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Women‘s Invaluable Contribution in the Development of Anatomical Knowledge and Education through the Centuries

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Stereotypes and prejudice have long been significant barriers to women‘s participation in the development of anatomical knowledge and education. Despite these challenges, generations of women have persevered, overcoming numerous obstacles to establish themselves in the field. The history of anatomy is often viewed as male-dominated, yet women have made significant contributions, even when societal norms or legal restrictions sought to limit their involvement. Women excelled as prosectors, anatomists, researchers, and educators – even when such practices were viewed as scandalous or were prohibited. This historical review aims to shed light on the contributions of female anatomists, who were not just scientists but also philosophers, innovators, and visionaries. By documenting their achievements, we seek to raise awareness of their invaluable role in shaping the field of anatomy. Recognizing the history of these women is crucial in understanding both the progress made and the ongoing need for gender equality in science and medicine.

Key words: history of medicine, women anatomists, history of anatomy, dissection, wax modeling

Anatomy is a foundational subject for many fields of study. A deeper exploration of this discipline often inspires admiration in those who choose to pursue it further. However, it is not only the complexity and significance of the subject itself that draws admiration, but also the discoverers who showed courage and boldness in their exploration. As a mark of respect, many anatomical structures and anomalies have been named after their discoverers [12, 21]. What stands out, however, is that most of the well known anatomical terms named after scientists are associated with male names. This raises important questions: What has been the role of women in anatomy and anatomy

education? Did they contribute to the field of science? Were they allowed to participate, and did they have the desire, ambition, and vision to advance the field? In response to these questions, this review seeks to examine the role of women in the development of anatomy and anatomical education throughout history.

1. Before the Early Modern Period

1.1. Ancient History

The earliest historical connections between women and anatomy can be traced back to ancient Greek myths and legends. One such figure is the goddess Iris, daughter of the gods Thaumas and Electra. Iris, the personification of the rainbow and messenger of the gods, served the Olympians, particularly Queen Hera. Later, the colored part of the eye surrounding the pupil was named after her. The term „iris“ comes from the Greek word for „rainbow,“ reflecting both the goddess and the multiple colors found in this part of the eye.

Allesandra Gialini (1307-1326)

Alessandra Giliani is regarded as the world's first female anatomist and prosector [20]. She entered the University of Bologna at the age of 16 and, disguised as a man, worked as a prosector and demonstrator during anatomy lectures (**Fig. 1).** Giliani developed an innovative technique for visualizing blood vessels in cadavers using injected dyes, enabling detailed observation of vascular structures. Her career was brief, ending with her death at the age of 19 in 1326. One theory suggests that she succumbed to an infected wound, while others believe her death was linked to a colleague‘s romantic feelings, which revealed her true gender. According to some accounts, her exposure led to her being condemned by the Inquisition and burned at the stake as a witch outside the Church of San Pietro e Marcellino in Florence, for daring to work alongside men.

2. The Period Between the 15th and 18th Century

The period between 1400 and 1700 saw advances in the natural sciences, but progress in anatomy and women's participation slowed due to traditional beliefs, religious restrictions, limited scientific methods, and restricted access to medical education. Socioeconomic challenges such as wars, epidemics, and poverty further hindered development. Nevertheless, this period laid the foundation for theories that later flourished during the Enlightenment.

2.1. Early Modern Period – Enlightenment (17th and 18th centuries)

Laura Maria Katerina Bassi (1711-1778)

Laura Bassi began studying biology, natural history, and medicine at the age of 13 (**Fig. 2**). In 1731, she started teaching anatomy at the medical faculty of the University of Bologna, and at 21 earned a doctorate in philosophy and became a professor [17,20]. Despite her family responsibilities, she continued teaching anatomy through private courses and was highly respected in scientific and political circles in Italy.

Anna Morandi Manzolini (1714-1774)

Anna Morandi Manzolini was an internationally renowned anatomist and creator of wax anatomical models at the University of Bologna [13,17,20]. Together with her husband, Giovanni Manzolini, she worked in ceroplasty, initially collaborating with the Bologna Museum and later continuing independently in their home laboratory (**Fig. 3**) [1,17,18]. She served for several years as a professor of anatomy and made significant contributions, including the discovery of the attachment points of the oblique muscles of the eyeball. Morandi Manzolini became widely known for her highly detailed wax models, accurately reproducing fine anatomical structures such as capillaries and nerves (**Fig. 4**). Her collection, the *Supellex Manzoliniana*, was recognized throughout Europe as an important educational resource (**Fig. 5**) and influenced later developments in anatomical modeling.

Marie-Marguerite Biheron (1719-1795)

Marie-Marguerite Biheron was a French anatomist, medical illustrator, and artist renowned for her anatomically precise wax models [7]. Due to the limitations of working with cadavers, she turned to ceroplasty, producing durable models widely used for anatomical education in laboratories, medical schools, and museums. Her innovative techniques gained international recognition; however, restrictions at the Royal Academy of Sciences in Paris prevented her from teaching anatomy, leading her to continue her work in England. In May 1761, she opened an exhibition of her anatomical models in her home on Rue Vieille Estrapade, known as the „Exhibition of Artificial Anatomy".

Maria Petracini (1759 – 1791)

Maria Petracini was an Italian physician and professor of anatomy at the University of Ferrara (**Fig. 6**) [17]. In 1789, she published an influential work on maternal and newborn care, combining medical knowledge with personal experience. Petracini criticized harmful infant swaddling practices and advocated early breastfeeding, while also providing guidance on congenital malformations and infectious diseases (**Fig. 7**).

3. 19th to 20th centuries

Augusta Déjerine-Klumpke (1859 – 1927)

Augusta Déjerine-Klumpke was an American-born French physician noted for her contributions to neuroanatomy and the description of Klumpke paralysis (**Fig. 8**) [26]. She was among the first female hospital interns in Paris, although her medical training was initially hindered by gender-based restrictions [22]. During her externship, she studied neurology under Jean-Martin Charcot and focused on the anatomy of the brachial plexus. Her clinical observations formed the basis of her doctoral thesis, published in 1885, which earned several prestigious academic awards.

Vera Mikhailovna Danchakova (1879 – 1950)

Vera Mikhailovna Danchakova was a prominent Russian anatomist, embryologist, and cell biologist. In 1908, she became the first woman in Russia elected as a professor

of anatomy at Moscow University (**Fig. 9**). In 1915, Danchakova moved to the U.S., working at the Rockefeller Institute and later at Columbia University‘s College of Medicine, teaching anatomy during the early inclusion of women in medical education. In 1916, she proposed that all blood cells develop from a single type of cell, introducing the term „stem cell“ and noting that stem cells could undergo pathological changes [14]. She is recognized as a pioneer in hematopoietic stem cell research, called the „Mother of Stem Cells“ by M. A. Lichman (2001). Between 1934–1937, she worked at the Lithuanian Medical University. In 1938, she conducted experiments exposing female guinea pig foetuses to testosterone, showing it could increase masculine sexual behavior in adulthood.

Mabel Heath Palmer (1885 – 1949)

Mabel Heath Palmer, known as the „First Lady of Chiropractic“ (**Fig. 10**), was an American chiropractor and anatomist [23]. Married to B. J. Palmer, she graduated from the Palmer School of Chiropractic in 1905 and studied anatomy and dissection in Chicago. In 1918, she published *Anatomy*, the first anatomy textbook for chiropractic students. Returning to the Palmer School, she taught anatomy for 40 years and founded Sigma Phi Chi, the first chiropractic sorority.

Katharine Julia Scott Bishop (1889 – 1975)

Katharine Julia Scott Bishop was an anatomist, physician, researcher, and educator, best known for codiscovering Vitamin E (**Fig. 11**) [10, 24]. After graduating from medical school, she taught histology at the University of California Medical School in Berkeley until 1923. Working with Herbert McLean Evans, she studied the reproductive cycle of rats, publishing a monograph on vital staining of connective tissue. Their experiments on dietary deficiencies led to the identification of a factor essential for reproduction, initially called „Factor X,“ later named Vitamin E, derived from lipid extracts of lettuce and wheat germ.

4. Contemporary History (1945 to today)

Marian Diamond (1926 – 2017)

Marian Cleeves Diamond was an American neuroscientist and a pioneer in neuroplasticity (**Fig. 12**) [2,8,9,25]. She was the first female graduate student in the Department of Anatomy at UC Berkeley and taught well into her eighties. In the early 1960s, Diamond provided the first evidence that the cerebral cortex can change structurally in response to enriched or impoverished environments, from prenatal stages to old age. Her experiments showed that rats in enriched environments had a cortex 6% thicker and a greater learning capacity than those in impoverished conditions. Diamond also analyzed preserved blocks of Albert Einstein’s brain, discovering an increased glial cell-to-neuron ratio, particularly in area 39 of the left hemisphere. Her integrative biology lectures became globally popular on YouTube, and the 2017 documentary *My Love Affair with the Brain* highlights her scientific contributions and teaching legacy.

Eva Braak (1939-2000)

Eva Braak was a German anatomist known for her work on neurodegenerative diseases, especially Alzheimer's (**Fig. 13**) [3-6]. As a professor at Johann Wolfgang Goethe University, she and her husband Heiko Braak led a research group studying degenerative brain disorders. In the 1970s, they refined the silver-iodate histological technique to examine thick brain sections, advancing understanding of Alzheimer's and Parkinson's diseases. In 1987, they first described argyrophilic grain disease, a previously misclassified tauopathy. Their 1991 classification system for Alzheimer's, the Braak and Braak stages, delineated six pathoanatomical stages based on neurofibrillary changes. In 1998, Eva Braak became the first female recipient of the Lifetime Achievement Award in Alzheimer's Disease Research.

Carolyn Larabell (1947-)

Carolyn Larabell (**Fig. 14**) is an American scientist pioneering biological imaging through soft X-ray microscopy [11,15,16,19]. Since 1997, she has been at Lawrence Berkeley National Laboratory, advancing X-ray microtomography for 3D visualization of cells. In 2004, she founded the NCXT to develop soft X-ray tomography, including Beamline 2.1 (XM-2), the world's first soft X-ray microscope. Her work enables the study of cellular pathways for clearing misfolded proteins, offering insights into Alzheimer's, Parkinson's, and Huntington's diseases, bridging light and electron microscopy and providing unprecedented views of cellular structures.

Conclusions

"I am among those who think that science has great beauty." ***Marie Curie***

This sentiment, echoed by luminaries such as Marie Curie, encapsulates the profound impact that women have had in the scientific realm, particularly in anatomy and medical research. Throughout history, women have not only contributed groundbreaking discoveries but have also enriched the field with diverse perspectives and innovative approaches that highlight the intricate beauty of biological systems. From the pioneering work of Alessandra Giliani in the 14th century to the contemporary advancements of Carolyn Larabell, women have consistently broken barriers and challenged conventions, illuminating the path for future generations. Their dedication and resilience remind us that the pursuit of knowledge is a collaborative endeavor that thrives on inclusivity and diversity. By recognizing and celebrating the achievements of women in science, we honor the beauty inherent in scientific inquiry and inspire a more equitable future where all voices are heard. In doing so, we gain deeper insight into life's intricacies while embracing the wonder, innovation, and beauty that science has to offer.

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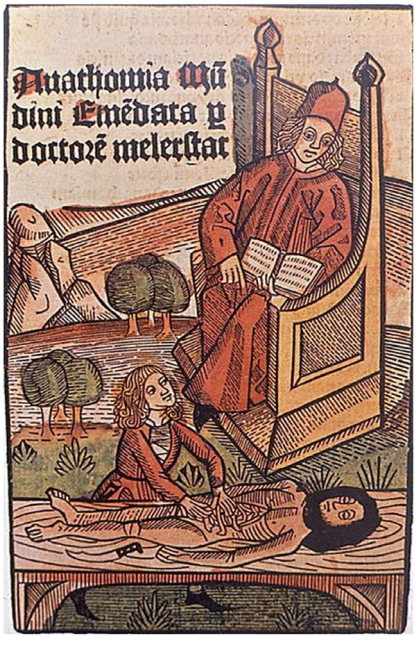

Figure 1. Anathomia corporis humani title page (Leipzig edition dated 1493).

Figure 2. Portrait of Laura Bassi by unknown author.

Figure 3. Anna Morandi Manzolini (1714-1774), Italian anatomist and sculptor, from a drawing of Cesare Bettini.

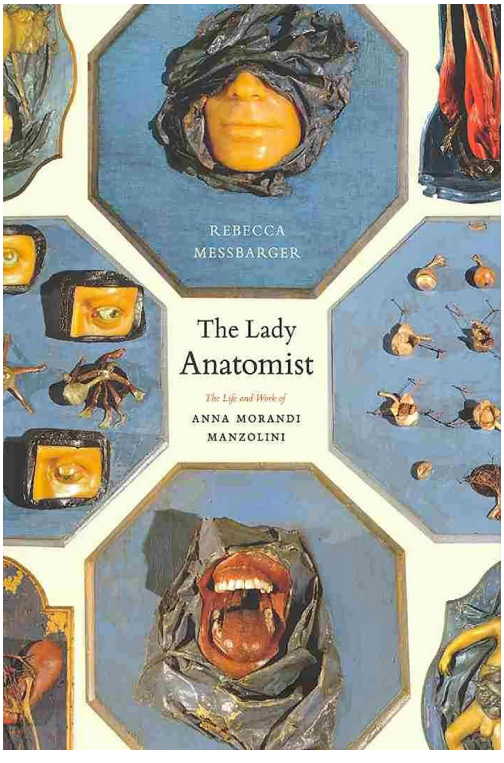

Figure 4. The front cover of the book: The Lady Anatomist, The Life and Work of Anna Morandi Manzolini by Rebecca Messbarger. The University of Chicago Press.

Figure 5. Anna Morandi and Giovanni Manzolini, muscles of the forearm. Courtesy of Museo di PalazzoPoggi, Universita di Bologna.

Figure 6. Portrait of Maria Petracini by unknown author.

Figure 7. Maria Maddalena Petraccini, Memoria per servire alla fisica educazione de‘ Bambini, Ferrara, 1789.

Figure 8. Augusta and Jacqueline Dejerine-Klumpke. Author Andre-Thomas.

Figure 9. Vera Mikhailova Danchakova (Unknown author - http://www.sbras.ru/HBC/article.phtml?nid=656&id=3).

Figure 10. The bronze bust of Mabel Heath Palmer in Heritage Courtyard on the Davenport Campus of Palmer College of Chiropractic.

Figure 11. Katharine J. Scott Bishop. Smithsonian Institution Archives. Image SIA2009-3085.

Figure 12. Dr Marian Diamond smiles, standing in her laboratory, 28 December 2022.

Figure 13. Photograph of Eva Braak

Figure 14. Carolyn A. Larabell (https://biosciences.lbl.gov/profiles/carolyn-a-larabell/)