SHORT HISTORICAL REVIEW

RJME Romanian Journal of Morphology & Embryology http://www.rjme.ro/

Leonardo da Vinci – ingenious anatomist: 500 years since the death of the famous erudite

MIRCEA VICENŢIU SĂCELEANU[1)], AUREL GEORGE MOHAN[2)], ANDREI ALEXANDRU MARINESCU[3)], ALINA MARINESCU[3)], ALEXANDRU VLAD CIUREA[3,4)]

[1)]*Department of Neurosurgery, "Victor Papilian" Faculty of Medicine, "Lucian Blaga" University, Sibiu, Romania; Department of Neurosurgery, Emergency County Hospital, Sibiu, Romania*

[2)]*Department of Neurosurgery, Faculty of Medicine and Pharmacy, University of Oradea, Romania; Department of Neurosurgery, Bihor Emergency County Hospital, Oradea, Romania*

[3)]*"Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania*

[4)]*Department of Neurosurgery, "Sanador" Clinical Hospital, Bucharest, Romania*

Abstract

Born on April 15, 1452, in a modest family in a hamlet from Tuscany, Leonardo da Vinci became the unassailable icon of Renaissance. Pushed throughout his entire life by his relentless curiosity, he was a painter, draughtsman, sculptor, poet, musician, writer, engineer, stage designer, architect, physicist, astronomer, cartographer and anatomist. His earliest surviving anatomical drawings (ca. 1485–1493) include studies of the skull, meninges, brain and cerebral ventricles. He was the first to pith a frog, concluding that piercing the spinal medulla will result in immediate death – a completely unexpected result in that era. In an effort to better understand the origins of the sensory and motor functions of the brain – which at the time was believed to be in the ventricles – he developed a method of injecting hot wax into the ventricles of an ox. He was the first to correctly describe the four ventricles of the brain. Thus, he circumvented a 16 century-long flaw in the dissection technique, which did not allow the correct study of the shape of the ventricles – decapitation and drainage of fluids before study. Even though he was never formally educated in the study of medicine, his work continues to inspire us today, 500 years after his death.

Keywords: Leonardo da Vinci, Renaissance, anatomy, history.

Humble origins – promising future

Famously known as the icon of Renaissance, Leonardo da Vinci (1452–1519) (Figure 1) was born in Vinci, a little town under the jurisdiction of Florence, led by the Medici family. Despite him being the archetype of the erudite, he had a humble beginning. He was the out-of-wedlock son of a wealthy legal notary and a 15-year-old orphan peasant, named Caterina. He spent his first years of his life in the home of his mother in the hamlet of Anchiano (Figure 2).

Figure 1 – ***Portrait of Leonardo da Vinci, ca. 1515–1517, by Francesco Melzi (1491–1568).***

Figure 2 – ***The birthplace of Leonardo da Vinci, Anchiano, Tuscany (photo by Roland Arhelger).***

From the age of 5, he lived in his father's household in Vinci. In all, Leonardo was the oldest brother of 12 half-siblings who were much younger than he was (the youngest was born when he was 40 years old). Throughout his life, he had very little contact with them [1].

After his family moved to Florence, around the age

of 14, Leonardo became the *garzone* (studio boy) of Andrea del Verrocchio, a well-known Florentine painter and sculptor. By the age of 17, Leonardo became his apprentice. In this workshop, he was taught both theoretical and practical skills: drafting, chemistry, metallurgy, metal working, plaster casting, leather working, mechanics, woodworking. Of course, he studied the arts of painting, drawing and sculpting [2, 3].

In this workshop, he was exposed for the first time to the study of anatomy. He would later write in *Treatise of Painting* (first printed in 1651) why the artist should have a good grasp of anatomy: "It is necessary for the painter, in order to be good at arranging parts of the body in attitudes an gestures which can be represented in the nude, to know the anatomy of the sinews, bones, muscles and tendons" [4].

By the age of 20, he was admitted into the Painter's Guild of Florence, but due to his great attachment to his teacher, he continued to work with him until the age of 25.

First steps in the study of anatomy

Da Vinci got especially interested in the study of anatomy in his mid-30s. He wanted to know all about the body, its functions and connections. At this time, he was working for the Duke of Milan, Ludovico Sforza (1452–1508).

The beginning of his career as a court artist for Ludovico Sforza is documented in his earliest known sketches of anatomical drawings, which survived the passage of time. In a set of seven sheets dated ca. 1485–1487, Leonardo describes pithing a frog (Figure 3): "The frog retains life for some hours when deprived of its head and heart and all its bowels. And if you puncture the said nerve (*n.ed.*, spinal medulla), it immediately twitches and dies." On the *verso*, he continues: "Here therefore, it appears, lies the foundation of movement and life." [5].

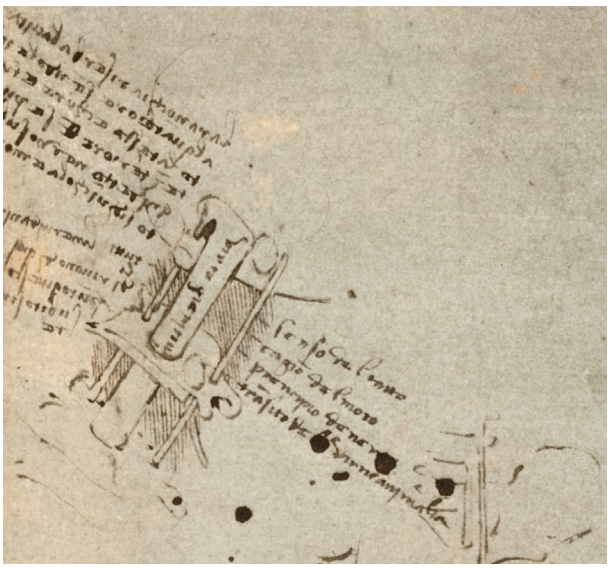

Figure 3 – ***The pithing of the frog. Leonardo da Vinci, ca. 1485–1487.***

This discovery must have been unexpected for him, considering the understanding of the spinal cord at the time. According to the teachings of Hippocrates and Plato, the spinal cord was the source of semen and sent down tubes to the penis. Leonardo makes a considerable leap forward after approximately 18 centuries of stagnation in the understanding of neuroanatomy and labels the spinal cord. He concludes that "All the nerves of animals derive from here" and names it *virtu gienjitua* (generative power) [6].

This event is remarkable because it is the first documented pithing experiment. However, Leonardo never returned to killing animals by vivisection even though it was necessary in order to advance his knowledge. Even more, he soon became a vegetarian [7]. This, in turn, did not stop him from dissecting dead animals, such as pigs, cattle, horses, monkeys, hares, lions, dogs, birds and insects and later humans [8].

The following years, he was determined to better understand the human anatomy, even the relation between structure and function. Thus, Leonardo, began performing postmortem dissections. Even though the Catholic Church strictly forbade those practices, between 1489 and 1513 be worked by candlelight in the crypt of a church where he dissected more than 30 bodies, both men and women of all ages. He did notice that this might seem a frightening experience for others: "... might be deterred by the fear of living in the night hours in the company of these corpses, quartered and flayed and horrible to see." [9].

It is remarkable to note that Leonardo was not formally trained as neither an anatomist nor a physician. Beyond his original discoveries, he introduced modern illustration techniques in the Renaissance era and is even called the "father" of embryology. In his studies (Figure 4), he correctly described the human fetus in proper position inside the uterus. It is worth mentioning he depicted the uterus with one chamber, contrary to the belief of the time that the organ had multiple chambers, which would separate twins [10].

Imaging the ventricles

His first study of the human ventricles and meninges is dated ca. 1493 (Figure 5). His first important step in unraveling the mystery of neuroanatomy was the discovery of meninges, which he compared to the layers of an onion: "If you will cut an onion through the middle you will be able to see and enumerate all the coats or rinds, which circularly clothe the center of the onion." […] "Similarly, if you will cut through the middle of the head of a man, you will first cut the hairs, then the scalp, then the muscular flesh and pericranium, then the cranium; and inside, the *dura mater*, the *pia mater* and the brain; then again the *pia mater* and *dura mater* and the *rete mirabile* and then the bone, their foundation." [5]. At this time, his illustration of the ventricles is according to the accepted notion of three connected spherical ventricles. It is clear that he was relying on the knowledge of past anatomists.

The incredible stagnation of the understanding of the human brain is most likely explained by the anatomists' dissection technique. This involved decapitation prior to the study of the brain and thus the complete drainage of all cerebrospinal fluid. This method was still used by Vesalius and is illustrated in the miniatures of his famous anatomy treatise *De Humani Coporis Fabrica* (1543) (Figure 6).

Step 1 (letters "**I**" and "**L**"): **Obtaining the cadaver**. During Vesalius' and Leonardo's time, it was extremely difficult to obtain human cadavers for dissection, thus they regularly resorted to grave robbing (letter "**I**") or taking the bodies of executed criminals (letter "**L**").

Step 2 (letters "**D**" and "**T**"): **Dissection techniques**. The cadaver is decapitated prior to dissection (letter "**D**"). This technique is the main reason anatomist could not advance their understanding of ventricles and cerebrospinal fluid for such a long time. Next, the cadaver is hung from the legs (letter "**T**") to drain the blood, allowing for a better visualization of internal organs.

Step 3 (letters "**Q**" and "**S**"): **Comparative study**. The human subject is dissected side by side with an animal, allowing a better understanding of the work of past scholars (Hippocrates, Galen) who studied mostly animals.

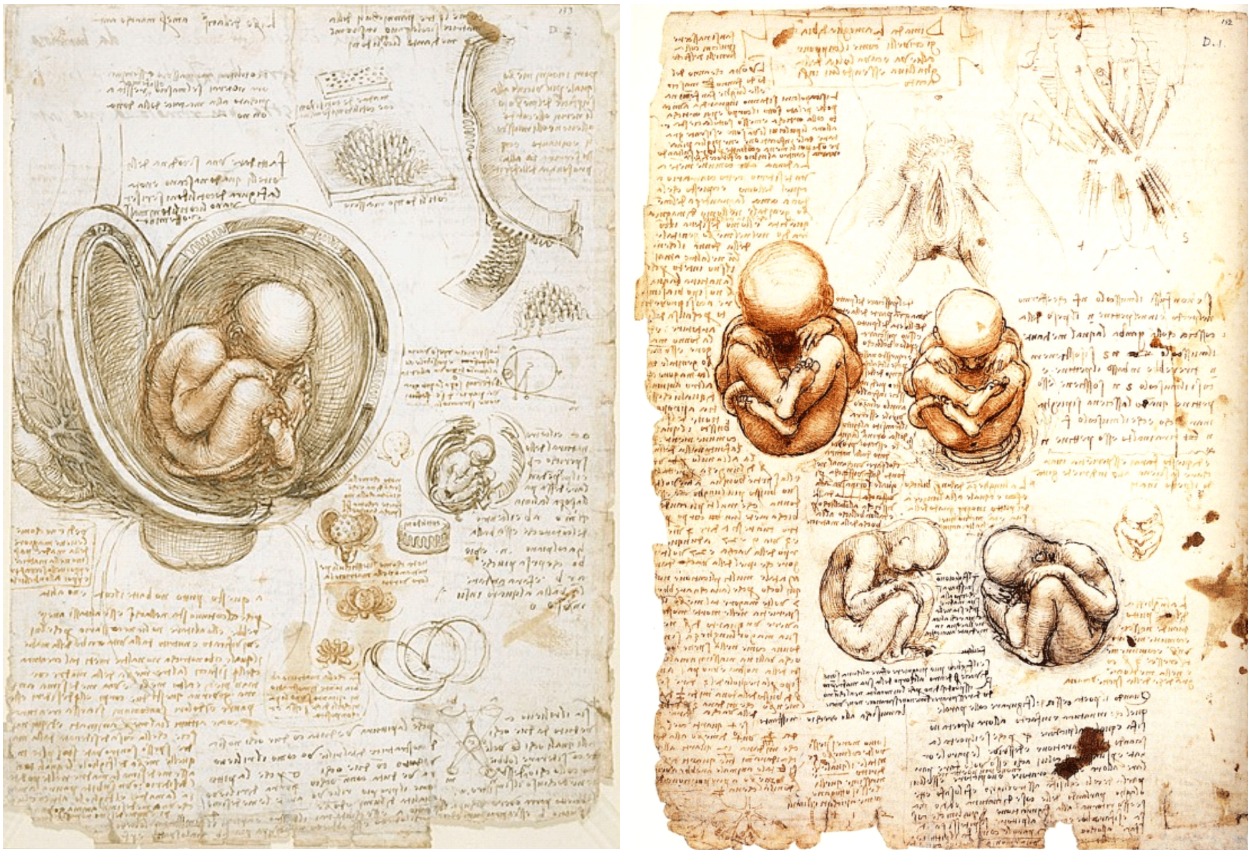

Figure 4 – ***Left: The fetus in the womb; Right: The female external genitalia and five views of the fetus in the womb. Leonardo da Vinci, ca. 1511 (Royal Library, Windsor Castle).***

In a great leap forward and with remarkable ingenuity, Leonardo performed a new experiment ca. 1506–1508. In a slaughterhouse, he injected hot wax into the brain of an ox and after the wax cooled and hardened, he performed a dissection of the animal's brain and obtained a perfect cast of the ventricles. He is the first to correctly describe the lateral third and fourth ventricles (Figures 7 and 8). At the top left of the drawing, he sketched a lateral view of the ventricles and described his procedure: "Make two vents in the horns of the great ventricles and inject melted wax with a syringe, making a hole in the ventricle of the *memoria* (*n.ed.*, fourth ventricle) and through such a hole fill the three ventricles of the brain. Then, when the wax has set, take away the brain and you will see the shape of the ventricles perfectly. But first put narrow tubes into the vents so that the air which is in these ventricles can escape and make room for the wax which enters into the ventricles." [8].

Conclusions

Leonardo's place in the canon of western art is uncontestable, but his role in medicine is a subject of debate. Even though da Vinci realized over 750 drawings of all the principal organs of the body, he never published an anatomy treatise. The fact that he was the first to correctly describe the ventricles, meninges, coronary arteries and many more had no mark in the literature of the time. The lack of his publishing allowed, for example, Valsalva 200 years after da Vinci's discovery to name the coronary arteries after himself (the Valsalva sinuses).

However, had he succeeded in publishing his anatomy treatise, would it have revolutionized medicine? The answer is most likely not. First, there is the matter of language. Like English in contemporary times, not knowing Latin in Leonardo's time will not offer the possibility of international academic recognition. Would Vesalius or Valsalva, university-trained professors of Paris, Padua and Oxford, have opened an anatomy treatise written in vernacular by a court painter? Second, there is the matter of intent. Most likely, da Vinci, wasn't truly interested in such a project. His work could have only been deciphered and correctly understood only after the 20th century, thanks to the sophisticated photographic facsimile techniques and many years of teamwork. And last, is the matter of impact. It took Andreas Veaslius's *De Humani Corporis Fabrica*

Libri Septem over a generation to achieve its greatest recognition and he had all the resources of a famous university at his disposal.

We shall remember Leonardo, 500 years after his death, not for what he could have been, but as what he was: the unassailable icon of the Renaissance humanism. A truly remarkable person not only in his work, but his personality as well, a man who could not only impress with his famous inventions and art, but also with his exuberance and style. "There is Leonardo the showman, captivating the Sforza court in Milan with his virtuoso improvisations on a silver *lira da braccio* – a kind of violin, perhaps one made to his own design in the shape of a horse's skull." [11].

Figure 5 – ***The layers of the scalp and the cerebral ventricles. Leonardo da Vinci, ca. 1490–1492 (Royal Library, Windsor Castle).***

Figure 6 – ***Illuminated letters from Andres Vesalius,*** **De Humani Corporis Fabrica,** ***Basel, 1543.***

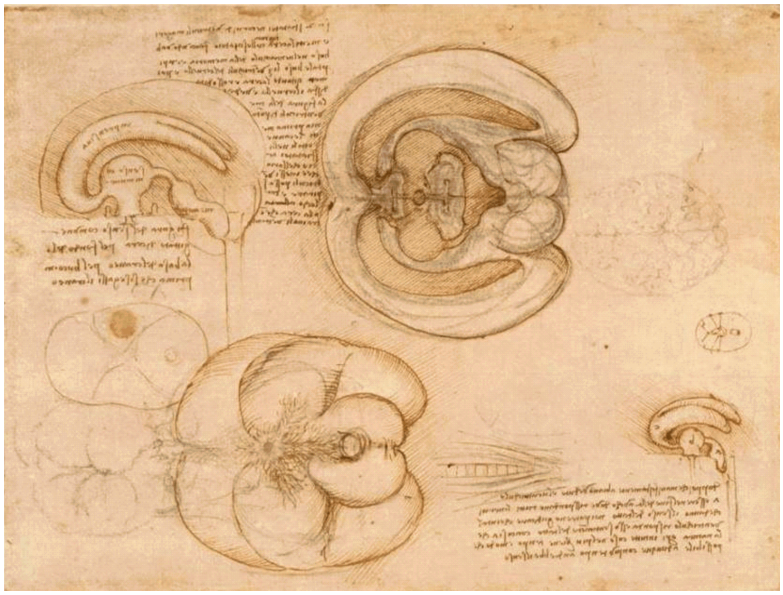

Figure 7 – ***Cerebral ventricles of the ox brain. Leonardo da Vinci, ca. 1508 (Royal Library, Windsor Castle).***

Figure 8 – ***Composite drawing of human brain, cranial nerves and ventricles. Leonardo da Vinci, ca. 1508 (Royal Library, Windsor Castle).***

Conflict of interests

The authors declare that they have no conflict of interests.

References

[1] Wallace R. The World of Leonardo, 1452–1519. EX-LIB edition, Time-Life Books, New York, 1972, 11, 13.
[2] Rosci M. Leonardo. Bay Books Pty Ltd., 1977, 13.
[3] Martindale A. The rise of the artist in the Middle Ages and Early Renaissance. Series: "Library of Medieval Civilization", McGraw–Hill, New York, 1972.
[4] McMahon AP. Leonardo da Vinci: Treatise on painting [*Codex Urbinas Latinus* 1270]. Princeton University Press, Princeton, 1956.
[5] Keele KD, Pedretti C. Leonardo da Vinci: Corpus of the anatomical studies in the collection of Her Majesty, the Queen, at Windsor Castle. Johnson Reprint Co., London, 1978, 1r, 1v, 32r.
[6] O'Malley CD, Saunders JBDM. Leonardo da Vinci on the human body. Henry Schuman, New York, 1952, plate 153.
[7] Clark K. Leonardo da Vinci. Penguin Books, New York, NY, 1988, 119.
[8] Pevsner J. Leonardo da Vinci's studies of the brain. Lancet, 2019, 393(10179):1465–1472.
[9] Richter JP. The literary works of Leonardo da Vinci [Compiled and edited from the original manuscripts by Jean Paul Richter]. 3rd edition, Phaidon, London, 1970, 796.
[10] Gilson H. Leonardo da Vinci's embryological drawings of the fetus. The Embryo Project Encyclopedia (2008-08-19), http://embryo.asu.edu/handle/10776/1929.
[11] Barnett R. Obituary: Leonardo da Vinci. Lancet, 2019, 393(10179):1409–1410.

Corresponding author

Aurel George Mohan, Associate Professor, MD, PhD, Department of Neurosurgery, Faculty of Medicine and Pharmacy, University of Oradea, 10 1 December Square, 410073 Oradea, Bihor County, Romania; Department of Neurosurgery, Bihor Emergency County Hospital, 65 Gheorghe Doja Street, 410163 Oradea, Bihor County, Romania; Phone +40740–514 636, e-mail: mohanaurel@yahoo.com

Received: December 11, 2019

Accepted: January 18, 2020