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The anatomical wax collection at the University of Bologna: bridging the gap between tradition and scientific innovation

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Abstract. The "Luigi Cattaneo" Anatomical Wax Collection belongs to the network of Museums and Collections of the University of Bologna. It is closely related to the Anatomy Centre of the Department of Biomedical and Neuromotor Sciences of the University of Bologna, and holds a significant place in the history of medicine, art, and scientific innovation. This review explores the museum's rich historical background, its cultural importance, and its role in promoting the encounter between the past and the present. Preserving the legacy of anatomical wax modelling, the museum adapts to modern education and to research needs. It bridges artistic expression and scientific knowledge, emphasizing the importance of art as a tool of medical education. In this context, augmented reality, 3D models, CT scan and new methods of communication, integrate tradition and progress, expanding anatomical exploration. As part of the University of Bologna, the Collection catalyzes interdisciplinary collaboration, unlocking new scientific avenues. It works as a bridge through time, uniting craftsmanship, exploration, and knowledge-seeking in the study of the human body.

Keywords: wax collection, Anatomy Centre, tradition, innovation, education, human body.

INTRODUCTION

Museums of anatomy and pathology hold significance in preserving anatomical specimens and their high-quality reproductions, as well as their role in education and research (Mariño Gutierrez et al., 2019). Although museums experienced a moment of great prosperity in the eighteenth century, they were characterized by a progressive decline and a dramatic loss in the following historical period. Nevertheless, there is currently an increasing interest in revitalizing and acknowledging the importance of these collections, especially thanks to the development of anatomical teaching in medical education and its relevance in the advancement of medical research. The "Luigi Cattaneo" Anatomical Wax Collection, belonging to the network of

Museums and Collections of the University of Bologna, fits perfectly in this cultural context. It is based in the historical institute of Human Anatomy of the University of Bologna, today known as Centre of Clinical Surgical Experimental and Molecular Anatomy (Anatomy Centre). It is formed through the merger of two pre-existing collections and showcases the artistic and scientific legacy of wax modelling in the study of human anatomy and pathology. Its anatomical collection includes wax models, natural bones, dry and platinated preparations, mummified and formalin-preserved specimens. These models illustrate the various conservation techniques of the human body, from the antique mummification process to the contemporary plastination technique.

Anatomical wax modelling has an ancient origin but rose to prominence in fourteenth century in Italy with the cult of votive artefacts. With the advent of Neoclassicism, this art continued to survive in scientific fields (Ballestriero, 2010). The primary goal of wax modelling art was to effectively communicate the discoveries that had made anatomy the most advanced of the biological sciences (Riva et al., 2010). Indeed, the need to show the true nature of the human body and its pathologies in the most realistic way possible, prompted medical science academics to enlist the help of different artists, in order to create three-dimensional drawings and models. This signaled both an educational-scientific and aesthetic value and gave rise to an intense and fruitful collaboration between anatomists and artists, sanctioning the meeting between science and art.

Therefore, this review focuses on the collection's historical background and highlights its cultural significance, while emphasizing the incorporation of scientific innovation in providing an immersive educational experience. Consequently, the museum represents a testament to the enduring connection between art and science.

1. HISTORICAL BACKGROUND

Interest in anatomical wax models spread throughout Europe during the eighteenth century (Pastor et al., 2016), first in Bologna with Ercole Lelli (1702-1776), a talented artist with a great interest in anatomy, Giovanni Manzolini (1700-1755) and Anna Morandi (1714-1774), spouses anatomists and experts in wax modelling, and then in Florence with Felice Fontana (1730-1805) and Clemente Susini (1757-1814) (Ballestriero, 2010). Indeed, wax is a malleable material that has been used for different purposes since ancient times by Egyptians, Greeks and Romans and throughout the centuries many anatomical artists used wax modelling due to the remarkable mimetic likeness obtained, far surpassing any other substance (Rodriguez and Parish, 2020). This material is particularly flexible, easy to color, and it can be decorated using organic tools such as body hair, hair, teeth and nails. With the beginning of Neoclassicism these characteristics made the realistic nature of wax models seem repulsive, and the practice of artistic ceroplastics started a slow decline. Moreover, religious authorities began to discourage the worship of saints and votive offerings and many of the most talented votive artists moved toward anatomical ceroplasty (i.e. Susini). However, despite the disappearance of the use of wax modelling techniques from an artistic point of view, there was a notable growth in its use for educational and scientific purposes for the study of normal and pathological anatomy, obstetrics, veterinary medicine, zoology and botany (Ballestriero, 2010). During the Renaissance, the new scientific interest in anatomy motivated artists and physicians to study post-mortem bodies. In this context, wax again proved to be the most suitable material to meet the needs of artists considering the extreme difficulty in finding usable corpses and the understandable unwillingness to dissect and examine unpreserved dead bodies. Indeed, only later it was found the way to preserve the cadaver for investigative and teaching purposes. Therefore, for a long time, wax was considered a necessary alternative method capable of providing an accurate reproduction of the various organs of the human body.

2. CULTURAL IMPORTANCE

The Luigi Cattaneo Anatomical Wax Model Collection, inaugurated in 2002, represents the result of the merger of two separate display sections previously existing in the Institutes of Human Anatomy and Pathological Anatomy (Figure 1). It shows a rich collection of anatomical preparations and wax models dating back to the nineteenth century, most of them concerning pathological anatomy. With the nineteenth century, in fact, the demonstrative spaces of ceroplasty expanded to new fields of medical knowledge. From normal anatomy they moved on to pathological anatomy and the depiction of clinical manifestations of multiple morbid pictures. The creation of pathological models was thus the logical consequent development of the success of models devoted to normal anatomy. Once again, life-like appearance of the anatomical waxes, resembling human flesh, were able to blurs the lines between a real body and a representation illustrating pathological malformation. According to the "*modus operandi*" of the Bolognese School, these specimens were arranged in the Anatomical Cabinet in

Figure 1. Anatomical Wax Collection "Luigi Cattaneo". Detail of the sign above the entrance commemorating Ercole Lelli, the founder of the Bolognese Ceroplastic School.

order to realistically reproduce the pathological cases observed during autopsies and dissections. They usually represented supporting material to research articles that were read and discussed in front of the scientific community. Indeed, these materials on clinical cases became a powerful tool in the pursuit of educational and scientific aims. From this point of view, the Collection is an example of how ceroplastics took on particular value in the nineteenth century for the dissemination of scientific and artistic culture.

The achievement of having made known the use of wax modelling as a teaching aid for human anatomy is generally attributed to the Sicilian abbot Gaetano Giulio Zummo (1656–1701) better known as Zumbo (Riva et al., 2010; San Juan, 2018). He was succeeded by the previously mentioned Ercole Lelli, founder of the Bolognese Ceroplastic School, who was commissioned to create an anatomical collection of models made of durable material (Maraldi et al., 2000). This artist considered the knowledge of human anatomy essential to characterize the language of the human body. Among his activities, he produced a wax model of two kidneys joined at the lower end ("horseshow" kidneys), which had been discovered during a "public dissection" (Riva et al., 2010). Tables showing colored wax models of normal kidneys and horseshow ones, are preserved in Palazzo Poggi Museum in Bologna and definitively won over the academicians of the Institute of Science. He also realized the so-called *notomie,* statues of skinned bodies, in clay, wood and wax (Cushing, 1937). Their anatomical perfection, obtained through a careful representation of post-mortem bodies used for dissection, served as a reference model for the study of anatomy. In this way, the foundations for the art of wax modelling of anatomical preparations for medical practice studies at the University of Bologna, were laid (Maraldi et al., 2000). Subsequently, other artists' wax models, dating back to the eighteenth century, and mainly the Anna Morandi's works, the first Italian female anatomist and ceroplastic artist, were well-recognized all over Europe and are now exposed and Palazzo Poggi Museum (Rosito et al., 2004).

Among the works belonging to the collection and hosted in the Anatomy Centre of the Department of Biomedical and Neuromotor Sciences of the University of Bologna, of notable interest is the collection of over two thousand skulls (Figure 2) belonging to the Bolognese anatomist Luigi Calori (1807-1896) (Galassi et al., 2016). This collection testifies the important development in the anthropological studies for the human racial classification in the first half of the nineteenth century.

Moreover, the museum's collection includes pigmented beeswax models of normal and pathological anatomy created by other important ceroplastic artists of the late eighteenth and nineteenth centuries, belonging to the Florentine or Bolognese wax sculpture school: Clemente Susini, Giuseppe Astorri (1785-1852) and Cesare Bettini (1801-1885). Wax modelling was basically a craft technique and each school adopted modifications and variations of the original method. The Florentine School, represented by Clemente Susini, differentiates itself for the use of wax reinforced by iron and wood supports and for the creation of plaster molds for mass production. Instead, the Bolognese School shaped the wax models using real bones (Manzoli et al., 2022). In this context, wax models became valuable tools for medical education, providing a tangible representation of the human body's intricate structures. During the Enlightenment period, anatomical wax models gained recognition not only for their educational value but also for their artistic merit. Artists meticulously crafted lifelike representations of human anatomy, joining science and art. This fusion of disciplines helped elevate anatomical wax modelling to a form of scientific artistry.

It is also appropriate to underline the importance that wax models had in medical education and public outreach through the representation of both authentic and simulated smallpox pustules in humans and cows, of which the Luigi Cattaneo Collection preserves two models (Figure 3) (Zampieri et al., 2011). These ones were aimed at educating not only doctors but also a wider audience of health professionals. This historical

Figure 2. Collection of skulls. Professor Luigi Calori's collection of skulls hosted at the Anatomy Centre of the Department of Biomedical and Neuromotor Sciences of the University of Bologna.

Figure 3. Wax model of smallpox pustules created with didactic and diagnostic purposes. The model is part of the "Luigi Cattaneo" Anatomical Wax Collection closely related to the Anatomy Centre of the Department of Biomedical and Neuromotor Sciences of the University of Bologna.

context underscores the enduring importance of wax models as effective tools for medical education and the broader communication of critical health information.

A perfect example of the "*modus operandi*" followed by anatomists and pathologists of the Bolognese School in the nineteenth century, is represented by the clinical case described by Cesare Taruffi (1821–1902), the first professor of Pathological Anatomy at the Bologna School of Medicine (Quaranta et al., 2020). In a scientific paper he reported the case of a man with pronounced prognathism and skeletal deformities, an unrecognized case of acromegaly. As anticipated, to fully describe clinical cases to the scientific community, anatomists and professors typically used to prepare dried anatomical specimens and create tables, engravings, and wax replicas. All Taruffi's examined samples currently reside at the 'Luigi Cattaneo' Anatomical Wax Collection in Bologna (Quaranta et al., 2020). Because of his observations of craniofacial and skeletal deformities, Prof. Taruffi's article is often cited as a scientific contribution to the origin of the definition of acromegaly in the era preceding Pierre Marie (the one who for first introduced the term acromegaly) (Mammis et al., 2010; Pearce, 2006). This fact underlines the cultural importance that wax samples could have in the anatomical-scientific field. All in all, the models present in the Anatomical Wax Collection in Bologna, reflect the evolution of anatomical understanding, capturing the scientific and artistic perspectives of their time. Preserving this anatomical, technical, and educational heritage allows for an appreciation of the contributions made by early anatomists and artists to the field of medicine. Indeed, independent of the material used, whether wood, wax or clay, which varied according to the periods and the different workers, anatomical models were always considered merely craft works confined to hospitals or faculties of medicine

and have survived to this day because of their scientific interest (Manzoli et al., 2022).

3. SCIENTIFIC INNOVATION AND LEAP INTO THE MODERN ERA, PRESERVING TRADITIONS

The encounter between past, present and future is fundamental to the educational mission of the Anatomy Centre of the Department of Biomedical and Neuromotor Sciences of the University of Bologna, to which the Anatomical Wax Collection is closely related. Just as cultural vicissitudes and new trends in medical education had changed the role of dissection as a method of teaching anatomy in medical schools in the past, giving way to wax models and plastination, scientific progress has inevitably changed also the role of these last techniques (Papa and Vaccarezza, 2013; Ghosh, 2015). In the museum context, while the wax models continue to retain their historical charm, the need for the integration of modern technologies is increasingly evident, not only to improve the visitor experience, but also to complement the classes of dissection of modern medical and surgical students. Interactive laboratories, virtual reconstructions, and multimedia presentations provide a bridge between the past and the present, allowing for a comprehensive exploration of human anatomy and pathologies, involving not only medical students or people belonging to the scientific community, but also kids of all ages and their families. Indeed, the Anatomy Centre continuously adapts to incorporate innovative teaching methodologies. Traditional wax models are nowadays supplemented with tools based on the combination of augmented reality (AR) technologies and tangible 3D printed models that can be studied and manipulated by students/trainees, thus favoring a three-dimensional and topographical learning approach (Cercenelli et al., 2022). These advancements offer students and researchers new ways to study and comprehend the complexities of the human body (Ma et al., 2016). Indeed, several recent studies have reported the positive effects of using AR in medical training, with increased learner immersion, a higher engagement and a better perception of the studying time (Cercenelli et al., 2022).

Consequently, incorporating AR into medical education alongside traditional methods might prove advantageous for students' academic and future professional activities (Neri et al., 2024). Therefore, the presence of the collection inside the Anatomy Centre fosters collaborations between anatomists, clinicians, and researchers, continuously bringing to light new forms of communication in the medical and scientific fields.

The Centre recently obtained funding from the European Union for the purchase of a Computed Tomography (CT) tool. The challenge is to apply modern morphological and structural investigation techniques to the materials collected in the museum, opening up new perspectives in the enhancement of this historical and scientific heritage, in terms of both better knowledge and dissemination and recovery of the educational role of the waxes (Figure 4). Imaging techniques in medicine have evolved with great rapidity and innovative solutions and, in this context, CT is planned to be applied to the examination of the museum's anatomical waxes. The incorporation of a CT scanner within the museum's conservation toolkit stands as a significant advancement in the preservation and dissemination of historical artefacts. This sophisticated equipment plays a pivotal role in the digitalization of museum items, thereby aiding in their conservation. By converting physical objects into high-resolution digital forms, the CT scanner ensures that these cultural treasures are preserved for posterity, while simultaneously reducing the need for physical handling, which can often lead to deterioration. Furthermore, this technological adaptation extends the reach of the museum's collection, allowing a broader audience to access and appreciate these artefacts in their digital form, democratizing access to cultural heritage. Additionally, the CT scanner's ability to perform extensive material analysis unveils intricate details of the artefacts, offering insights into their composition, construction, and historical context. Such detailed examination enriches the understanding of these items, enhancing both scholarly

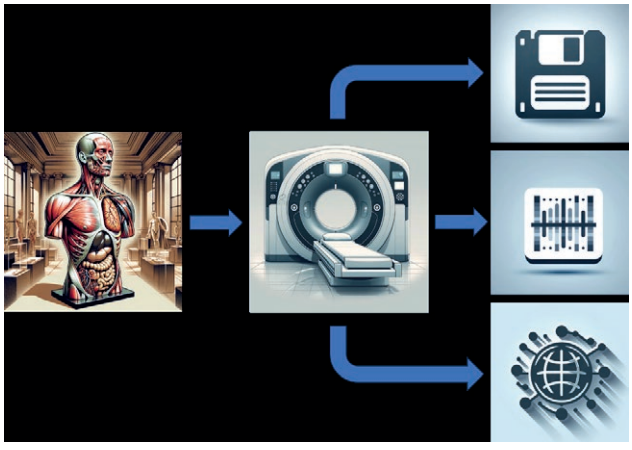

Figure 4. Use of Computed Tomography (CT) tool. Reconstructing anatomical models through CT scans results in a virtual representation, providing insights into the various techniques used and contributing to the development of a multi-level accessible virtual museum project.

research and the general public's engagement with the museum's collection. Altogether, the CT scanner emerges as an invaluable asset, revolutionizing the way museums conserve, share, and study historical artefacts (Peccenini et al., 2015; Tian et al., 2022, Maher, 2020).

Nevertheless, in an era where modern technologies offer increasingly precise alternatives to traditional bodies' dissection, preserving the age-old practice of examining post-mortem bodies remains crucial. Since 2013, a whole body donation program was set up at the Institute of Human Anatomy of the University of Bologna (De Caro et al., 2021) and in February 2020 the law n. 10/2020 entitled "Rules on the disposal of one's body and post-mortem tissues for the purposes of study, training, and scientific research" was approved, and the Institute was appointed National Reference Centre for body donation by the Ministry of Health (Orsini et al., 2021b). The dissection rooms located within the Centre (Figure 5), playing the role of modern "surgical theatres", ensure ongoing clinical education and training through the use of both traditional gross anatomy and innovative technology (Orsini et al., 2021a, Marre and Villet, 2020), achieving once again a harmonious balance, perfectly blending modern elements with tradition. This enduring tradition ensures that surgeons and doctors receive a comprehensive understanding of anatomy that cannot be replaced by advanced technologies alone, underscoring the durable importance of hands-on learning in the field of medicine. Practicing with post-mortem bodies, not only imparts a deep understanding of anatomy but also cultivates essential qualities of respect, compassion, and empathy for patients, a dimension that modern technologies can only partially replicate, further emphasizing the enduring value of this tradition.

In this context, also the "graphic medicine" (GM) workshops that the Anatomy Centre promotes fit perfectly (De Stefano et al., 2023). These workshops, focused both on human anatomy and on body donation, contribute to raising awareness among students and members of the scientific and non-scientific community on complex and delicate topics, which, unfortunately, are not talked about enough. Therefore, the anatomical wax museum and graphic medicine converge in promoting the understanding of human anatomy and the awareness about body donation. While the museum preserves the tradition of anatomy and expands its understanding through the use of modern technologies, GM offers a new communicative approach to engage medical stu-

Figure 5. "Giovanni Mazzotti" Dissection Room. Dissection room is located at the Anatomy Centre of the Department of Biomedical and Neuromotor Sciences of the University of Bologna.

dents in studying and understanding sensitive topics such as body donation, before using it with the general population.

4. CONCLUSION

The Anatomical Wax Museum in Bologna stands as a remarkable convergence of history, science, and art. This museum encapsulates the enduring value of anatomical and pathological preservation while adapting to the demands of modern education and research. The wax models, meticulously crafted through a centuries-old tradition, bridge the gap between scientific knowledge and artistic expression. Rooted in the historical legacy of anatomical wax modelling, the museum preserves the tangible evidence of a collaborative journey between anatomists and artists. It records the transition from artistic representation to a scientific tool that revolutionized medical education and research. This transformation reflects not only the shift in societal perspectives but also the innate human drive to comprehend the complexities of our own bodies.

Furthermore, the museum's embrace of technological innovation, and increasingly creative methods, signifies a harmonious blend of tradition and progress. Augmented reality, tangible 3D models and graphic medicine, propel anatomical education into the digital age and into a more engaging and ethical context, empowering medical students to engage with anatomy in unprecedented ways. This fusion of past and present expands the boundaries of anatomical exploration and enriches the understanding of human health and disease. Overall, it is clear that both post-mortem bodies dissection, anatomical wax models and modern interactive systems based on artificial intelligence represent strong innovations in medical teaching for their respective historical period. In this context, the Anatomy Centre is able to offer all these opportunities, creating a strong impact and representing a reference point in the academic world.

As an integral part of the Department of Biomedical and Neuromotor Sciences at the University of Bologna, the museum represents a hub for interdisciplinary collaboration, uniting anatomists, clinicians, and researchers in a collective pursuit of knowledge. The anatomical wax models, once tools for study, have now evolved into conduits for unlocking new realms of scientific discovery.

All in all, the Anatomical Wax Museum in Bologna serves as a bridge across time, offering a profound glimpse into the evolution of anatomical understanding. Waxes new value is no longer related to the functionality they had in the past but it is related to their ability to tell a story, to be witnesses of a reality that represents the past but can still carry us to the future. Waxes and the museum's collection itself, are at the same time concrete and symbolic manifestation of the scientific progress. They also represent the point from which research started and from which it can measure where it has arrived. They remind us that the exploration of the human body is a timeless endeavor, harmonizing artistic craftsmanship, scientific exploration, and the unquenchable thirst for knowledge.

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DATA AVAILABILITY STATEMENT

All information can be found at the following link: https://site.unibo.it/centro-anatomico/it

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