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Anatomy: Past, Present and Future

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Editorial

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Editorial

The term anatomy derives from the Greek "anatomē" meaning dissection and concerns the study of the structural organization of organisms and their parts. The generation of accurate anatomical images has always allured the scientific minds seeking to better portray and understand human anatomy, physiology and disease. The history of anatomy began over 1000 years ago with the examination of sacrificial human bodies. The systematic anatomical study started with the work of Greek scientists like Alcmaeon (ca. 500 B.C.), and Hippocrates (ca. 460-377 B.C.). In the next centuries, Aristotle (ca. 384-322 B.C.) and his contemporaries produced a more descriptive anatomical system based on animal dissection. Herophilus (335–280 B.C.) performed the first systematic dissection of the human body and is widely acknowledged as the father of anatomy. Galen (ca. 130-200 B.C.) dissected animals and wrote treatises on human anatomy. During the next few centuries, the knowledge of Greek anatomical treatises was lost, though some were translated into other languages like old English, Latin, and Arabic and some retained in Byzantium and the Islamic world.

Slowly, medical science, anatomy and medical teaching regained prominence. The first European medical school was founded (1235) in Italy by Mondino de Luzzi (ca. 1270 – 1326), incorporating a systematic study of anatomy and dissection into a medical curriculum. Hand drawing on paper and woodcut engraving were the main mediums to represent anatomy. The 15th century saw the involvement of artists in the scientific depiction of the human body, including the famous anatomical paintings by Leonardo da Vinci (1452-1519). Andreas Vesalius (1514-1564), the father of modern human anatomy, set a new dimension to the subject by integrating systematic text and drawing in his De Humani Corporis Fabrica (On the Structure of the Human Body). The field of anatomy reached new heights during the renaissance period, due to the contributions of scientists like Realdo Colombo (1515 – 1559). Realdo Colombo described and named the placenta in his book, "De Re Anatomica". William Harvey (1578 –1657) reported how the heart propelled the blood in a circular course through the body in his book "Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus". New discoveries were made and experimental methods to scientific research were introduced. Marcello Malpighi (1628 – 1694) founded microscopic anatomy. New artistic methods of copperplate engraving, copper plate etching, and lithography improved the speed and accuracy of producing anatomical images. Medical interest was so high in the Renaissance that many famous artists as Michelangelo (1475 –1564) and Rembrandt (1606-1669) produced anatomical drawings. The advent of the printing press in the 15th to 17th century gave greater access to these drawings by mass production. In the 16th century the rapid growth of medical schools leads to a high demand for cadavers. In the absence of available cadavers, anatomical drawings became critical. Gaetano Zumbo (1656–1701) developed anatomical wax modeling techniques by the end of the 17th century, creating the first method of 3D anatomical modeling. Methods for the storage and preservation of dissected specimens, including drying and wax injection were gaining importance. The later anatomical research was extended not only to histology but also to developmental biology of both humans and animal. Based on the techniques of Gaetano Zumbo wax embedding and histology could be performed. During the late 17th to the early 19th century, scientists like Giambattista Morgagni (1682-1771), Scott Matthew Baillie, and Xavier Bichat served to demonstrate the importance of "pathological anatomy". To correlate the knowledge of anatomy with the disease physiology, scientists needed a way to image the human body in a more non-invasive way.

In the past hundred years, significant advances have been made in anatomical research. New mediums of photography, relief halftone and color photography have changed the way anatomy is taught. Since the discovery of X-Ray machines by Wilhelm Rontgen in 1895, the inside of a human body was made visible without dissection. In 1930 the Felix Bloch developed the Magnetic Resonance Imaging (MRI) machine, which generates images of organs using magnetic fields and radio waves that cause atoms to give off tiny radio signals. The discovery of computed tomography (CT) in 1972 by Godfrey Hounsfield and Allan Cormack has enabled researchers to visualize patients' organs in unprecedented detail. A reminiscent of Gaetano Zumbo's wax modeling, an effort was made to introduce three-dimensional (3D) anatomical representation in anatomy, teaching using clay and plastic models.

Progress in anatomy today centers on understanding development, evolution, anatomical function, physiology, pathological interpretation, and regenerative medicine. We now have catalogs of detailed macroscopic and microscopic reproductions of human anatomy, but current directions in research require better resolution. Cadaveric body donations have drastically reduced, mainly due to religious and disease transmission issues and certain government acts (e.g. the Human Tissue Act 2004 in Britain), decreasing the availability of human bodies to anatomy departments. This led the Visible Human Project (VHP) in America to create a detailed set of transverse CT, MR and cryo-sectional photographs of the entire human body. A male and a female cadaver were cryosectioned at one or one-third of a millimeter intervals full length. CT, MR and cryosection images of representative sections were also recorded. The U.S. National Library of Medicine started the VHP project in 1986. The data set of the male subject was completed in 1994 and one of the females in 1995. This incredible collection serves as a milestone in medical imaging and anatomy education and is displayed at the National Museum of Health and Medicine near Washington, DC.

To obtain even higher resolution images, VHP was repeated as the Korean Visible Human Project in 2002, and Chinese Visible Human Project (2002-03). By volumetric reconstruction, these cross-sectional images are transformed into 3D accurate images of anatomic structures. These compilations of 3D anatomic images have created an invaluable library for medical education and research. The advent of the 3D renderings led to the development of virtual surgery and virtual medical procedures such as endoscopy, lumbar puncture and cardiopulmonary resuscitation via the virtual dissection software. Cross-sectional images and digital virtual human anatomy models were offered for medical education and clinical practice. Medically accurate 3D anatomy software and platforms like Anatomage, Biodigital, Netter3DAnatomy, Visible body, Primal pictures are among the few that have revolutionized anatomical studies. These have better promise than cadaver-based studies as they eliminate challenges of dissection, such as structure recognition, cost, repaired fragile structures, ethics, and hygiene. The virtual human is an interactive computer model integrating anatomical, biophysical, physiological and biomechanical characteristics of a human being.

One of the newest goals in anatomy is 3D printing of human anatomy models. Charles Hull originally developed 3D printing technology to allow rapid prototyping of plastic parts in 1986. 3D printing, or additive printing technology, repeatedly layers a variety of printing materials based on a computerized 3D object model to manufacture an object. Using a range of polymers, metals, and ceramics and others chemicals, 3D printing technology offers the possibility of generating complex 3D reproductions. 3D printing applications have increased in use, ranging from basic 3D model-based anatomy education to surgical practice and advanced regenerative biology research application. 3D printing is revolutionizing new applications in medicine and addresses the current needs of scientists and engineers toward the production of biomaterial scaffolds. The acquisition and analysis of accurate 3D anatomical datasets as well as advanced software-based 3D rendering have led to the better 3D representation of the complex anatomical systems. Advanced software like Blender, Sketchup, Solidworks, Autocad, Maya, Meshmixer, Rhinocerous create printable designs, which is a crucial first step in the 3D printing process. This progress has led to the 3D printing of biocompatible materials, cells, and supporting components into complex 3D functional living tissues, a process called bioprinting. Though in its infancy, 3D bioprinting raises high hopes to address the need for tissue in organ transplantation and regenerative medicine. Several hospitals already use 3D bioprinting for the accurate generation of tissues like multilayered skin, bone, vascular grafts, tracheal splints, heart tissue and cartilaginous structures to name a few. 3D bio printed meso and micro tissue/organoid models are used to develop human disease models for high-throughput screening in research, drug discovery, and toxicology. Complex decisions must be made in 3D bioprinting, such as choice of materials, sensitivities of cell types, growth and differentiation factors and technical challenges relating to mimicking the tissue niche. The integration of knowledge from several fields, including engineering, biomaterials science, cell biology, physics, and medicine is necessary to overcome bioprinting challenges. The advent of virtual reality-based visualization software can virtually present unique anatomical views to better present patient-specific disease symptoms. Over the past years, 3D printed anatomic models have served as high-quality educational tools for medical and surgical training, as well as clinical tools for surgical pre-visualization and creating implants for reconstructive surgery. Virtual reality, holographic representation and google glass can bring new dimensions to the 3D accurate visualization and better understanding of anatomy and physiology. Complexing 3D printing and virtual reality will pave the way for future regenerative therapies, better medical education, and sound medical procedures.

Conflict of Interest: I have no conflict of interest.