physics are traced from the first use of weighing as a means of monitoring health by Sanctorius in the early seventeenth century to the emergence of radiology, phototherapy and electrotherapy at the end of the nineteenth century. The origins of biomechanics, due to Borelli, and of medical electricity following Musschenbroek's report of the Leyden Jar, are included. Medical physics emerged as a separate academic discipline in France at the time of the Revolution, with Jean Hallé as its first professor. Physiological physics flowered in Germany during the mid-nineteenth century, led by the work of Adolf Fick. The introduction of the term medical physics into English by Neil Arnott failed to accelerate its acceptance in Britain or the USA. Contributions from Newton, Euler, Bernoulli, Nollet, Matteucci, Pelletan, Gavarret, d'Arsonval, Finsen, Röntgen and others are noted. There are many origins of medical physics, stemming from the many intersections between physics and medicine. Overall, the early nineteenth-century definition of medical physics still holds today: 'Physics applied to the knowledge of the human body, to its preservation and to the cure of its illnesses'.

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Introduction

Historical origins are often difficult to determine. The discovery of X-rays by Wilhelm Conrad Röntgen in November 1895 offers an event, seductive in its clarity, for the origin of *Medical Physics*. But this marks only the start of 'medical radiation physics' [1]. This present short review gives in outline the key developments in medical physics up to the end of the 19th century. The later role of physics and physicists in the introduction of ionizing and non-ionizing radiation into medicine is a subject for a separate historical review.

Iatrophysics

Some links between physics and medicine may be found in the records from ancient civilizations [2]. A document from ancient Egypt mentions the treatment of breast abscesses by cauterization, and Hippocrates described how skin temperature distributions could be mapped by using wet clay. Another Greek physician, Herophilus, used a water clock to measure the pulse rate, applying the physics of time metrology to clinical assessment. The Arabic scholar Ibn al-Haytham (Alhazen) (965–1040), demonstrated by logic and experiment that the eye is simply a receiver of light, and does not emit a beam as the Greek scholars had imagined. It would be another 600 years before Kepler added anything new to this understanding, by describing the creation of an inverted image on the retina by the crystalline lens.

My own geographical and temporal point zero for medical physics is much later, in the Italian Renaissance. Santorio Santorio (1561–1636), also known as Sanctorius, was the first to take a measurement technique from physics and apply it successfully in medicine and physiology. The technique was weighing. He was appointed in 1611 as professor of theoretical medicine in Padua and soon published a slim volume, *De statica medicina* [3]. He had designed a whole-body scale, with which, for very many years, he had regularly weighed himself and everything that he ate, drank and excreted (Fig. 1). From this study he developed his theory of 'insensible perspiration' to account for the difference between material added and material excreted. Many later physiologists would learn the value of physiological measurement through similar weighing experiments [4,5]. His view of the body as a machine became a widely used metaphor in the succeeding decades.

The next important figure was the Italian physicist Giovanni Borelli (1608–79), who was the first to make a serious attempt to place mechanistic ideas of the body on a firm mathematical footing. The word that later became associated with these ideas is iatrophysics, 'physics applied to medicine', but only used in the narrow sense of a physiology that explained all the workings of the body in purely mechanistic terms.

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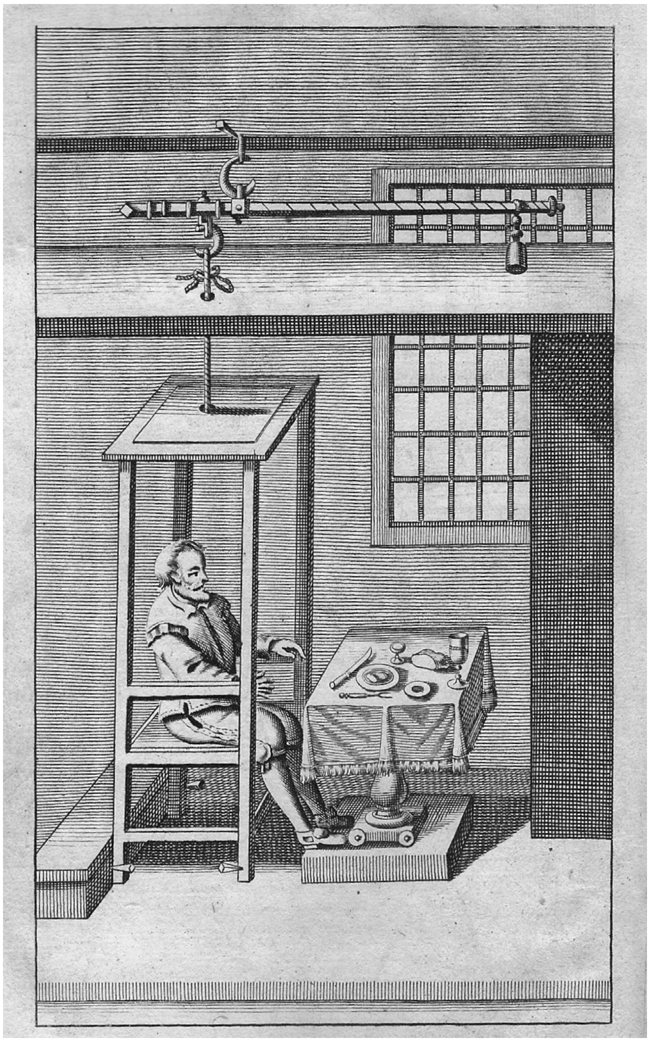

Figure 1. Sanctorius' scale with which he measured his own weight, several times daily, for many years, demonstrating the existence of *insensible perspiration*. Frontispiece from John Quincy's translation of Sanctorius' *Medicina Statica*, first published in 1614 [3].

Borelli was born in Naples on 28 January 1608. He studied mathematics in Rome and spent time as professor of mathematics at the University of Messina. In 1656, Borelli was appointed as professor of mathematics at the University of Pisa. During his 12-year stay there he made important contributions to mathematical astronomy, showing that the orbits of the moons of Jupiter were elliptical, and tracking the parabolic trajectory of a comet. Both Newton and Huygens recognized the importance of Borelli's anticipation of a gravitation force to explain these movements.

His reputation as an astronomer was established. Yet, at nearly 50 years old, he launched himself into a completely new area of study. He established his own anatomical laboratory, obtained human cadavers to dissect and brought in live animals and birds for vivisection. By the time Borelli left Pisa in 1668 he had accumulated all the experimental material that he required for his book on mathematics and physics as applied to physiology. His final years were spent in Rome where his *De Motu Animalium* [6] was published shortly after he died in 1679.

Borelli approached his subject as a mathematical physicist, not a physician. He knew that physics had converted star-gazing into astronomy, using a combination of improved experimental observation and mathematical analysis. He set about applying the same principles to physiology. Borelli's vocabulary describing the actions of living beings was exclusively mechanical: forces and moments, gravity and weight, contraction and expansion, volumes and velocities, swelling, binding and wrinkling, effervescence, mixing, and scraping. His analogies were mechanical too; pulleys and scales, goatskin bottles, sieves and balls of string. He gave an extensive analysis of the movements of muscles, and the forces they exert, when walking, lifting, flying and swimming. He included numerous detailed illustrations (Fig. 2). His was an entirely new quantitative approach to what later became known as biomechanics. Borelli also explored the causes of the internal motions of animals and correctly challenged several currently-held views. He described lung expiration as a passive process. He states that 'respiration was not instituted to cool and ventilate the flame and heat of the heart'. He used the new alcohol thermometers of the *Accademia del Cimento* to show that the intra-cardiac temperature of a live stag was no different from the temperature within any other organ.

However, he struggled to describe how muscles actually work. Borelli did his best with his mechanical models but, perhaps unsurprisingly, got it wrong. According to Borelli, muscle fibres swell and become harder and tighter, which causes a contraction between the ends of the muscle. This is caused by bubbles formed when nervous juice is shaken out into the muscle fibres. Later physicists also had views about this challenging problem. Isaac Newton speculated that nervous action might be mediated by the aether. Bryan Robinson, a Dublin doctor and enthusiastic Newtonian, saw Newton's aether acting in both nerves and muscles [4].

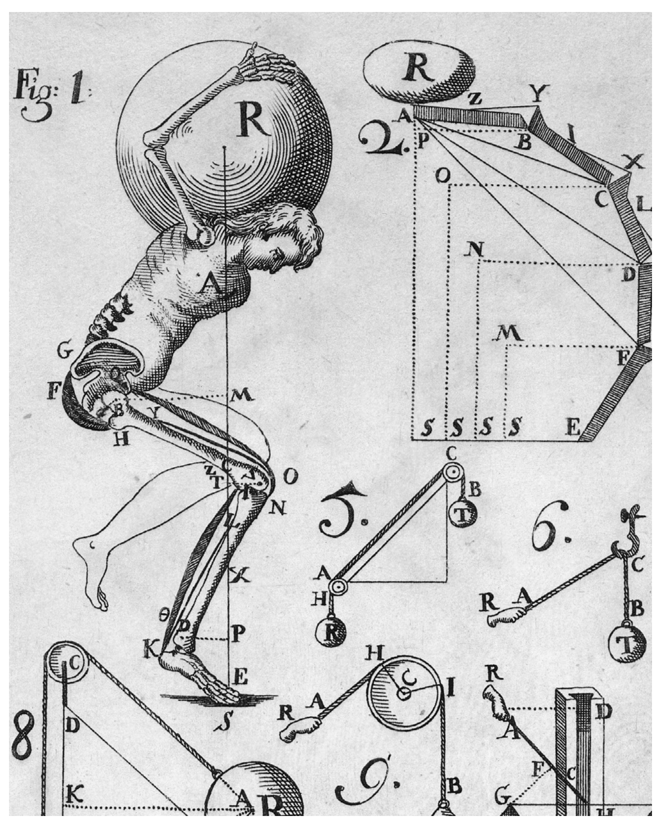

Figure 2. Mechanics of the spine. 'If the spine of a stevedore is bent and supports a load of 120 pounds carried on the neck, the force exerted by Nature in the intervertebral disks and in the extensor muscles of the spine is equal to 25,585 pounds. The force exerted by the muscles alone is not less than 6404 pounds'. Borelli's *De Motu Animalium* Vol 1, 1680 [6]. Wellcome Library, London.

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