

Review

Leonardo da Vinci's studies of the heart

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ABSTRACT

Leonardo da Vinci's detailed drawings are justly celebrated; however, less well known are his accounts of the structures and functions of the organs. In this paper, we focus on his illustrations of the heart, his conjectures about heart and blood vessel function, his experiments on model systems to test those conjectures, and his unprecedented conclusions about the way in which the cardiovascular system operates. In particular, da Vinci seems to have been the first to recognize that the heart is a muscle and that systole is the active phase of the pump. He also seems to have understood the functions of the auricles and pulmonary veins, identified the relationship between the cardiac cycle and the pulse, and explained the hemodynamic mechanism of valve opening and closure. He also described anatomical variations and changes in structure and function that occurred with age. We outline da Vinci's varied career and suggest ways in which his personality, experience, skills and intellectual heritage contributed to these advances in understanding. We also consider his influence on later studies in anatomy and physiology.

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1. Introduction

Leonardo da Vinci (1452–1518 CE) is now regarded as “the most varied genius probably who ever lived” [1]. The life of this great artist and scholar was characterized by an itinerant existence, a unique career, and his interests – while being only formally trained in the fine arts – in various fields of science including engineering and human anatomy and physiology. Notably, and of interest from our point of view, da Vinci was intensely preoccupied with the issue of human morphology and function in the final period of his productive life. Combined with his talents, profound artistic ability, technical skills, creativity and immense pleasure in exploring new areas, this led to several remarkable discoveries in the history of medicine. Among approximately 800 anatomical illustrations made by da Vinci, a great number of drawings are devoted to the cardiovascular system [2]. Da Vinci claimed that he had dissected more than 10 human bodies in order to understand the blood vessels [2]. Doby attributed this drive to da Vinci's “irresistible attraction” toward mechanics and hydrodynamics.

Herein, we provide an account of da Vinci's life and his varied career and contributions that led to advances in understanding cardiovascular anatomy and physiology. Throughout the text, we outline ways in which his personality, experience, skills and intellectual heritage contributed to these advances, and ultimately, we consider his influence on later studies in anatomy and physiology. Owing to his significance in the history of art, medicine and engineering, da Vinci's life and work have been described in numerous sources [3–18], and the following biographical sketch is summarized from those sources.

2. Biography

Leonardo was born on April 15, 1452 in Italy; his father, Ser Piero di Antonio, was a wealthy notary [3–6]. His mother, Caterina, was a remarkably beautiful 16-year-old girl from a poor, lower-class family [6,7]. Sadly, Ser Piero and Caterina could not marry because of the difference in their social status [6,7]; his mother married another man just after Leonardo's birth [6]. Leonardo spent his earliest years in his mother's home in Anchiano [8]. At the age of five years, he entered his father's household in Vinci, Tuscany [8]. Therefore, he was known by the surname of “da Vinci” (literally meaning ‘from Vinci’). The status of illegitimacy prohibited him from a formal education in the schools, so basic training had to be provided by his father, and for

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more than basic reading and writing he had to train himself in other subjects [6]. This probably led his childhood talents in art to promote.

When he was 14 years old, da Vinci was apprenticed to the eminent Florentine artist Verrocchio (Andrea di Cione), in whose workshop he was trained in art theory and a wide variety of technical skills [6,8,9]. Six years later, in 1472, he attained the status of master and joined of the Guild of St. Luke, a Florentine guild of artists, physicians and apothecaries, as a painter [8,9]. He continued to collaborate with Verrocchio, and was able to set up his own workshop in Florence [8,9]. It is not exactly clear when he left Verrocchio's studio, but in 1478 he had several independent commissions [9].

In 1482, Lorenzo de' Medici (also nicknamed Il Magnifico) commissioned da Vinci to give a gift, a silver lyre, to Ludovico il Moro, Duke of Milan [8], who was a patron of science and art. In 1485, da Vinci was appointed director of the Academy of Science and Art of Milan [10]. For the following 17 years he was largely based in Milan, working on a number of engineering, architectural and sculptural projects for Ludovico [3–5,8]. His mother, Caterina, came to live with da Vinci in Milan in 1493, and apparently he took care of her until her death in 1495 [6].

When Louis XI of France invaded Milan in 1499 and overthrew the dukedom, da Vinci (Fig. 1) – losing his patron – inevitably fled to Mantua and then to Venice [10–12]; in 1500, he returned to Florence [10] where he was welcomed by Filippino Lippi [13] and set up a new workshop in the monastery of Santissima Annunziata [8]. In 1502, he entered the service of Cesare Borgia, son of Pope Alexander VI, and

developed his interests as a cartographer and military engineer [8]. He was issued a passport by Borgia to travel for six months in the region [14]. He spent the years 1503–1506 in Florence, and completed the Mona Lisa – “the most celebrated portrait of all time” [15]. Because of his fame as an artist, Louis XII welcomed him to the court and thus he returned to Milan [15]; he had to visit Florence several times to resolve difficulties arising from his father's estate; his father had died leaving his half-brothers to challenge him over his inheritance [6]. During his second stay in Milan, da Vinci performed most of his anatomical works [15]. The French rulers of Milan were defeated in 1513 [15], and da Vinci next moved to the Vatican. The circumstances in Rome, however, were not favorable; he was too obsessed with anatomy [16], and his relationship with Michelangelo did not go well [10]. His privacy was also violated by a German mirror-maker [17] who accused him before the Pope of evocation of the dead and necromancy [18] and he was subsequently prohibited from conducting his anatomical works at the hospital [18]. But fortunately, da Vinci met King Francis I in Italy, and in 1519 accompanied him to France where he was entitled to receive an annual salary of 700 crowns [10]. However, his health condition did not allow him to conduct genuine work in France [10]. At the end of his life, he was gifted a manor in France by the French king; his death in the arms of King Francis I was painted by Ménageot and Ingres [8].

Among the numerous published studies of da Vinci (Fig. 2), many have focused on his contributions to medicine and natural philosophy, later dubbed ‘science’ (e.g. [5,19–22]). His plans to publish his notebooks were not realized during his life or for fifty years after his death. His anatomical drawings were highly praised by William Hunter in 1784 and some were published in 1883 [23] and 1916 [24]. All the notebooks that survived were collected and meticulously edited by Keele (1979–81), who has published a number of scholarly accounts of da Vinci's contributions to anatomy, with particular emphasis on his studies of the heart and blood vessels [24–27].

In the subsequent sections, we review the motivation and significance of da Vinci's drawings and descriptions of the heart. We begin with an overview of the beliefs about the heart and blood vessels in medieval and early Renaissance Europe, and then summarize the new discoveries revealed by da Vinci's drawings and notes. In the succeeding section, we discuss the influences that led him to such a radical departure from accepted beliefs. In the final substantive section of the text, we consider the influence of da Vinci's discoveries about the heart and blood vessels on his contemporaries and successors, and the significance of his work for us today.

3. Da Vinci's intellectual heritage: beliefs about the heart in medieval Europe

The timeline of major historical discoveries in the anatomy and physiology of blood circulation is given in Table 1. Those closely relevant to the present article are discussed in some detail. Medieval Europe accepted Galen's teaching about the heart and the blood vessels. This had four major aspects [30]: First, venous and arterial blood differ and are separate; venous blood is created by the liver and nourishes the tissues, whereas arterial blood transports vital spirits to the body from the heart. Secondly, the pulmonary vein is not a blood vessel but supplies pneuma/spirits from the lungs to the arterial blood and evacuates its ‘sooty vapours.’ Thirdly, diastole is the active phase of the cardiac cycle, sucking blood out of the veins. Fourthly, venous blood passes from the right to the left heart through invisible pores in the interventricular septum. According to this view, the heart was the seat of the vital force and of the soul, so it could not be merely a muscle. The statement “All the arteries [emanate] from the heart, all the veins from the liver” is attributed to Nicolaus of Salerno [41], of whom little is known except that he flourished around the middle of the twelfth century CE.

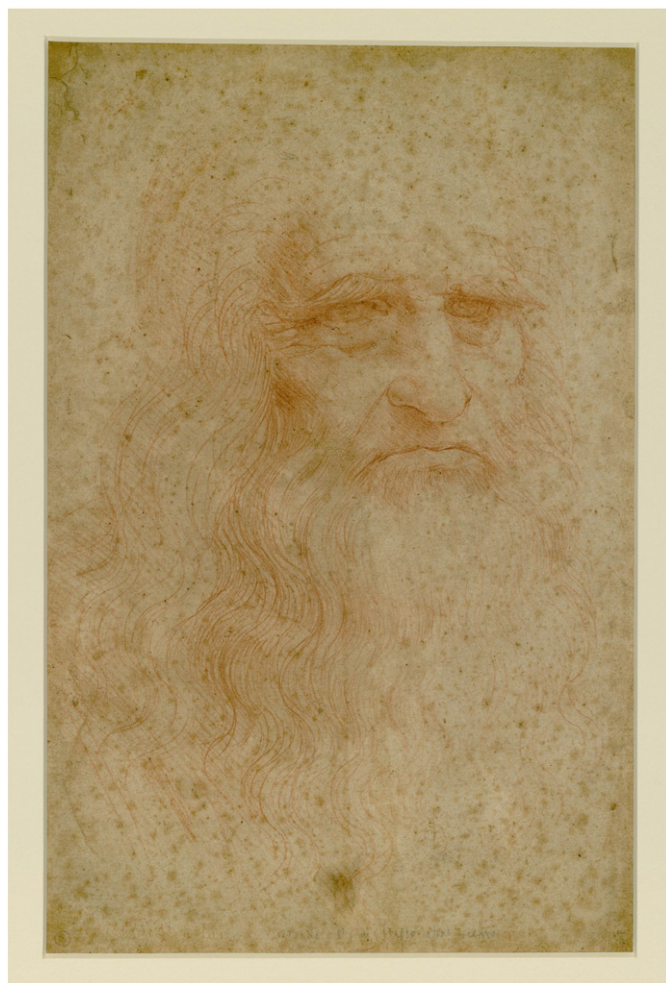


Fig. 1. A self-portrait of Leonardo da Vinci, reproduced with written permission (“Su concessione del Ministero per i Beni e le Attività Culturali – Biblioteca Reale – Torino”, Courtesy of the Ministry of Heritage and Culture – Royal Library – Turin, Italy).

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