Total Knowledge of the Circulatory System

El conocimiento total del sistema circulatorio

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William Harvey's work produced a boom in the study of the circulatory system, not only at the level of its anatomical integrity, but also in an attempt to understand it as a mechanical system. It also stimulated the analysis of the respiratory process, with the harvest of achievements that allowed the total understanding of blood physiology.

The description of these findings includes the capillaries; the chyliferous vessels; the lymphatics; new anatomical studies on the heart and blood vessels; the beginning of mechanical circulatory reasoning and the biochemical study of respiration. Although his account sectorizes the knowledge, we should know that all the fragments involved in the structured understanding of the subject were given in a concomitant way until reaching the full understanding of the circulatory system.

MARCELO MALPIGHI AND CAPILLARY VESSELS

After Harvey had completed his brilliant description of the circulation of the blood, there still remained to be discovered a link in its physiology: the passage from the arteries to the veins. For such an event to occur, something more than reflexive supposition or direct vision was needed. In this sense, the origin of the optical microscope, although Galileo Galilei (Pisa, 1564-1642) was one of the first to use it around 1610, seems to correspond to the Dutchman Zacharias Jansen and Cornelius Drebbel (1573-1674) around 1590, independently. This construction had been carried out by assembling a biconvex lens (objective) with a biconcave one (eyepiece).

The advent of the microscope has enormous relevance for the understanding of capillary circulation. The term microscope was introduced by John Faber (1570-1640), of the *Accademia dei Lincei* (Rome). Although there are studies of blood vessels by the Englishman Thomas Willis (1621-1675), the first observations appear with a paper by Pierre Borel (circa 1620-1689) in 1653, *Observartionum microscopicarum centuria*.

But the great microscopists were essentially the Italians Marcello Malpighi (1628-1694) and Lorenzo Bellini (1643-1704); the Dutch Anton van Leeuwenhoek (1637-1680) and Jan Swadermmerdam (1632-1723); and the English Nehemiah Grew (1641-1712) and Robert Hooke (1635-1703). The latter wrote the first treatise devoted exclusively to the description of the microscope and also to the objects observed. Hooke's book *Micrographia* (1665) details the observation of the cell (*celullae*) on a cork slide.

Marcello Malpighi or Malpigio was born on March 10, 1628, paradoxically the same year of the publication of *De Motu Cordis*, in Crevalcore, near Bologna. He began his studies in philosophy and then embraced the medical discipline. Graduated as a physician in 1653, he was Professor of Medicine in Bologna, Pisa and Messina. In Pisa, he met Giovanni Alfonso Borelli (1608-1679), professor of mathematics, who strove to apply experimentation with an atomistic-mechanical integration. It was in Borelli's laboratory that the spiral fibers of the heart were described around 1657. Malpighi returned to Bologna where he continued his studies and was later appointed archiatrist to Pope Innocent XII; he died in Rome on November 29, 1694. His autopsy was performed by a famous physician, Giorgio Baglivi (1668-1707).

His work, based on the vision through the microscope, was remarkable. In one of his early writings, together with the microscopist Carlo Fracastori (died 1672), he described the missing link for the circulation to be complete: the capillary circulation. Although in Harvey's text *De Motu Cordis* some reference is made to *carnis porositates*, it was far from giving it the physiological meaning actually offered by Malpighi. His writing *De pulmonibus observationes anatomicae*, which appeared in Bologna in 1661, four years after Harvey's death, consists of excellent plates, taking the frog's lungs as an object of study. This circumstance was ideal for the description of the capillaries, since the lungs are provided on their surface with capillaries, being an organ endowed with transparency. He also found them in the mesentery. For his part,

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Franz de le Boë "*Sylvius*" (Dutch, 1614-1672), suggested that the capillaries consist of a single tunic, since transudation through them would otherwise be impossible.

Borelli, who was an iatromechanical physiologist, had introduced Malpighi to the concept of experimentation and the physical-mathematical model in biology. In his research Malpighi performed the injection of water into the pulmonary artery and collected it in the pulmonary veins, as a demonstration of the existence of the capillary system. He himself says of Borelli: "*He was pleased to lead me to the study of free and democratic philosophy, and to this I owe the progress I have made in philosophizing*". His work was diverse and wide-ranging. He studied embryonic development, dental structure, liver, kidney, spleen, plants and insects. In the hedgehog, he made the description of red blood cells in the text *Exercitatio omento, pinguedine et adiposis ductibus* (Bologna, 1665), although he did not deepen his knowledge, facts that would be reserved to Swammerdam (works in frogs) and fundamentally to Leeuwenhoek. Let us remember that in 1658 the German Athanasius Kircher (1602-1680), in studies carried out on plague, had found red blood cells, but he thought that they were the cause of this disease, without glimpsing its significance.

Anton van Leeuwenhoek was active in the development of microscopic study. He built his own lenses, achieving up to 300 magnifications in his microscopes. Not being a physician, his work was based on his interest in optics. In 1688 he made a complete study of red blood cells, and also studied the capillary circulation in the membranes of palmipeds and in the mesentery of the frog. He also succeeded in observing the reticular structure of the cardiac muscle. His work was published by the Royal Society of London.

The visual verification of blood circulation would have to correspond to Lazaro Spallanzini. A priest by profession, he was born in Scandiano, near Modena, in 1729, and was a professor in the latter city and in Pavia. He wrote several works, including *Del azione del mori ne' vasi sanguigni* (Modena, 1768) and *De fenomeni della circolazione* (Modena 1777).

In 1771 he observed in a chicken embryo the red blood cells circulating from the arteries to the veins. His account in 1773 describes the event in these words: "*The room in which I found myself was not sufficiently lighted, and wishing in any case to satisfy my need, I decided to examine the egg in direct sunlight. Having placed the egg in Lyonnet's little machine, I soon directed the lens at it and, notwithstanding the great brightness that surrounded it, I was able, by sharpening my eyes, to see the blood flowing through the complete circuit of the umbilical, arterial and venous vessels. Then, seized with unexpected joy, I exclaimed eureka! eureka!*".

In addition to the circulatory process, Spallanzini investigated the generation of living beings, digestion and respiratory function. His phrase: "*The voice of nature must prevail over that of philosophy*" demonstrates his scientific stature. He died in Pavia in 1799.