Medicina Historica 2019; Vol. 3, N. 2: 69-77

Original article: history of medicine

The teaching of anatomy throughout the centuries: from Herophilus to plastination and beyond

Veronica Papa[1, 2], *Elena Varotto*[2, 3], *Mauro Vaccarezza*[4], *Roberta Ballestriero*[5, 6], *Domenico Tafuri*[1], *Francesco M. Galassi*[2, 7]

[1] Department of Motor Sciences and Wellness, University of Naples "Parthenope", Napoli, Italy; [2] FAPAB Research Center, Avola (SR), Italy; [3] Department of Humanities (DISUM), University of Catania, Catania, Italy; [4] School of Pharmacy and Biomedical Sciences, Faculty of Health Sciences, Curtin University, Bentley, Perth, WA, Australia; [5] University of the Arts, Central Saint Martins, London, UK; [6] The Gordon Museum of Pathology, Kings College London, London, UK; [7] Archaeology, College of Humanities, Arts and Social Sciences, Flinders University, Adelaide, Australia

Abstract. Cultural changes, scientific progress, and new trends in medical education have modified the role of dissection in the teaching of anatomy in today's medical schools. Dissection is indispensable for a correct and complete knowledge of human anatomy, which can ensure safe as well as efficient clinical practice and the human dissection lab could possibly be the ideal place to cultivate humanistic qualities among future physicians. In this manuscript, we discuss the role of dissection itself, the value of which has been under debate for the last 30 years; furthermore, we attempt to focus on the way in which anatomy knowledge was delivered throughout the centuries, from the ancient times, through the Middles Ages to the present. Finally, we document the rise of plastination as a new trend in anatomy education both in medical and non-medical practice.

Key words: anatomy, dissection, medical education, wax modelling, body donation, plastination

1. Introduction

Dissection is indispensable for a correct and comprehensive knowledge of human anatomy which can ensure both safe and efficient clinical practice and the human dissection lab could possibly be the ideal place to cultivate humanistic qualities among future physicians in the 21st century (1, 2). Nevertheless, cultural changes, scientific progress, and new trends in medical education have modified the role of dissection in teaching anatomy in today's medical schools. Towards the end of 20th century dissection was the core basis in medical education. Even today defining the exact anatomical site of a lesion is crucial for a physician to resolve a problem effectively and safely. Therefore, adequate anatomical knowledge is essential for surgeons and anyone performing an invasive procedure on a patient. Anatomical knowledge is also pivotal to complete a medical examination, to make a diagnosis and also to properly communicate with colleagues. To date worldwide curricula reforms, which have resulted in a reduction both in the gross anatomy teaching hours and its context, lead to a serious re-examination of the way in which anatomy is taught (3, 4).

1.1 Human dissection from the Ancient times to the Middle Ages

Human cadaveric dissection has been the primary way of teaching gross anatomy to medical students for centuries. Before any "scientific" autopsies and formal teaching in ancient times were established, an early attempt to explore the inner structure of the human body was made by pre-historic people. This often coincided with invasive interventions such as the cranial trepanations still visible on skulls from the Palaeolithic. Those

traces have sometimes been interpreted as surgical operations, following traumatic or pathological events as would be suggested by the evidence of new bone formation at the margins of the excised area, although purely religious or medico-magical rituals have also been proposed as a valuable explanation (5, 6).

According to Porter (7), the ancient Egyptians were the first people to recognize medicine as a craft; moreover, dissection was more a ritual needed to eviscerate the bodies in the final step of the embalming process, than a scientific procedure being required as a rite of passage to the kingdom of the dead (1, 8): the mummification practices, which required the removal of internal organs, most notably lungs, livers, intestines and stomach, destined to canopic jars (9, 10), failed to provide the ancient Egyptians with an exact anatomical knowledge. As a matter of fact, the embalming process only required a small incision (e.g. a left oblique inguinal one) to remove the viscera and the priests who carried out the process were not primarily interested in studying the extracted organs (5).

The introduction of systematic human cadaveric dissection represented a milestone in the history of medicine: in the 5th century BC, the development of Greek medicine culminated with Hippocrates (c. 460-c. 375), who founded a medical school in Kos (Dodecanese); Herophilus (c. 335-c.280 BC), a disciple of Praxagoras of Kos (born 340 BC), later became a well-respected anatomist of the so-called Alexandria School during the 3rd century BC (11-13) and together with his colleague Erasistratus of Ceos (fl. c. 250 BC), became the first Greek physicians to perform systematic dissections of human cadavers in the first half of 3rd century BC (11), elevating cadaveric dissection to a fundamental tool for learning anatomy. However, after the deaths of Herophilus and Erasistratus, human dissection first decayed in Alexandria and subsequently across the Hellenistic world (13).

After the glorious Alexandrian season, the fall of the Western Roman Empire and the beginning of the Middle Ages, limited advances were made in the study of human anatomy (14); physicians could therefore only follow the works of the eminent figures from past such as Aristotle or Galen, without seriously questioning their scientific validity (15). It was only in the early 14th century that human dissection was revitalized as a tool for teaching anatomy at the University of Bologna (16,17).

Recently, the idea that the Middle Ages were a time of obscurantism and decadence has been revised: the middle-to-late Middle Ages indeed were marked by many scientific accomplishments. Moreover, the late 11th and 12th centuries saw the establishment of a number of universities across Europe, for example in Bologna (1088), Paris (1150), Oxford (1167), Montpellier (1181) and Padua (1222) (15, 18); from the 12th century onwards, the Church did not forbid human dissection in general even if certain restrictions remained: in 1163 a bull by Pope Alexander III (c. 1105-1181) stated the prohibition of clerics being involved in the studies of physical nature; in 1231, Frederick II (1194-1250), Emperor of the Holy Roman Empire, decreed that medical schools were allowed to dissect at least one human body each five years (19) for anatomical studies and attendance was made mandatory for everyone who practiced medicine or surgery (20-22). Only in 1292 did a bull by Pope Nicolas II permitted all doctors having graduated from Bologna to teach at any University in the world (23).

One step forward and one step back, when Pope Boniface VIII (c. 1235-1303) issued a Papal bull entitled "*De sepolturis*" declaring that anybody "cutting up bodies of the dead and boiling them in order to separate the bones" would be excommunicated (15), therefore the post-mortem manipulation of corpses and their reduction to bones might have been partly limited. The bull has often been misinterpreted: it was indeed intended to stop the dismemberment of the cadavers and prohibit the bones trading from soldiers killed during the Crusades. It was not meant to prevent human dissection and in the end the bull did not have any significant impact on the anatomical activities in Italy (24).

The first public dissection was made in 1315 by Mondino de' Liuzzi (1275-1326) the "Restorer of Anatomy" (17), who is considered the first to have followed in the foosteps of after Herophilus and Erasistratus.

The dissected cadaver belonged to an executed criminal, most likely a woman and was observed by medical students and the public with the purpose of showing the exact position of the anatomical elements described by Galen. According to the custom of the

time, Mondino did not perform the dissection himself: a professor, because of his distinguished status, he would sit on a large, elevated chair, above the dissection table, and would read aloud from Galen's works commenting on it to the audience, while a demonstrator attempted to isolate or point the body parts according to the professor's instructions (2, 15, 25).

When a cadaver was made available, time became a capital issue, since there were no means to preserve it. This is why the abdominal cavity, which contained organs that putrefied most easily, was dissected first, followed by thorax, head, and extremities. To prevent putrefaction dissections were scheduled in winter when the weather conditions were more suitable to preserve the organs at best (26-30).

Mondino's book *Anothomia* was completed around 1316 and, due to the clarity of his text, became the reference book in nearly all European medical schools for the next 3 centuries: the structure of the book followed the order of dissection, starting from the abdominal cavity and ending with the head; the specification of the basic elements of organ anatomy, the position in a topographic region of the body, relationship with the surrounding structures, shape, size, texture, parts, physiology, and pathology was made (31).

Moreover, the widely known author of the *Decameron*, Giovanni Boccaccio (1313-1375), in the sixth story of the Fourth Day of his famous novellas, tell us that certain doctors, by order of the *Podestà* (chief magistrate) presumably performed a rudimentary forensic examination on Gabriotto's body to certify the nature of his death and deliver their verdict of cardiac failure (32). Thus, it appears clear that in the Middle Ages autopsies could also be carried out for legal purposes.

1.2 The Renaissance: Anatomical theatres and wax modelling

The first permanent anatomical theatre designed for public anatomical dissections was built by Fabricius ab Aquapendente (1533-1619) at 1594 in the University of Padua. This was followed by the anatomical theatre at the University of Bologna built in 1595 and reconstructed in 1636.

During the Renaissance, anatomy was considered an artistic and spiritual exploration of life, suffering and death. These theatres were everything—a place to understand human anatomy, a place to witness the celebration of life through the analysis of death, and a place to be captivated by science.

Anatomists began to dissect bodies in order to investigate their inner structure and produced texts illustrated with images based on their own "autoptic" dissections (1, 33, 34).

In the 16th century, Andreas Vesalius (1514-1564), a student from Brussels who frequently attended human dissections, decided to investigate the accuracy of the Galenic concepts and made records of his findings (35). In 1537 a day after obtaining his doctoral degree, he became professor of anatomy and surgery and six years later, at the age of 27 years, he finished his masterpiece, *De Humani corporis Fabrica* (36). His work proved a milestone in the history of human anatomy and Vesalius himself changed the face of anatomical studies and teaching with his observational studies of dissected human tissues.

De Humani Corporis Fabrica was the first illustrated scientific work to evoke astonishment and admiration from the scientific community: Vesalius's work translated the exquisite detail and three-dimensional form of the human body onto paper. His work and publications captivated, engaged and educated scholars and students setting the standard for subsequent generations of anatomical publications, research and training (37, 38).

The text and iconography of Vesalius' *Fabrica* had a tremendous influence on medical thinking since its publication in 1543. The reasons were manifold: the visualization of natural and realistic human anatomy rather than theologically-inspired anatomy, the magnificent Renaissance depiction of the human body in different poses and in various stages of the dissection process, the unprecedented use of anatomical terminology, the classification into seven organ systems, and the reaction against the millennia-old Galenic theories (30).

Moreover, during the Renaissance the increasing popularity of anatomy was not confined to physicians or medical students but also involved contemporary artists: Italian Renaissance artists started to perform their own dissections, tightly binding the science of anatomy and the artworks in a *crescendo* that reached

its peak in the work of Leonardo da Vinci (1452-1519) and Andreas Vesalius himself (40).

By the beginning of 15th century, the increasing interest in dissection and anatomy led to shortage of cadavers available. Therefore, medical students taking part in the dissections were charged with an attendance fee and were also required to be at the subsequent funeral of the corpse after dissection to encourage families to offer their loved dead for anatomical studies. Nevertheless, the problem of supply was not perceived as critical because dissection did not become the main teaching tool for learning anatomy during the 15th century (41). In those days the role of dissection was that of an extension of anatomical illustration and its goal was not to add to the existing body of knowledge concerning human anatomy but to help students and physicians remember the text in which the knowledge was contained (42).

Furthermore, the time devoted to dissection was hardly adequate to acquire a command of the discipline by the student and was mainly restricted to wintertime.

By the 17th century, the difficulty in acquiring enough cadavers to meet the growing demand of anatomy students resulted in the need to produce a non-perishable surrogate. The outstanding result was the highly accurate anatomical wax models that were sculpted through direct observation of dissected cadavers: they served as an invaluable substitute for first-hand dissection, as well as stylized, two-dimensional textbook images (43, 44).

In the beginnings, wax was mainly used for votive and *ex voto* images; the first attempts to use injection to preserve anatomical preparations of the human body from deterioration were carried out by the Italian physician Marcello Malpighi (1628-1694). Moreover, the endless *liaison* between wax and anatomy began towards the end of the 17th century when a collaboration between the Sicilian wax artist Gaetano Giulio Zumbo (1656-1701) and the French surgeon Guillaume Desnoues (ca. 1650-1735) resulted in the creation of the first realistic anatomical models made from coloured wax (34).

His successor was Ercole Lelli (1702-1766), whose name is strongly tied to the anatomical chamber in the Academy of Sciences of the Institute of Bologna, sponsored by Prospero Lambertini, Pope Benedict XIV (1675-1758). According to Dacome (45), the anatomy room, was employed in the training of both artists and surgeons; conversely according to other findings (46), the anatomy room clearly evoked the moral tone of the public anatomical lessons held in the Bolognese anatomical theatre and was envisioned as a venue for artistic training rather than medical learning.

Although his entry into the anatomical wax modelling was somewhat of stormy, Lelli created a collection that was unparalleled because of its accuracy: using a technique of sculpting wax musculature upon natural bone, Lelli focused his work on osteology and myology (44): when in 1765 the Neapolitan anatomist Domenico Cotugno (1736-1822) visited him, Lelli introduced his guest to his art: the anatomical statues were built on natural bones, therefore one had to choose the bones of a young and slender body; the bones were then pierced, boiled twice and injected with hot water. After being exposed to the open air, they were finally coated with white wax and tied with metal and hooks (47); Giovanni Manzolini (1700-1755), who served for a period as Lelli's main assistant, would subsequently dye the material on a coloured wax that "imitated the truth" and started modelling on the skeleton.

As a young man, Lelli apprenticed in the workshop of Domenico Brugnoli in Via delle Cavature, where he was well-known as a harquebus maker (45); while he was working at the workshop, he met Giovan Gioseffo Dal Sole and later built a strong friendship with the Bolognese Giampietro Zanotti (1674-1765) who introduced him to the study of anatomy (48). As Zanotti observed, Lelli devoted himself to dissect and reconstruct the origin and the progress of muscles and in order to retain knowledge and remember what he saw dissecting, he made anatomical wax models of the dissected parts (45). By then Lelli started to devote himself to the first project of an anatomical museum launched by Lambertini; a number of anatomical statues were assembled in order to show "the origin and the progress, insertion and direction of the fibre of each muscle so as to acquire the knowledge of its use"(45, 49). Indeed, Lelli's was not the first collection to be acquired by the growing museum, since in 1720 the Institute of Sciences inherited a collection of dry anatomical

specimens by Antonio Maria Valsalva (1666-1723); the entire cabinet was donated to the Institute of Sciences by Valsalva's widow, Elena, shortly after his death.

Lelli worked with other artists/anatomists such as Giovanni Manzolini, Lelli's coworker in the period 1740-1745, and his wife Anna Morandi Manzolini (1714-1774), who was appointed an Anatomy teacher in 1760 (49). Leaving behind complaints, broken collaboration and disappointments occurring between Lelli and his friend, the Bolognese anatomical cabinet was finally completed in 1751.

Ercole Lelli's works represented the artistic gold standard of the Bolognese wax modelling school and his workshop spread and influenced the wax modelling in Italy and all over Europe. The art of anatomical wax modelling spread from Bologna to Florence, where the second great wax modelling workshop was created by Felice Fontana (1730-1805) at the Natural History Museum 'La Specola', probably towards the end of 1771 (50).

According to Ballestriero (43) the Italian anatomical waxes differ from models created in other countries across Europe: Italian waxes are imbued with a real sense of beauty; they are usually refined, pleasant, and everything that could provoke repulsion or disgust in the viewer is removed; specimens from northern countries instead are usually more realistic, almost brutal, preferring anatomical accuracy rather than artistic flair and are intended for use exclusively by the medical world.

1.3 Towards the 21st century: the modern era

The role of dissection and the teaching of anatomy evolved during the second half of the 20th century: traditional anatomy education based on topographical structural anatomy taught in lectures and in gross dissection classes, has been recently replaced by a multiple range of study modules, including problem-based learning, plastic models and/or computer-assisted learning and curricula integration. Dissection and light microscopy are in fact not problem-free: storing human bodies is expensive and may display logistical problems due to the lack of space or and other issues such as preservation, staff costs and as well as furniture and equipment.

History repeats itself and in the modern era as well as between the 15th and the 17th centuries, one of the main problems in the teaching of anatomy is therefore the shortage of cadavers available as well as the increasing staff and equipment costs. Moreover, dissection and prosection have also issues concerning ethical convictions and legal restrictions. Once more these two factors led to alternative methods for teaching anatomy resulting in new preservation techniques and technological tools based on the imaging such as plastination and 3D-printing (51, 52). 3D-dissection/virtual dissection units and body donation programmes.

In the biomedical context, the dead human body is a crucial resource in teaching, research and training: many universities around the world have dissection labs and body donations programs even if the availability of donated human bodies for training and research purposes is not free of ethical, legal and even religious issues. Therefore, the acquisition of deceased human bodies as a scientific tool had to be managed carefully.

Nevertheless, although body donation for scientific purposes requires careful ethical consideration, it can also be argued that there is a more general "human objection" to dissection involving, for example, bodies whom the dissector could be familiar with either by personal, social, racial or even religious background (53).

Over the centuries, the sources of bodies changed from executed criminals, to "unclaimed bodies", to donated bodies and although the ethical issues concerning the use of unclaimed bodies still exist in some Universities worldwide (54), even regulated body donation programs might warn ethical and even legal uncertainties.

Usually the legal situation concerning body donation programs is regulated by different local laws based either on burial or transplantation laws. Finally, it should be mentioned that in contrast to research on living human beings, research on human cadavers is not yet regulated internationally.

Anatomists and body donation programs have to handle the dead body physically: in this context we can consider the human cadaver simply as research material, a condition that does not have any ethical implication; nevertheless, most people properly ascribe dignity to the donated body extending honours from the living persons to her/his mortal remains. Even today, just as during the

15th century, most modern body donation programs include a thanksgiving ceremony at the presence of the deceased's relatives special guests and students during the Memorial Services and thought Memorials gardens.

> "*As students of human anatomy in the health sciences, we wish to acknowledge formally in this Act of Recognition, our gratitude for the gifts of human bodies and our respect for those people who have generously bequeathed their mortal remains so that we may study and understand.*
> *We also recognise that there is something special about this material, that each of these bodies represents the tangible remains of a person with a living history of growth from childhood, of a rich and varied life story, of health and illness, of joy and sadness, of human relationships, of intellectual and spiritual achievement*" (55).

Moreover, as a result of the present era of E-learning", computer animation and 3D-printing, some anatomists suggested to substitute gross dissection classes with the more modern techniques partially or completely (56). Others defend traditional practise; for both perspective, these experiences are irreplaceably important (57). A good balance might be the use of virtual dissection tables, such as for example the *Anatomage Table*. This virtual dissection table has both complete male and female anatomy; the images are consistent for colour and shape and can be sectioned and tissues can be sliced as well. According to Nambiar and Moro, this novel technology could be comparable to traditional dissection sessions in neuroanatomy and could be included in undergraduate curricula in medical schools as a further teaching tool to improve anatomy learning and retention among student (58).

Plastination, created by Gunther Von Hagens, was an innovation in the anatomy laboratory at Heidelberg University in Germany in 1978 (59, 60). It is currently used in both teaching and research and according to some findings it may be considered a furtherance of the wax modelling practice (44, 49). This preservation technique has changed the ability of people not from the anatomy field to see the human body, and there are exhibitions of plastinated bodies and body parts around the world (called Body- Worlds), resulting in the concept of "anatomical art" (61). Not surprisingly, there are different opinions about exhibits like BodyWorlds (11, 62).

Over the past 20 years plastination has made its way into anatomy departments, principally as an additional teaching tool. The technique has begun to revolutionize the way in which the human body can be presented to students; the development of plastination has opened up new vistas for gross anatomy. In particular, it has led to a major expansion in the range of human anatomic specimens available for teaching and its potential value in research is increasingly being appreciated.

Thiel embalming fluid contains formaldehyde in a very low concentration, along with glycol, water and various salts, and hence is safer than a traditional embalming medium. Following the embalming process, the tissue is preserved without the need for refrigeration or special storage facilities suggesting that Thiel cadavers may be suitable for use in a broad range of medical skills and human factors training; furthermore, the issues traditionally associated with cadaveric dissection, such as disturbing odour, ethical constraints and cost, are definitely more affordable using Thiel cadavers. Moreover, the anatomical accuracy and fidelity of tissue properties were rated highly; according to a recent study by Yiasemidou and coworkers, organ and tissue realism are truly excellent with the exceptions of brain, eyes and blood vessels (63).

2. Discussion

Anatomy is essential to the health and medical professions: by learning anatomy, medical students learn about the structure of the human body, providing them with the basic tools needed for understanding pathology and clinical problems.

According to Estai and Bunt (64) plastination can be considered a specialized way of preserving prosections and nowadays many anatomists favour plastinated specimens over formalin fixed material, because they are odourless, allow convenient storage, and ease of handling. Moreover, plastinated specimens can be carried out using low cost equipment which is readily available in most anatomy departments (65). Previous studies

showed that plastinated specimens were deemed useful by students and accommodated their needs at various levels (66, 67). However, plastination is not free of disadvantages: it shows the most common variations, in time, plastinated sections lose their novel character and eventually students master the exposed variations by heart (68). Wax models were widely used before photography was introduced in the medical teaching and provide students with a three-dimensional vision of human structures otherwise barely comprehensible if solely learnt from books. Moreover, it could be used for understanding structures of normal and pathological anatomy and ceroplastic collection are currently used in some medical courses for undergraduate students.

Hence, we strongly suggest that anatomy be vertically vertically integrated into medical education so that dissection and prosection may raise to a prominent position; nevertheless, it is also undoubtedly true that it is necessary to examine the curriculum, the way of teaching, the quality of how it is delivered, and the infrastructure within which it takes place, for optimal and proficient tailoring of anatomy teaching and learning material. Of course, integration is also comprehensive of the new digital resources available. In the past two decades, the "digitalisation" of anatomy has profoundly influenced the field of anatomy education (69, 70). Students have now several digital programs (such as Anatomedia, Complete Anatomy, Biodigital Human and so on) that can reproduce 3D structures in a detail manner with the possibility of substantial manipulation of the specimen examined (rotation, virtual dissection,etc). We welcomed this helpful resource to the anatomy teaching armamentarium and we feel that these new tools are useful and complementary to the more traditional methods used in teaching anatomy. In this regard, recent publications have timely assessed the efficacy of the various methods used for teaching and learning anatomy. Three large and careful meta-analysis of the previous literature (71, 72) in the field reached a somewhat surprising conclusion that dissection was neither better neither worse in regard to short term anatomy recall ability. The useful and substantial impact of the digitalisation was also acknowledged (72) and subjects engaged in more innovative pedagogies such as student-centred learning and computer-aided instruction outperformed more classically trained students (72). Of note, these data are valid only for short term retention (72, 73) and we do not know the validity of the methods used for long term retention. Furthermore, at this stage and with this data it is not possible to clearly assume if some special cohort of student (such as Medical students) are favoured by classical tools (dissection) vs modern tools. We strongly suggest that the best anatomy teaching practice is a careful adaptation of resources and methods in a realistic integrated scenario (dissection if possible, plasinated specimens, digitalisation, 3D models, Student centred and computer aided learning). Citing Bergman (74) " *there is no single method that can function as an answer for how anatomy should be taught. ....it is not about the method you are using, but about how you are using it*."

3. Conclusions

We suggest that the study of ceroplastic and plastinated models should be reconsidered as an integral tool in expanding students' understanding of human anatomy. In addition, plastinates are essential to complement the traditional dissection courses and contribute to a better preparation of postgraduates and clinicians. Lastly, careful integration with the new available pedagogies and with the new computer tools is warranted and helpful in setting the best practice of anatomy teaching.

4. Acknowlegments

All authors declare that there have been no involvements that might raise the question of bias in the work reported or in the conclusions, implications, or opinions stated. This research did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

5. References

1. Papa V, Vaccarezza M, Liston R. Teaching Anatomy in the XXI Century New Aspects and Pitfalls Sci World J. 2013.
2. Ghosh SK. Human cadaveric dissection: a historical account from ancient Greece to the modern era. Anat Cell Biol. 2015;48(3):153-69.
3. Bergman EM, Prince KJAH, Drukker J, van der Vleuten

CPM and Scherpbier AJ. How much anatomy is enough? Anat Sci Educ. 2008;1(4):184-88.
4. Craig S, Tait N, Boers McAndrew. Review of anatomy education in Australian and New Zealand medical schools. ANZ J Surg. 2010;80:212-6.
5. Habbal O. The Science of Anatomy: A historical timeline. Sultan Qaboos Univ Med J. 2017;17(1):e18-22.
6. Hershkovitz I. Trephination: The earliest case in the Middle East. Mitekufat Haeven jounal Isr Prehist Soc. 1987;128-35.
7. Porter R. The Greatest Benefit to Mankind: A Medical History of Humanity. WW Norton Company. New York, NY USA; 1999.
8. von Staden H. Herophilus—The Art of Medicine in Early Alexandria,. Cambridge University Press, Cambridge, Mass, USA.; 2004.
9. Eppenberger PE, Cavka M, Habicht ME, Galassi FM, Rühli F. Radiological findings in ancient Egyptian canopic jars: comparing three standard clinical imaging modalities (x-rays, CT and MRI). Eur Radiol Exp. 2018; 20(2):12.
10. Galassi F, Habicht M, Bouwman A, Rühli F. The Canopic Jar Project: Interdisciplinary Analysis of Ancient Mummified Viscera. CIPEG J Anc Egypt Sudan Collect Museums 2017;1:75-79.
11. Elizondo-Omaña RE, Guzmán-López S, De Los Angeles García-Rodríguez M. Dissection as a teaching tool: Past, present, and future. Anat Rec - Part B New Anat. 2005;285(1):11-5.
12. Serageldin I. Ancient Alexandria and the Dawn of Medical Science". Glob Cardiol Sci Pr. 2013;(4):395-404.
13. von Staden H. The Discovery of the Body: Human Dissection and Its Cultural Contexts in Ancient Greece. Yale J Biol Med. 1992;65(3):223-41.
14. Numbers R. Galileo Goes to Jail and Other Myths about Science and Religion. Cambridge, Massachusetts & London, England: Harvard University Press; 2009. 45 p.
15. Mavrodi A, Paraskevas G. Mondino de Luzzi: a luminous figure in the darkness of the Middle Ages. Croat Med J. 2014;55(1):50-3.
16. Gregory S, Cole T. Msjama. The changing role of dissection in medical education. JAMA. 2002;287(9):1180-1.
17. Rengachary S, Colen C, Dass K, Guthikonda M. Development of Anatomic Science in the Late Middle Ages: The Roles Played by Mondino de Liuzzi and Guido Da Vigevano. Neurosurgery. 2009;65:787-93.
18. Siraisi N. Medieval and Early Renaissance Medicine: An Introduction to Knowledge and Practice. Chicago: The University of Chicago Press; 1990.
19. Pilcher L. The Mondino Myth. Med Libr Hist J. 1906;4(4):311-31.
20. Somerville R. Pope Alexander III and the Council of Tours (1163): A Study of Ecclesiastical Politics and Institutions in the Twelfth Century. The University of California Press, Berkeley.; 1977.
21. Persaud T. Early History of Human Anatomy: From Antiquity to the Beginning of the Modern Era. Springfild: Charles C. Thomas S, editor. 1984.
22. Aufderheide A. The Scientific Study of Mummies. Cambridge University Press, Cambridge.; 2003.
23. Walsh J. The Popes and the History of Anatomy. Med Libr Hist J. 1904;2(1):10-28.
24. Park K. The Criminal and the Saintly Body: Autopsy and Dissection in Renaissance Italy. Renaiss Q. 1994;47(1):1-33.
25. Di Matteo B, Tarabella V, Filardo G, Mosca M, Lo Presti M, Viganò A, et al. Art in Science: Mondino de' Liuzzi: The Restorer of Anatomy. Clin Orthop Relat Res. 2017; 475(7):1791-5.
26. Goff ML. Early postmortem changes and stages of decomposition. In: Current Concepts in Forensic Entomology. 2010.
27. Goff ML. Early post-mortem changes and stages of decomposition in exposed cadavers. Exp Appl Acarol. 2009; 49(1-2): 21-36.
28. Hau TC, Hamzah NH, Lian HH, Amir Hamzah SPA. Decomposition process and post mortem changes: Review. Sains Malaysiana. 2014; 43(12): 1873-82.
29. Mann RW, Bass WM, Meadows L. Time Since Death and Decomposition of the Human Body: Variables and Observations in Case and Experimental Field Studies. J Forensic Sci. 2015 Aug 12;35(1):12806J.
30. Vass A. Beyond the grave - understanding human decomposition. Microbiol Today. 2001; 28:190-193
31. Crivellato E, Ribatti D. Mondino de' Liuzzi and His Anothomia: A Milestone in the Development of Modern Anatomy. Clin Anat. 2006;19(7):581-7.
32. Toscano F, Spani G, Papio M, Rühli FJ, Galassi FM. A Case of Sudden Death in Decameron IV.6: Aortic Dissection or Atrial Myxoma? Circ Res. 2016;119(2):187-9.
33. Porter R. Blood and Guts. A Short History of Medicine. Penguin Press, New York.; 2002.
34. Richardson R. Death, Dissection and the Destitute. University of Chicago Press, Chicago.; 2000.
35. Heseler B, Eriksson E. Andreas Vesalius' First Public Anatomy At Bologna 1540: An Eyewitness Report. Almqvist & Wiksells, Uppsala.; 1959.
36. Garrison D, Hast M. The Fabric of the Human Body: An Annotated Translation of the 1543 and 1555 Editions of De Humani Corporis Fabrica Libri Septem. Karger Publishers, Basel.; 2013.
37. Mazzotti G, Falconi M, Teti G, Zago M, Lanari M, Manzoli FA. The diagnosis of the cause of the death of Venerina. J Anat. 2010;216(2):271-4.
38. McLachlan J, Patten D. Anatomy Teaching: Ghosts of the Past, Present and Future. Med Educ. 2006;40(3):243-53.
39. Van Hee R, Wells F, Ballestriero R, Richardson R, Mazzarello P, Cani V, et al. The Art of Human Anatomy: Renaissance to 21st Century. Vesalius. 2014;20(1):25-9.
40. Sellmer R. Anatomy during the Italian Renaissance: A Brief History of How Artists Influenced Its Development.". In: The Whitelaw WA C, editor. In The Proceedings of the 10th Annual History of Medicine Days.; 2001.
41. Park K. The Life of the Corpse: Division and Dissection in Late Medieval Europe. J Hist Med Allied Sci. 1995;50(1):111-32.

42. French R. Dissection and Vivisection in the European Renaissance. Ashgate A, editor. 1999.
43. Ballestriero R. Anatomical models and wax Venuses: Art masterpieces or scientific craft works? J Anat. 2010;216(2):223-34.
44. Maraldi NM, Mazzotti G, Cocco L, Manzoli FA. Anatomical waxwork modeling: The history of the Bologna Anatomy Museum. Anat Rec. 2000;261(1):5.
45. Dacome L. Malleable Anatomies: Models, Makers, and Material Culture in Eighteenth-Century Italy. Orford University Press, Oxford.; 2017.
46. Messbarger R. The Lady Anatomist. Chicago University-Press, Chicago. Chicago University Press, Chicago.; 2010.
47. Cotugno D. Iter Italicum Patavinum. 1765.
48. Botteri G, Ticozzi S. (1982) Raccolta Di Lettere Sulla Pittura, Scultura Ed Architettura Scritte Da Personaggi Celebri Dei Secoli XV, XVI e XVII. Silvestri G, editor. Milanno; 1982.
49. Galassi FM, Ruggeri A, Petti K, Ashrafian H. Marvels of the Bologna Anatomical Wax Museum: Their Theoretical and Clinical Importance in the Training of 21st Century Medical Students. HAPS Educ. 2015;19(2):4-9.
50. Azzaroli M. La Specola. The Zoological Museum of Florence University. In: La Ceroplastica Nella Scienza e Nell'arte Atti Del I Congresso Internazionale. Leo S. Olschki Editore, Florence.; 1977.
51. Garas M, Vaccarezza M, Newland G, McVay-Doornbusch K, Hasani J. 3D-Printed specimens as a valuable tool in anatomy education: A pilot study. Ann Anat. 2018;219:57-64.
52. Vaccarezza M, Papa V. 3D printing: a valuable resource in human anatomy education. Anat Sci Int. 2015;90(1): 64-65.
53. Winkelmann A. Consent and consensus—ethical perspectives on obtaining bodies for anatomical dissection. Clin Anat. 2016; 29(1):70-7.
54. Jones DG, Whitaker MI. Anatomy's use of unclaimed bodies: Reasons against continued dependence on an ethically dubious practice. Clinical Anatomy 2012;25(2):246-54.
55. UWA Body donation program.
56. Sbayeh A, Qaedi Choo MA, Quane KA, Finucane P, McGrath D, O'Flynn S, et al. Relevance of anatomy to medical education and clinical practice: perspectives of medical students, clinicians, and educators. Perspect Med Educ. 2016;5(6):338-46.
57. Gamlin C, Womersley K, Taylor L, Fay I, Brassett C, Barclay S. "Can you be a doctor, even if you faint?" the tacit lessons of cadaveric dissection. Psychiatr Danub [Internet]. 2017;29:S247-53. Available from: http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L618463970
58. Periya SN, Moro C. Applied learning of anatomy and physiology: virtual dissectiontables within medical and health sciences education. Bangkok Med J. 2019;15(1):121-127
59. von Hagens G, Tiedemann K, Kriz W. The current potential of plastination. Anat Embryol (Berl). 1987;175(4):411-21.
60. Eisma R, Lamb C, Soames RW. From Formalin to Thiel Embalming: What Changes? One Anatomy Department's Experiences. Clin Anat. 2013;26(5):564-71.
61. Jones DG. Re-inventing anatomy: The impact of plastination on how we see the human body. Clin Anat. 2002;15(6):436-40.
62. Wetz F. The Dignity of Man. Von Hagens G, Editor. Anatomy Art: FascinaTion beneath the Surface. Catalogue on the Exhibition. Heidelberg: Institute for Plastination; 2000.
63. Yiasemidou M, Roberts D, Glassman D, Tomlinson J, Biyani S, Miskovic D. A Multispecialty Evaluation of Thiel Cadavers for Surgical Training. World J Surg. 2017;41(5):1201-7.
64. Estai M, Bunt S. Best teaching practices in anatomy education: A critical review. Ann Anat 2016;208:151-7.
65. O'Sullivan E, Mitchell B. Plastination for gross anatomy teaching using low cost equipment. Surg Radiol Anat. 1995;17(3):277-281.
66. Latorre R, García-Sanz M, Moreno M, Hernández F, Gil F, López O, et al. How useful is plastination in learning anatomy? J Vet Med Educ. 2007;34(2):172-176.
67. Fruhstorfer B, Palmer J, Brydges S, Abrahams P. The use of plastinated prosections for teaching anatomy - the view of medical students on the value of this learning resource. Clin Anat. 2011;24(2):246-252.
68. Korf H, Wicht H, Snipes R, Timmermans J, Paulsen F, Rune G, et al. The dissection course-necessary and indispensable for teaching anatomy to medical students. Ann Anat. 2008;190(1):16-22.
69. Murgitroyd E, Madurska M, Gonzalez J, Watson A. 3D digital anatomy modelling - Practical or pretty? Surgeon. 2015;13(3):177-80.
71. Trelease RB. From chalkboard, slides, and paper to e-learning: How computing technologies have transformed anatomical sciences education. Anat Sci Educ. 2016; 9(6):583-602.
71. Losco CD, Grant WD, Armson A, Meyer AJ, Walker BF. Effective methods of teaching and learning in anatomy as a basic science: A BEME systematic review: BEME guide no. 44. Med Teach. 2017;39(3):234-43.
72. Wilson AB, Brown KM, Misch J, Miller CH, Klein BA, Taylor MA, et al. Breaking with Tradition: A Scoping Meta-Analysis Analyzing the Effects of Student-Centered Learning and Computer-Aided Instruction on Student Performance in Anatomy. Anat Sci Educ. 2019;12(1):61-73.
73. Vaccarezza M. Best evidence of anatomy education? Insights from the most recent literature. Anat Sci Educ. 2018;11(2):215-6.
74. Bergman EM. Discussing dissection in anatomy education. Perspect Med Educ. 2015; 5(4):211-213.

Correspondence:
Dr. Veronica Papa
Department of Motor Sciences and Wellness,
University of Naples "Parthenope",
80132, Napoli NA, Campania, Italy.
E-mail: veronica.papa@uniparthenope.it