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Unit 7 - Anatomy Book and Instruments for the Construction of Anatomy

Reading

The history of anatomy, between the end of the Middle Ages and the modern age, is part of the wider European intellectual landscape characterized by the emergence of Humanism and the cultural trends of the new century. On one hand, it is based on the rediscovery of the ancient and the recovery of the classical tradition; on the other, it fully accepts the challenges of innovation and the signs of modernity.

The background is the process of cultural change that has spread throughout Europe, marked by a dense network of exchanges, the circulation of texts, journeys to discover new continents and the interweaving of the arts and sciences. Central-northern Italy has been the main European theatre in this history. Padua, Venice, Bologna, Florence and Rome became the centers of irradiation of anatomical culture, both on the more traditional side of philological work on ancient sources, and on the innovative side of rewriting anatomy on the basis of autopsy research on the corpse.

Historians indicate the year 1543 as a turning point in the history of anatomy. The publication of De humani corporis fabrica by Vesalius, accompanied by magnificent illustrations, is, in fact, unequivocally a break with previous anatomical treatises. With this book, Vesalius proposes a revision and rewriting of the Galenic anatomy that had dominated the teaching of this discipline, both in the Christian and then Muslim East, and in the Latin West.

Texts such as De juvamentis membrorum - a medieval compendium of the De usu partium corporis humani di Galen (129/130-200/216), and above all the Anothomia corporis humani (1316) by the Bolognese Mondino de Luzzi- read, studied and memorized by entire generations of students of late medieval and Renaissance Europe, were marked by the anatomical model of Galen.

At the beginning of the 1300s, Mondino, professor at the University of Bologna, undertook the direct and methodical study of the bodies, thus giving rise to the first school of human anatomy in Italy and Europe. However, it did not lead to the uncoupling of anatomy from the then dominant concepts, as it was strongly influenced by Galen, Aristotle and Avicenna (De Medicina). However, Mondino's work, Anathomia, of 1316, was adopted for over two hundred years by Italian and foreign universities.

In Vesalius' Fabrica aims to correct the mistakes handed down for over a millennium by the Galenic anatomical tradition. The main tools of this radical revision are the art of dissection and a meticulous reading of Galen's books. The practice of dissection is already attested in Italy since the early years of that century.

The first testimony can be found in Mondino's cited Anathomia. The author recalls, in 1315, that he dissected the bodies of two women.

Vesalius' operation in Fabrica seems to be the culmination of a process whose methodological and technical premises had been laid down at least a couple of centuries earlier, while the reversal of the order

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of priority between text and dissection, between reading and observation, constitutes a revolutionary innovation.

The scene printed in the Fasciculus shows a lecturer reciting a text: the sources relating to the teaching of anatomy in European universities inform us that it is a text of Galenic tradition. The anatomist is responsible for dissecting the corpse. In this way, the parts described verbally by the lecturer during the lesson could be shown to the students on the table.

In the Fabrica, this way of conducting the anatomy lesson became controversial. In the preface, Vesalius mockes his predecessors and his contemporaries for teaching what they have learned from books without verifying the truth or draw knowledge from direct experience of human anatomy.

On the title page of the Fabrica, Vesalius is represented in the act of practicing a dissection with his own hands in order to emphasize and reiterate - even iconographically - the idea of an anatomical text built on the practice of dissection, observation of the corpse.

This implies the distortion of the objectives assigned to the practice of dissection. If it was initially, from the 14th century, conceived and used as a tool for teaching and demonstrating the truthfulness of the content of authoritative texts of galenic origin, with Vesalius it becomes an investigative function, as well as a didactic one: only through openness, manipulation and observation of the corpse is it possible to acquire new knowledge about the body and its parts; only dissection makes it possible to write down anatomy, correcting the erroneous descriptions of the ancients who obviously lacked the opportunity to study it properly. Dissection plays a decisive role in the communication and production of anatomical knowledge, both when used solely for educational and demonstration purposes, and when it becomes an indispensable tool for research. This role is conferred on it by the fact that it is a technique based on visual experience, to which specific tasks are assigned from time to time according to the operational context in which it is practiced.

The different values of the visual experience represented by the practice of dissection mean that similar considerations on the possible uses of it recur in the pages of Renaissance anatomists, bringing together not only representatives of the Galenic tradition, but also the theorists of the revision and correction of the classical anatomical paradigm. In fact, the Renaissance anatomists agreed that the role of sensory perception in the production and communication of anatomical knowledge is important, as opposed to a cognitive process based exclusively on the written word. "Who is guided by love for the truth", warns Vesalius in the preface to Fabrica, "lend more faith to his eyes and to reasoning not useless, more than to the writings of Galen.

Berengario also wrote in his long commentary on Mondino's Anathomia:

"One does not believe that one can learn this discipline only through the hands-on voice (of the teachers) or reading, since here sight and touch are necessary (Commentaria [...] super "Anathomia" Mundini, 1521, f. 6v).

Dubois, professor of medicine in Paris in the first half of the 16th century, who theorizes the learning of anatomy through the senses, joins this choir.

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1. Anatomical Images

Despite the declarations of principle of the sixteenth-century anatomists, the students, philosophers, surgeons, barbers who populated the anatomical theaters of modern Europe had above all the word and the vision to be initiated into the knowledge of human anatomy. The insufficiency and inadequacy of a knowledge that is mainly based on the act of seeing constitutes the presupposition on which lie not only the practice of dissection and its performance in the anatomical theatre, but also the use of images both in didactics and - with the invention of the printing press - in anatomical publishing.

The regularization of the practice of dissection in Italian universities and in other European countries, as well as the proliferation of images of the human body during the sixteenth century, must be traced back to the fact that it was precisely in this period that the cultural, institutional and technical conditions that allowed the definitive establishment of a visual culture of anatomy were created.

However, it was certainly with the advent of the press and in chronological coincidence with the regularization of the practice of dissection in the major European universities, that anatomical illustrations multiplied and began to play the role of indispensable complement to the word indicated by Aristotle, Guido da Vigevano and Leonardo.

For a first step towards the integration of the image in the anatomical text, it is necessary to wait until 1521, with the publication of the cited Commentary on Mondino's Anathomia written by Jacopo Berengario da Carpi, and especially 1522, with the publication of the Anatomia Carpi. Isagoge breves perlucide ac uberime, in Anatomiam humani corporis by Berengario himself, used as a textual guide to the university teaching of anatomy in Bologna and Padua as well as in other Italian and European universities.

Rather than explaining and clarifying the content of the text, these figures in the Isagogae Breves constitute first of all a typographic ornament, so much so that some seem almost artistic exercises. The figures in which the front and back muscles of the body are represented seem to have been created not so much for doctors and medical students, but rather for those interested in superficial morphology.

The illustrations in Berengario's books offer a general view of some parts of human anatomy (muscles, skeleton, female genital apparatus, heart) and at the same time constitute an ornament that pushes anatomical information beyond the strictly scientific sphere. The communication of anatomical knowledge is in fact combined with a metaphorical discourse on the body and on death through aesthetic mediation. This metaphorical and aesthetic character of printed anatomical iconography, which appears in Berengario's books, is one of the main characteristics of the visual culture which, established with the advent of mechanical reproduction of images and texts, culminated in Vesalius work and became the expressive form proper to figured anatomy at least until the end of the 18th century.

This conception of visual communication that manifests itself in Renaissance anatomical culture came to full maturity in Vesalius' work: in Fabrica he proclaimed the need to figure anatomy, he used images designed to promote the aesthetic reception of knowledge about the human body, he thought of images as a tool to expand the circuit of diffusion of anatomical knowledge outside the medical area and the university world. Here, all the insights, suggestions and intentions enunciated in the previous literature are put to good use in the realization of the figures,

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The illustrations of the Fabrica, which are among the highest achievements of sixteenth-century xilography, are extremely effective both from the scientific point of view, and from the artistic point of view. Philosophers, painters, humanists, theologians and intellectuals were the readers of anatomical treatises throughout the modern age.

In 1538 Vesalius published the Tabulae Anatomicae Sex, a typographic product resulting from the same need to figure out the anatomy, to map the human body and to provide - thanks to the use of the image - a didactic tool for rapid and effective consultation.

The Tabulae consist of six loose sheets, each of which contains a xilograph and a text arranged above and on the sides of the illustration. The first three figures, drawn by Vesalius himself, are more anatomical-physiological diagrams than anatomical images in the strict sense, and represent the liver with the portal vein and the male and female reproductive apparatus, the path of the vena cava, the heart with the artery magna (aorta) and its ramifications. Van Calcar, who had copied from life a skeleton reconstructed by Vesalius in January 1537, instead, drew the other three plates.

These figures play an educational role for doctors, surgeons and students, but they were created to imprint in memory information about the body represented in the minds of both, those who may have witnessed the dissection, and those who have never had such an opportunity.

Artistic Anatomy was born during Hellenism because of the need of painters and sculptors to represent the human body. One of its aims is to study proportions; from the 1400s painters and sculptors dedicated themselves to it for the realization of their works. The concept that beauty was composed of proportions was well established at the time. Leonardo's tables often contain measurements of human features and their relationships, as in the famous drawing of Vitruvian man (1490 - Venice, Gallerie dell'Accademia).

2. Leonardo da Vinci and Anatomy

Leonardo approaches the studies of Human Anatomy through Artistic Anatomy, practiced by some painters of the 1400s, to represent the human body. But the "marvelous human machine" soon fascinated Leonardo's soul, who moved from the Artistic Anatomy of the surface, of muscles and bones, to the study of the internal organs. He began his dissections in the "Florentine shops", and then in the morgues where sometimes the authorities allowed doctors to observe and dissect the bodies of the executed, for research purposes. It was the muscles and bones that initially attracted the artist's attention, as he wrote in the Book of Painting: "the painter must know the anotomy of nerves, bones, muscles and fractures". Leonardo, therefore, considered, from the beginning, above all the aesthetic side of anatomical studies; this is also confirmed by a note in the margin of the sheets, where he wrote of his intention to compose an anatomical treatise and to name it "De Figura Umana" (The Human Figure). His continuous thirst for research in every field of knowledge and his tendency towards absolute perfectionism explain his interest in the observation and study of the human body. Leonardo kept his drawings and comments in detached sheets, notebooks, waiting to organize them in the treatise he designed and which was never printed.

The first painting in which the search for artistic anatomy is visible is the unfinished San Gerolamo, preserved in the Vatican Picture Gallery. Represented with dry but snappy muscles, exposed tendons. The

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neck and shoulder already reveal certain knowledge of the muscular anatomy. The bust arched behind the clavicles, the plastic gesture of the extended arm, the leg stretched forward, the head, hollowed out and bony, as well as foreshortened in its twist to the right, rendered with great expressiveness, stand out. While contemporary artists, such as Michelangelo, limit themselves to the superficial anatomy, Leonardo extends his research to the deeper parts of the body. In a series of drawings he analyses the internal dimensions of the skull. He dissects and measures the cranial structure with the intention of locating the soul. In the drawings, he offers cross-sections and sections of the cerebral hemispheres represented, layer-by-layer. He studies the bone head, presenting it at times intact, at times scalped, at times sawn in a sagittal way. The skull is then dissected frontally on one side to highlight the bone cavities: frontal sense at the top, ocular orbit, nasal sense, maxillary sense, and oral cavity.

Leonardo reproduced the exact shape of the ventricles of the brain using the method of introducing solidifiable liquid substances. This allowed him to make the first reproduction of this cavity. He represented the optical chiasm and a good part of the cranial nerves.

For information about the shape of the brain and the configurations of the brain convolutions, he developed an ingenious technique involving the injection of melted wax into the cranial cavity.

He claimed that the nerve ramifications, with their muscles, responded to the spinal cord. The spinal cord to the "sensus communis" and the latter directly to the soul, in a hierarchical order similar to the military one.

Better studied is the vagus or revulsive nerve, as it was called by the course of its lower laryngeal branch and the meninges, peripheral continuations around the nerves, distinguished in motor and sensory ones.

Leonardo noticed that the sensory nerves collected the sensations to bring them to the fourth ventricle. Finally, he conceived the nerves as hollow tubes in which the impulse passes in the form of a flow of spirits.

He then tried to locate the psychic faculties within three circular intracerebral cavities. Influenced by tradition, he imagines the nerves as tubes crossed by aerial flows that cause the muscles to contract through swelling.

3. Anatomo-Physiology

He gave impetus to the Anatomo-Physiology that was developing in those years in Italian universities, studying the movements of the body, the levers that the human musculoskeletal system use and the forces it produces. A detail that denotes the transition to physiological anatomy, born from the artistic research, is the observation that the muscles increase in volume while shrinking at rest. The concept is taken up in the Book of Painting. Leonardo criticizes his contemporary Michelangelo Buonarroti, who exaggerates the "muscular style", without precise knowledge of physiology. The study of anatomy and articular function helped the artist to improve the expressiveness of his paintings, particularly with regard to the movements of the hands; some, described in the Anatomical Tables, can be found in various works by Leonardo, such as the Virgin of the Rocks or the portrait of Cecilia Gallerani.

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In the illustrations of the articular apparatus, Leonardo first shows the bones isolated and then joined, depicting them as they move around an articulation and in different positions. He established the existence of four different types of bones: "medullary, spongy, empty, solid".

He pays particular attention to the spinal column distinguishing the vertebrae into: seven vertical, twelve dorsal, five lumbar.

For Leonardo, the sacred bone derives from the fusion of six vertebrae.

He conducted studies on the skeleton of the foot and carried out a comparative examination of the forearm in pronation and supination; observing how the passage from the first to the second makes the hand rise because of the oblique position of the radius.

The study of the various muscular elements is scrupulously dealt with several times and they are reproduced very faithfully. Leonardo has introduced an original method of studying the morphological elements of the limbs and their muscles: it is a procedure used even by the most modern anatomists.

A further innovation introduced by Leonardo in the study of myology is that of the figurative replacement of the muscles of the limbs with copper wires inserted in the points of the skeleton corresponding to their respective muscle insertions. This method allows Leonardo to specify the functional purpose of many muscles and the identification of synergism and antagonism of the muscles. In this regard, Leonardo investigated the points where blood vessels and nerves penetrate the muscle flesh and the various ways in which the latter fixate on the skeleton.

He also studies the muscles of the face, lips, mouth and forearm and their distinction between volunteers and involunteers. In particular, in examining the muscles of the face, he was able to establish a link between the movements of the muscles and their expressions: this allowed him to perform the miracle of the Mona Lisa.

He then analyzes the senses, the nervous, circulatory, urinary and reproductive systems. He devotes a large part of his research to the eye, which is reported in the manuscript D of the Windsor code. His procedure follows the method used in the modern microscopic technique, based on the incorporation into paraffin of fragments of organic tissues, to be cut with the microtome into very thin slices to be examined.

According to Leonardo, the optic nerve emerges from the back of the eye, establishing connections with the brain. Some inaccuracies concern, instead, the shape of the lens. He considers the area of the retina corresponding to the point of entry of the optic nerve on the optical axis (central line). He then specifies that, in addition to the distinct vision of the objects placed along the central line, there is a more limited visual sensitivity for things placed outside this line, the so-called indistinct vision, which today we know is due to the light rays that fall on the extra-facial regions of the retina.

An interesting observation is that expressed on the possibility that the eye has to discriminate the chromatic sensations when the objects are placed on the "central line". Leonardo studied comprehensively the essential aspects of visual function: the acuity of sight and optical illusions, monocular and binocular vision, stereoscopic sense and luminous stimuli, the phenomenon of the persistence of visual images, chromatic sensitivity, pupil modification, the size of images in relation to the visual angle, the application of

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the physical laws of refraction, the interpretation of certain pathological phenomena such as presbyopia and diplopia.

He devoted himself to the reproductive apparatus with an embryological analysis conducted on a human fetus of seven months, from which he concluded that this, located in the uterus, must be immersed in water; the liquid, in fact, allows the best disposition of the weight of the child.

Lastly, Leonardo studied several features of Pathological Anatomy, considering the modifications produced in the organism with age and even investigates the causes of death. With his rigorous method of investigation, his innovative discoveries, his accurate descriptions and the wonderful illustrations of his anatomical tables, Leonardo can, therefore, be considered the forerunner of modern medical science.

4. Anatomy and Mechanics

Leonardo resumed his anatomical studies around 1510, after a break of about ten years. Studies in mechanics influenced his late anatomy. The joints of the body are analyzed as semi-articulated joints subjected to the laws of the lever. The systematic use of dissection confronts him with the enormous complexity of anatomical data. He is convinced that every anatomical structure has a precise function: nothing, therefore, should be neglected in the representation. He makes use of innovative illustrative systems already used for machines: from the transparent representation with intact contours to the exploded view, from the view of the body from different points of view to the representation of muscles as lines of force.

Hydrodynamic studies also influenced the anatomy of Leonardo. The cardiovascular and respiratory systems and the urogenital apparatus are studied as systems of channels crossed by fluids in motion. The passage of blood through the heart valves forms vortexes similar to those generated by water in a bottleneck. The underground rivers are assimilated to the veins of the human body: the water they carry brings nourishment to the body of the Earth, like blood to the body of man. The foetus grows immersed in amniotic fluid as the terrestrial continents grow emerging from the seas surrounding them. The principles that regulate the ramifications of blood vessels are compared to those that govern the ramifications of trees. The heart generates the vessels as a kernel the plant.

5. The Heart According To Leonardo

One of Leonardo's most precious and accurate descriptions is undoubtedly that of the heart. Leonardo described with great accuracy atria and ventricles and provided the first explanation of the functioning of heart valves. But Leonardo's investigation did not stop at the simple description: to fully understand the mechanism of action of the heart muscle, he built a glass model of the aortic valve and pumped a mixture of water and seeds into it: in so doing he observed the formation of small vortexes, which he hypothesized to be fundamental to trigger the closure of the valve. It was not until the twentieth century that this extraordinary intuition was confirmed by cardiologists.

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Leonardo subverts the scheme of the treatises on anatomy, which at the time were mainly written: in the Anatomical Room the treatise was read by a reader, the dissector (cerusic/barber) physically performed the autopsy while the doctor commented on the reading, showing with a rod the internal organs. Leonardo instead argued for the importance of illustration. Leonardo's writing is simple and essential, constituting only a commentary in the margin of the graphic part.

Anatomy is decomposition (literally, from the Greek, "separating the parts"). Leonardo wants to make the complex forms of the human body comprehensible, so he dissects to understand anatomy and draws to explain what he has understood. The dissection (separation) of the various parts is followed by the recomposition, through the drawing, of what had been separated.

But the real innovation in his studies is Leonardo's research into the function of the organs and apparatus he examined. He constantly applies physiological study to anatomical study, characteristics of the "search for function" are the "exploded views", which break down the details in space, to better understand them.

Another artifice used by Leonardo is to represent the muscles as strings stretched between their bone insertions, to explain how the lines of force are applied in their contraction, "you will only make confusion in demonstrating the muscles ... if you do not draw them as strings, so you can represent them one above the other, as nature has placed them", and again: "each muscle uses its force along the line of its length".

The proportion and harmony of the forms are extended by Leonardo beyond the surface, in the descriptions and drawings of the dissections of the internal organs.

In his search for the relationships and proportions created by the "harmony of nature", Leonardo, especially in his late anatomical drawings, stylize the representations of organs and apparatus, making them appear slimmer than they are.

The English physician William Hunter, professor of Anatomy at the Royal Academy of Arts, discovered his manuscripts in the royal library at Windsor Castle, where he had been admitted by King George III (c.1783). After examining them, he proclaimed that "Leonardo was the greatest anatomist in the world in his time". Leonardo had been able to combine art and science like no one ever before, but he had also made countless anatomical discoveries (see "Leonardo's cave" the under-orbital sinus).

6. From Anatomo-Physiology To Pathological Anatomy

The passage from Anatomo-Physiology to Pathological Anatomy is more appreciable in the study of the human body through the different phases. Exposing the differences found in the arteries of young and old, it provides the first detailed description of the characteristics of atherosclerotic disease. It draws the vessels representing their lengthening and thickening, describes their tortuosity.

Leonardo's anatomopathological research culminates in the investigations into the cause of death conducted in Florence. The thought of the transcendent is often present in Leonardo, although he believes, as an indisputable truth, in what Science can demonstrate. He devoted himself to researching the site of the soul in the human body, recognizing the vital functions of breathing and blood circulation, which brings

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nourishment. He examines the heart, which he describes as "a muscle vivified and nourished by arteries and veins that, unlike other organs, "moves by itself and does not stop, if not eternally".

But Leonardo identifies the skull as the place where the soul resides, the "common sense" in which sensory impressions converge and their rational elaboration takes place.

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