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Completing the puzzle of blood circulation: the discovery of capillaries

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Summary

Marcello Malpighi is considered to be the founder of microscopic anatomy. For almost 40 years he used the newly invented microscope to study and discover many structures of human body, animals and plants. One of his greatest contributions to science was the establishment by direct observation of an anatomical linkage between arteries and veins, the capillary network, a monumental work that completed Harvey's theory of blood circulation.

Key words

Marcello Malpighi, microscope, blood circulation, capillaries

Introduction

The discovery of the blood circulation in 1615 by William Harvey is considered to be the most brilliant and important event that has ever happened in anatomy and physiology. Harvey had shown that the blood was passing from the veins to the arteries through the heart and lungs but having no microscope he was unable to demonstrate the capillary blood vessels and he reasoned that the blood was moving from the arteries to the veins through "the porosities of the tissues" [1]. This had to wait for Marcello Malpighi and his landmark work on capillaries that completed Harvey's views on blood circulation.

Malpighi's life and carrier

Marcello Malpighi was born on March 10th, 1628, in the town Crevalcore, near Bologna in Italy (Fig. 1). Son of an estate owner, he studied first philosophy and then medicine at Bologna University and in 1653 he received the doctor's degree. His teaching carrier and anatomical studies began at Bologna where in 1656 he was appointed Professor of medical practice and later the same year, the University of Pisa created a chair of theoretical medicine for him. It was at Pisa that Malpighi began a friendship with the eminent physiologist and founder of the iatro-mathematic school Giovanni Borelli (1608-1679). In 1661 Malpighi was called to the University

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Fig. 1 – Portrait of Marcello Malpighi.

of Messina where he stayed for 4 years and finally in 1666 he returned back in Bologna [2]. Teaching and practicing medicine in these three institutions, he continued his research with the newly invented and perfected microscope by Sacharias Jansen (1580-1638) and Galileo Galilei (1564-1642). Most of Malpighi's research results were published as articles in the *Philosophical Transactions* of the Royal Society of London. In 1667 Henry Oldenbrug (1619-1677), the founding editor of the *Philosophical Transactions*, invited Malpighi to correspond with the Royal Society regularly and in 1668 he had been granted honorary member, the first such recognition given to an Italian [3].

Despite his modesty, the immense impact of Malpighi's microscopic studies provoked envy and criticism on the part of his contemporaries; a conflict that reached a boiling point in 1683 when his house was burnt and his manuscripts, notes and laboratory equipment were destroyed completely [4]. In 1691 he was appointed as personal physician of Pope Innocent XII and received many honors that relieved the insults suffered for so many years. He died in Rome in 1694 after a massive cerebral hemorrhage [5].

His scientific work

Having a special skill in minute anatomy, Malpighi performed mainly vivisections. He dissected bats, frogs, chicken embryos and examined various parts of their organs under the microscope, making most important discoveries in histological anatomy [6].

In his manuscript entitled *De viscera structura exercitatio anatomica* published in 1666 he described the structure and function of the kidney. In his work in embryology *De formatione pulli in ovo* appeared in 1673, he reported the aortic arches, the neural groove, the cerebral and optic vesicles.

He also described the *rete mucosum* or Malpighian layer of the skin, the structure of liver and spleen, the taste buds of human tongue and the human fingerprints. While examining the omentum of a hedgehog he discovered the red blood cells, characterizing them as "globules of fat of a definite outline and red color". Also Malpighi did not limit his observations to animal tissues. He studied plant microanatomy as well and his book *Anatomia Plantarum* appeared in 1671, is considered to be the most exhaustive study of botany at the time.

But his greatest contribution to science was the description of the capillaries in the lungs. His work *De pulmonibus observationes anatomicae* published in 1661completed Harvey's work showing how the blood gets from the arteries to the veins [7].

Regarded as the founder of microscopic anatomy or histology, many anatomical structures are named after him, including the Malpighian layer, a skin layer, the Malpighian corpuscles in the spleen and kidneys and the Malpighian tubules in the excretory system of insects [8].

The discovery of capillaries

In 1615 William Harvey discovered the blood circulation although having no microscope he never saw the capillaries. It was Malpighi that demonstrated first that the blood did not leak out of its proper vessels into the air spaces, as it was believed, but made its way from artery to vein through the minute structures known as capillaries [9].

In 1661 Malpighi writes to his friend Giovanni Borelli the results of an examination in a frog's lung: "For while the heart is still beating, two movements contrary in direction though accomplished with difficulty are observed in the vessels so that the circulation of blood is clearly laid bare and indeed the same may be even more happily recognized in the mesentery and in other larger veins contained in the abdomen. And thus by this impulse, the blood is showered down in minute streams through the arteries, after the fashion of a flood, into the several cells, one or other conspicuous bronchi, passing right through or leaving off there, and the blood, thus repeatedly divided, loses its red colour and carried round in a sinuous manner, is poured out on all sides until it approaches the walls and the angles and the absorbing branches of the veins. The power of the eye could not be carried further in the opened living animal; hence I might have believed that the blood itself escaped into an empty space and was gathered up again by a gaping vessel and by the structure of the walls.

But an objection to this view was afforded by the movement of the blood being tortuous and scattered in different directions and by its being united again in a

determinate part. My doubt was changed into certainty by the dried lung of the frog which to a very marked extent had preserved the redness of the blood in very minute tracts. By the help of our more perfect glass the vessels joined together in a ring-like fashion. And such is the wandering about of these vessels as they proceed on this side from the vein and on the other side from the artery that the vessels no longer maintain a straight direction but there appear a network made up of the continuation of the two vessels. This network not only occupies the whole but extends to the wall and is attached to the outgoing vessel. Hence it was clear to the senses that the blood flowed away along tortuous vessels and was not poured into spaces

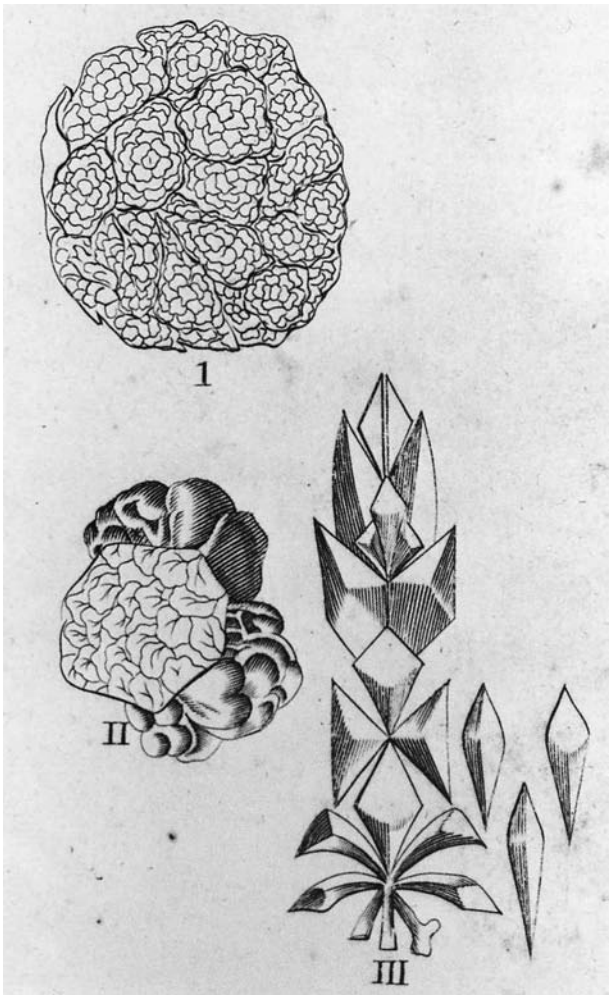

Fig. 2 – *Folio* from Malpighi's *Opera Omnia* (1686), showing microscopic views of the lungs and its network of capillaries.

but was always contained within tubules and that its dispersion is due to the multiple winding of the vessels. Nor is it a new thing in nature to join to each other the terminal mouths of vessels, since the same obtains in the intestines and other parts and indeed what seems more wonderful she joins together by conspicuous anastomoses the upper and lower termination of veins as the most learned Fallopius has very well observed" (Fig. 2), [10].

Soon Malpighi realized the importance of his discovery and published the results of his work in 1663 in the *Philosophical Transactions* of the Royal Society of London under the name *De pulmonibus observationes anatomicae* [11]. The concept of Harvey's blood circulation was complete.

Conclusion

Revealing the hair-like connections between veins and arteries, invisible to the naked eye, named capillaries after the Latin *capilla* meaning little hair, Malpighi made a major discovery in circulatory physiology. The missing link in Harvey's blood circulation has finally been found.

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