Special Article

# William Harvey (1578-1657): Discoverer of Blood Circulation

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William Harvey was the leading figure in cardiology during the 17th century. Although he had precursors, it is to him that we owe the discovery of blood circulation. It is known that Harvey, as "Lumleian lecturer", had developed the concept of blood circulation in his lectures since 1615.[1] In 1628, in his brilliant book *Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus* (An Anatomical Exercise on the Motion of the Heart and Blood in Living Beings), Harvey announced his discovery and, just as shocking, reported that the heart was a pump that pushed the blood around and around in the body. In the years that followed, Harvey's circulation theory was greeted with great controversy among his colleagues, but in the end his ideas prevailed.

## Life and career

Harvey was born in Folkestone in the county of Kent, England. He was educated at the King's School, Canterbury, and Caius College, Cambridge. After a serious illness, he went to Padua in 1600, studying under Fabricio d'Acquapendente (1539-1619), whose views concerning the valves of the veins influenced Harvey's research. In 1602, having graduated as a Doctor of Medicine, Harvey returned to England (Figure 1). In 1604 he married Elizabeth Browne. In 1615, he became Lumleian lecturer. By 1618 he had been elected a Fellow of the College of Physicians; he was appointed physician to St Bartholomew's Hospital, London and later Physician Extraordinary to King James I. Though he was physician and friend to King Charles I throughout his tragic reign, Harvey was not knighted.

In 1649, his health status deteriorated and he suffered from multiple attacks of gout. Nevertheless, he continued his research and published in 1651 *De generatione animalium*, ending his scientific life in embryology as he had begun. On 3 June 1657, at age 79, William Harvey suddenly lost his vision, then his speech, as he succumbed to a massive stroke at home. His last act was to personally pass on his ring, watch and other mementos to his nieces and nephews. He was buried in the family vault at Hempstead, Essex.[2]

## The blood circulation before Harvey

It is surprising to note that the exact mechanism of the blood circulation was ignored for a long time, despite the ideas of some innovators. Medical teachers were enslaved to the dogmatism of Galen's (129-201) tradition and theories, which led to erroneous conceptions. The publication of Harvey's theory formalised his discovery, brought closure to a long series of ana-

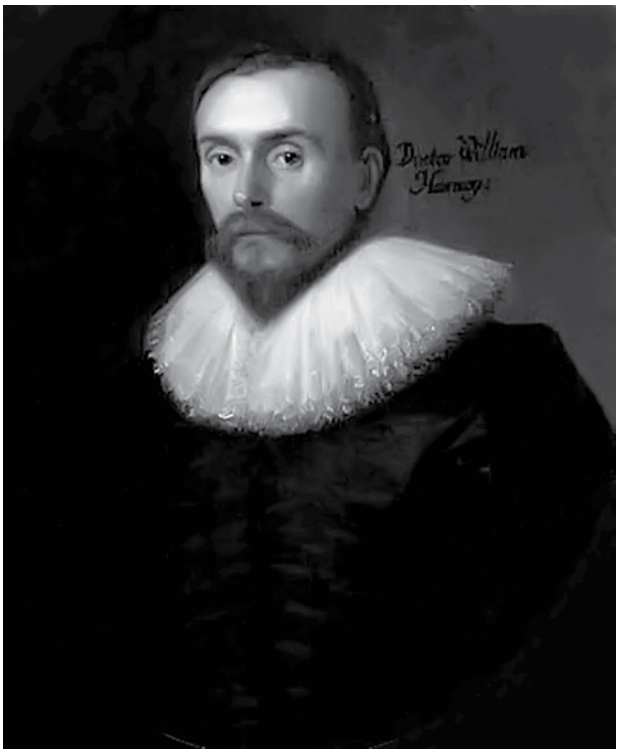

**Figure 1.** William Harvey (1578-1657): the immortal discoverer of the circulation of blood.

tomical works, and overturned the traditional medical ideas that had predominated for centuries.

What were the concepts admitted at the end of the 16th century to this fundamental domain of physiology?

Note that, since the era of Hippocrates and Galen, blood was considered to be synthesised from ingested foods in the gastrointestinal tract. The useful parts of the food were transported as chyle from the intestines via the portal vein to the liver. The liver transformed chyle into dark venous blood that travelled to the ventricles of the heart, where it was mixed with life-giving properties, the "vital spirits". Galen worked only with dead tissues and in these tissues only the veins were observed to contain blood; he thus concluded that the veins alone carried the blood of the circulatory system, while the arteries carried the life-giving air. Since there was no obvious direct connection between the two sides of the heart Galen suggested that the ventricles of the heart were linked by invisible pores called "septum" whose purpose was to allow the blood to move freely between the two sides. In his schema of blood circulation he maintained that the arterial blood, created from venous blood, passed from the left ventricle to the right through "pores", while air passed from the lungs via the pulmonary artery to the left side of the heart.[3]

The flaws in this view are striking, and we can only wonder how these concepts, established in real dogma, were able to prevail for centuries. However, in the 13th century, the lesser circulation had been described by the Arab physician Ibn-al-Nafis (1210-1288). In 1260, in his *Commentary on Anatomy in Avicenna's Canon*, he posed the hypothesis of a passage of the blood through the lung and denied the presence of "pores",[4] although his work did not become known in Western societies until the early 1900s.

## The famous treatise of Harvey

In his monumental work *de Motu Cordis*, Harvey "demonstrated that all written till that moment on the movement and the function of the heart and arteries is not solid enough." It was a great opportunity for him to refute Erasistratus and Galen and to greet Colombo and Fabricio d'Acquapendente. His treatise innovates by its conciseness, its clarity, the absence of ambiguous theories and the method of experimentation (Figure 2).

Chapter I of *de Motu Cordis* is largely a refutation of a number of ancient and traditional opinions concerning the heart, pulse and arteries. Harvey underlines the contradictions and the incoherence in the texts of Galen questioning "how blood, air and sooty vapours could be in pulmonary veins while their dissection reveals only blood?"[5]

In the 2nd chapter, entitled *The movement of the heart after the vivisection*, Harvey refutes the old doctrine that the diastole or expansion of the heart was the essential cause of the motion of the blood. Harvey

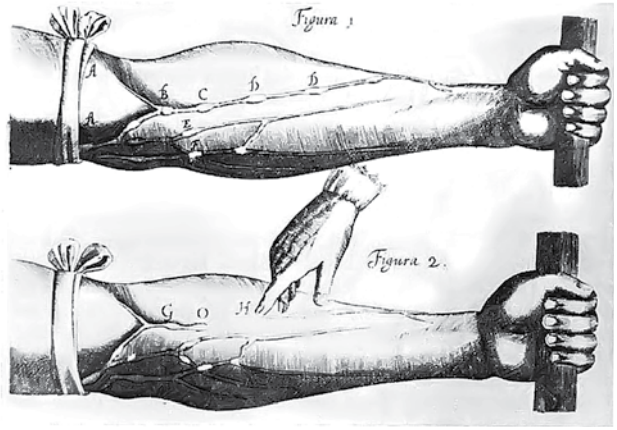


**Figure 2.** Image of Harvey's experiment showing the swelling veins in the arms after ligation.

says: "And in like manner the intrinsic motion of the heart is not the diastole but the systole; neither is it in the diastole that the heart grows firm and tense, but in the systole, for then only, when tense, is it moved and made vigorous."[6]

The valves of the heart and the veins help the blood to progress in a single direction. Harvey demonstrates the role of auricles in the filling of ventricles and, after vivisections, the movements of arteries and heart.

In the 3rd chapter, entitled *Movement of arteries after the vivisection*, he repudiates a second acquired idea, according to which the arterial diastole is an active phenomenon connected with the artery itself. He elaborates his statement that the pulse of the arteries is due to the systole of the ventricles and concludes: "Whence it appears that whenever the motion of the blood through the arteries is impeded, whether it be by compression or infarction [over-distension], or interception, there do the remote divisions of the arteries beat less forcibly, seeing that the pulse of the arteries is nothing more than the impulse or shock of the blood in these vessels."[6]

Having set out the arguments for these two fundamental statements, Harvey returns to the movement of the heart and examines in particular that of the auricles. The movement of the two auricles precedes that of the two ventricles. When the heart is beating very feebly there is, however, a distinct pause between the contraction of the auricles and that of the ventricles. When the heart is dying, the movement of the ventricles ceases first and the lower part of the heart remains still, whilst the auricles still continue to beat slowly.[7]

In the 6th and 7th chapters, concerning the pulmonary circulation, Harvey honours Realdo Colombo (1516-1559), Ibn An Nafis and Michel Servet (1509-1553) and refutes the concept of passage through the interventricular septum.[8]

After experiments in embryos he states: "In the unborn young of the higher vertebrates the lungs, although present are, of course, not used to aerate the blood. The blood derived from the mother through the umbilical cord proceeds first to the liver and then to the heart, which in the embryo is beating just as it will do after life, only more rapidly. The pulmonary artery and vein are present, but are not used by the greater part of the blood. Instead there are communications between the great vessels which provide a short circuit for the greatest part of the blood stream and there is also in the interventricular wall, an oval window which provides free communication between the two cavities."[6]

Harvey visualises circulation "as a cyclic process of blood regeneration" in which "blood that went out from the heart to the tissues in a hot and vaporous condition returns to it cooled down and condensed." At the commencement of the passage in chapter 8 he suggests a purpose for the circulation of the blood by drawing an analogy with the Aristotelian description of circular movements of air and rain and those of the "superior bodies" of the cosmos.[9]

This metaphor of the movements allowed Harvey in a few paragraphs to indicate his notions regarding the physiological significance of the blood for the life of the whole organism, as he writes: "The heart, consequently, is the beginning of life; the sun of the microcosm, even as the sun in his turn might well be designated the heart of the world; for it is the heart by whose virtue and pulse the blood is moved, perfected, and made nutrient, and is preserved from corruption and coagulation; it is the household divinity which, discharging its function, nourishes, cherishes, quickens the whole body ... ."[6]

In chapter 9 of *de Motu Cordis* Harvey repeatedly appeals to calculation concerning the quantity of blood coursing through the heart, arteries and veins. His calculation of the daily quantity of the blood ejected by the heart was afterwards seen as the core of the discovery, even as the beginning of quantitative biology and medicine.[10]

In the 10th to 13th chapters, Harvey provides a firm and independent confirmation of venous return and blood circulation. He presented an ocular experiment done with ligatures, which demonstrated the blood's single directional path, showing how blood entered the arm by way of the arteries and exited via the veins. He observed the procedure on "country people or those who were 'swollen veined'" in order to see the veins more clearly. The experiment showed the swelling of veins in the arm when a ligature is used to block blood flow back to the heart. Pressing between the swollen nodes, or valves, of the veins causes the blood flow to stop and the vein to flatten. After releasing the upper valve (the one closer to the heart), the vein does not refill until the lower valve is released.[7] In chapters 15-17 he presents the new proofs of the theory of circulation from a pathological and therapeutic point of view, expressed and summarised in chapter 14. Furthermore, Harvey's treatise goes beyond the theory of circulation, as it contains two notions that are fundamental to modern cardiol-

ogy: that of cardiac output and that of the pressures of the different sectors of the system.[5]

### Harvey becomes a cardiologist: the description of atheroma and arteritis

In his treatise Harvey does not refer to cardiovascular pathology. However in his second letter to Riolan, he becomes a true cardiologist as he writes: "The patient had reached to about the middle period of life, made frequent complaint of a certain distressing pain in the chest, especially in the night season; so that dreading at one time syncope, at another suffocation in his attacks he led an unquiet and anxious life ... he became cachectic and dropsical and finally, grievously distressed he died in one of his paroxysms. In the cadaver, we found the wall of the left ventricle of the heart distended having a rent in it of size sufficient to admit any of my fingers." Actually, Harvey had been the first to observe a rupture of the ventricular wall after myocardial infarction.[11]

In addition, he observed a case of aortic atheroma: "I beg here to refer to a portion of the descending aorta of a nobleman and which is converted into a bony tube; by this hollow tube, nevertheless, did the arterial blood reach the lower extremities of this nobleman during his life and cause the arteries in these to beat."[6]

### Discussion

Harvey was notable for collecting the prevailing ideas of his time and constructing his own schema of blood circulation. He presented his ideas in the *Lumleian lectures* in 1616.

His greatest work was his *de Motu Cordis* (1628). In this, and in two supplementary letters written twenty years later, he described his experimental analysis of the movements of the heart and blood, establishing that in systole the heart actively contracts in all dimensions, expelling its contained blood as a muscular pump. Cardiac diastole or dilatation he found to be passive, not active as Galen had held. By dividing arteries he showed that each systole of the heart pumped out blood in jets, the expansion of the arteries being felt as pulses in the limbs. Having demonstrated that the right ventricle is responsible for the pulmonary circulation, Harvey showed that the left ventricle supplied the rest of the body through its arteries. That blood flows towards the heart in the veins he demonstrated experimentally by cutting them, by obstructing them with ligatures, and by observing the action of their valves in preventing blood from moving to the periphery. Here again he contradicted Galen.[11] Harvey estimated that the quantity of blood expelled from the heart was far greater than that ingested as food in the same time; he concluded: "Therefore the blood must circulate."

Thus Harvey founded the systematic quantitative, experimental approach to physiology. Although at first violently opposed, Harvey's work on the heart found general acceptance in his lifetime.

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