

William Harvey (IV) *De Motu Cordis*. (Third part)

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De Motu Cordis. (Tercera parte)

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We continue with the analysis of *De Motu Cordis*

Chapter X. "The first hypothesis about the amount of blood that passes from the veins to the arteries and the existence of a circular movement of the blood is freed from objections and confirmed by experience"

Harvey presents arguments and experiments that prove his first hypothesis regarding the blood circuit. Thus, in the practice of vivisection in snakes and fish, he details that if the vena cava near the heart is compressed, the overlying vein, the heart and the aorta are left without blood. If, however, the aorta is occluded, the heart becomes engorged.

Chapter XI. "Confirmation of the second hypothesis"

The second hypothesis proposed by Harvey refers to the fact that the blood transported to the periphery by the arteries is much greater than that necessary for nutrition. When referring to "*the veins being the return route to the heart*," he must have reasoned about a necessary interconnection between arteries and veins. To settle this gap he speaks of "*porosities of the flesh*" ("*carnis porositates*"). Despite not being able to know the microscopic structure of the capillaries that were to be discovered by Malpighi in 1661, he successfully used the concept by saying "*blood passes from the arteries to the veins in the same way as it was already said that in the thorax it passes from the veins to the arteries.*"

He uses the ligatures on the arm to support the return of blood. Thus, a loose ligation stops the blood in the veins, engorging it in its distal portion. On the other hand, a very tight ligation will stop blood in both directions, arterial and venous, making the radial pulse disappear. With this he shows that blood flows towards the center through the veins and towards the periphery through the arteries.

The application of bleeding with moderate pressure on the arm had always shown venous engorgement. The Galenic paradigm explained this with the

assumption that the "*vis attractiva*" of the vein was stimulated by the ligation, or after phlebotomy by the "*horror vacui*" ("*horror of emptiness*") that the blood would have, the latter a concept of Erasistratus in Alexandria (3rd century BC). Harvey deduces that this mechanism of pressure would bring enough blood from the arteries to the venous network to make it plethoric. Therefore, with this use of ligation experimentation he demonstrates the error of the ancients and the true nature of circulation.

Chapter XII. "The confirmation of the second hypothesis allows us to recognize the existence of a circular movement of blood"

There is a reference that blood is driven by the force of the heart and only comes from it. He uses the method of calculation again when he states that if a phlebotomy is performed and blood is let out for half an hour "*lipothymia and syncope will occur... and if we then calculate how many ounces of blood pass through a single arm*" we will be able to know how much passes through the rest of the organism, resulting in the amount that circulates far exceeding the nutritional needs of the parts. He also expresses that as the phlebotomy diverts blood to the outside, the cardiac impulse is lost. That last statement is a clear demonstration that blood pressure varies and is not constant.

Chapter XIII. "The confirmation of the third hypothesis demonstrates the existence of a circular movement of blood"

Harvey's third hypothesis was the understanding of the venous valves function. Robert Boyle (1626-1691) infers that this was the initial subject in the original idea of blood circulation, referring to it with these words: "*I remember asking our famous Harvey, shortly before his death, what motives had suggested the idea of blood circulation to him. He answered me that this idea arose in his mind when he recognized that the venous valves in many parts of the body are*

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placed in such a way that they give free passage to the blood towards the heart, preventing its flow in the opposite direction. This fact led him to think that perceptive nature would not have placed so many valves in the veins without a certain purpose. Since blood cannot flow in the veins towards the extremities because of the interposed valves, their purpose seemed to be that the blood sent through the arteries would return through the veins whose valves do not oppose this direction of its course”.

In any case, the analysis of *De Motu Cordis* reveals that its author has not undermined to this venous valve function the importance of the rest of the topics discussed, which correspond to the problems that Harvey was solving and that were impediments to the true knowledge of circulation.

While in Padua, he became aware of the venous valves through his teacher Fabrizio d'Aquapendente, who had studied them thoroughly from a morphological point of view in his book *De venarum ostioliis* (Padua, 1603). Regarding their function, Fabrizio was oriented towards the regularization of peripheral blood volume, in order to avoid its accumulation in the hands and feet, which did not contradict the system set up by Galen. Harvey does not refer to those who studied venous valves before his teacher (Estienne, Vesalius, Cannano, Amatus Lusitanus, Colombo, Alberti); he even gives ownership of the drawings to Fabrizio “or perhaps to Jacobo Silvio, as claims the wise Riolanus.”

The fundamental thing about all this is that Harvey was able to understand the meaning through what he called the third hypothesis to confirm the blood circuit. He thus expresses that the veins are “so that (the blood) flows from the extremities to the center, since such a movement easily opens the most tenuous valves, and the opposite closes them.” To make the understanding of this mechanism clearer, he establishes an analogy with the sigmoid valves: “... it is clear that the valves of the veins have the same function as the three sigmoid valves that are arranged in the orifices of the aorta and the arteriosus vein, that is, to close perfectly to prevent the blood that passes through them from refluxing”. Furthermore, in the practice of dissection he verified that it is not possible to introduce a stylet along the vein against the current, due to the valves' closure.

To further clarify his position, he carries out experiments with ligatures on the arms, visualizing the valves at regular sections of the venous path and the centripetal direction of the blood flow, by pressing and decompressing the engorged path with a finger.

Chapter XIV. “Conclusion of the demonstration of the circular movement of blood”

After demonstrating his three hypotheses that confirm the circulatory idea, he succinctly summarizes the blood circuit. Upon reaching the arterial end he expresses that its path “... is suggested by the porosi-

ties of the flesh and by the veins themselves.” This expression of “porosities of the flesh” does not imply the discovery of capillaries made later by Marcelo Malpighi (*De pulmonibus observationes anatomicae*, Bologna, 1661), but simply the need to glimpse a passage between arteries and veins in the periphery.

Chapter XV. “The circular movement of blood is confirmed by plausible reasons”

He details the driving character of the heart, which he calls the “life principle.” Following Aristotle, mentioned repeatedly in this chapter, he finds “innate heat” in the heart, expressing that “it is necessary for the blood to return again to the source and origin to replenish both heat and spirits.” He also finds in the perpetual movement of circulation the ability to prevent blood from clotting.

The description he makes of the “muscular pump” that helps venous expression in the limbs, facilitating its return, is very interesting; adding that “due to the movement of the limbs and the compression of the muscles, it is prone and inclined to move (the blood in the veins) from the periphery to the center.”

Chapter XVI. “The circular movement of the blood is demonstrated by its consequences.”

He intelligently applies the concept of circulation to pathology (spread of rabies, syphilis) and therapeutics (medicinal absorption of colocynth, aloes, cantharides, garlic and cordials). Likewise, he wonders about the meaning of the different pulses, because, since Galen it had been accepted that each disease had a pulse.

Chapter XVII. “The movement and circulation of blood are confirmed by what appears in the heart and what results from anatomical dissection.”

He makes a description of the ventricles, including their internal conformation, distinguishing the right from the left by their function. In this way he explains the difference in thickness of each ventricular wall: (the left ventricle) “... has walls three times stronger and more robust than that of the right”, later adding the functional concept of its cause: “since it must carry the blood further, throughout the body.” He determines that the heart has a muscular structure by reporting “not without foundation did Hippocrates consider in his book *De Cordis* that the heart is a muscle.”

Next, he reviews the use of the sigmoid and atrioventricular valves. Regarding the mitral valve he says “Those of the left ventricle are two (the leaflets) in the shape of a miter”, an analogy with the papal hat already proposed by Vesalius.

There is also an essay on the explanation of the pulse, which he considers as an epiphenomenon of cardiac impulse. He also relates the thickness of the arterial tunic to the difference in pulse, determining that this tunic is thicker the closer it is to the heart:

“the closer the arteries are to the heart, the more their constitution differs from those of the veins, and the more robust and ligamentous they are.” He astutely establishes that the more distal the artery, the lower the driving force. The expression *“sometimes we feel the pulse in the teeth, in the tumors and in the fingers”* must be understood as a precursor statement of the capillary pulse.

Similarly, a reference is made to the *“arterial vein”* with the structure of an artery and the *“venous artery”* of a vein. This nomenclature may have origi-

nally been due to Andrea Cesalpino.

The completion of this last chapter and therefore of the book maintains the same fidelity to the work based on reasoning and experimentation to demonstrate blood circulation, appealing to both deep observation and an anatomy in movement. His final words are clear *“... when practicing vivisection (the circulatory phenomena) shed a lot of light... the explanation of all of them and the causes by which they are thus constituted, is extremely difficult unless it fits our way of seeing.”*