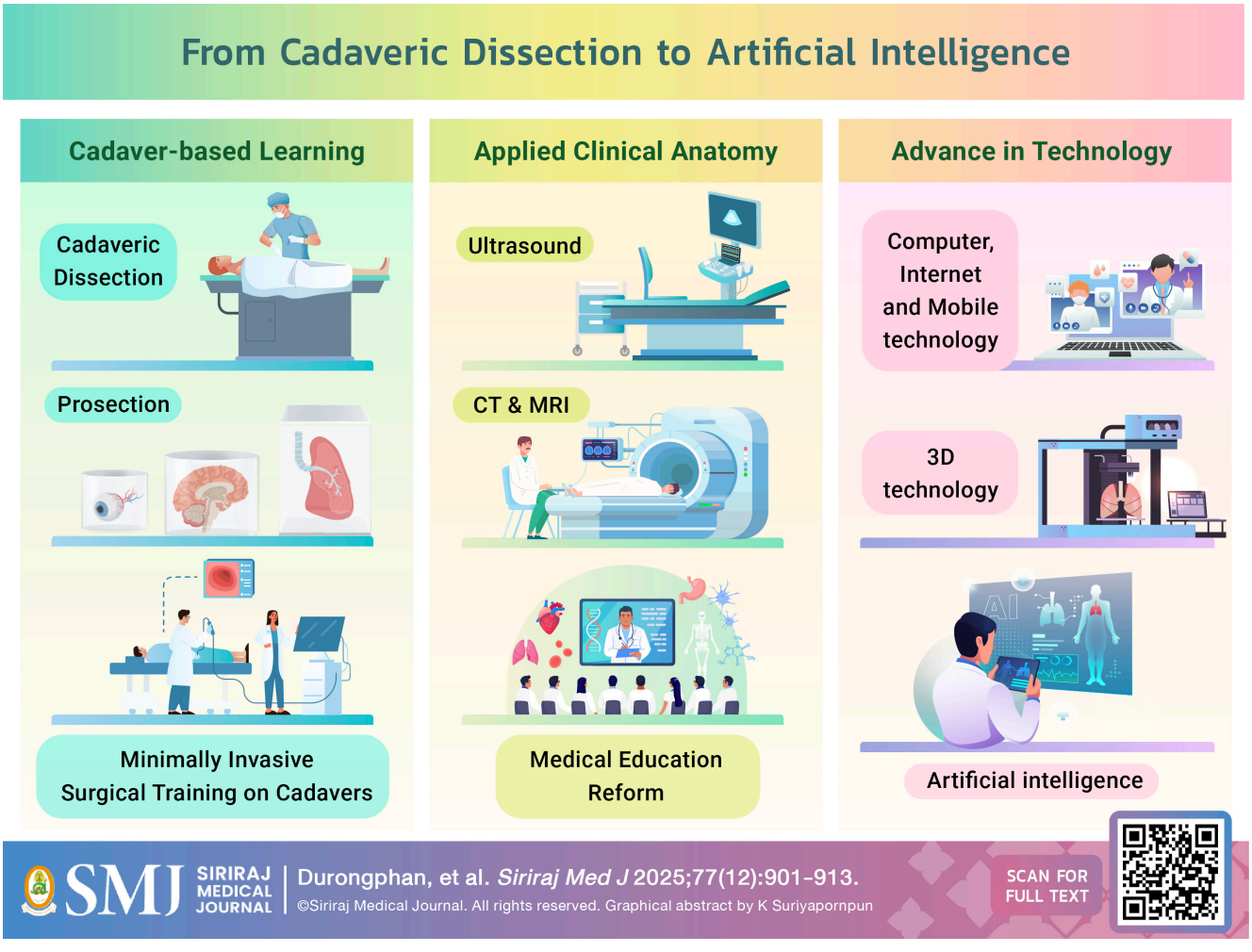
From Cadaveric Dissection to Artificial Intelligence: A Chronological Review of Advances in Anatomy Education

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ABSTRACT

Cadaveric dissection has traditionally been the cornerstone of anatomy education. However, in recent decades, its role has come under increasing scrutiny. Comprehensive historical analyses explaining this shift remain limited. This chronologically structured review traces the evolution of anatomy teaching from its origins with Herophilus in the 3rd century BC to the advent of contemporary digital and artificial intelligence (AI)-enhanced approaches. Key milestones include the 1910 Flexner Report, which emphasized integrated biomedical sciences, widespread curricular reforms, increased reliance on prosection, the rise of minimally invasive surgery, and the incorporation of cadaveric simulation in postgraduate training. Advances in imaging technologies such as computed tomography (CT) and magnetic resonance imaging (MRI), alongside innovations in three-dimensional (3D) printing, digital dissection platforms, and virtual or augmented reality (VR/AR), have significantly reshaped anatomy instruction. Internet-based learning and mobile technologies have further transformed self-directed study through accessible, interactive resources. Most recently, AI has introduced capabilities such as personalized tutoring, performance prediction, automated assessment, and intraoperative anatomical guidance. This review highlights the value of a blended approach that integrates cadaveric experience with technological innovations. Future curricula should prioritize optimizing the sequence and combination of these modalities while ensuring equitable access and preparing students for real-world clinical challenges.

Keywords: Anatomy education; cadaveric dissection; clinical anatomy; medical curriculum reform; problem-based learning (PBL); Artificial intelligence; ChatGPT (Siriraj Med J 2025; 77: 901-913)

INTRODUCTION

Anatomical science has shaped medical education for over two millennia. In the 5th century BC, Hippocrates laid the foundation of medical practice through the Hippocratic Oath and formulated principles for disease treatment.[1,2] In the 3rd century BC, Herophilus emphasized the importance of learning through dissections.[3,4] However, for over 1,700 years, the practice remained largely absent until the Renaissance, when Andreas Vesalius revived it with the publication of De Humani Corporis Fabrica. This landmark work, based on cadaveric dissection, marked the recognition of dissection as a fundamental tool in medical education.[5] In contrast, over the past two decades, the necessity of cadaveric dissection and the time allocated to anatomy instruction have been increasingly debated.[6] This narrative review will investigate these changes by addressing the following guiding questions: 1. What are the key changes in cadaver-based learning, applied clinical anatomy, medical education, and technologies that intersect with anatomy education? 2. What theoretical and technological foundations drive these changes? 3. What is currently known about the pedagogical value and implementation challenges of these emerging modalities? This review adheres to narrative review conventions and follows the Scale for the Assessment of Narrative Review Articles (SANRA) criteria to ensure clarity, coherence, and critical engagement with the literature.[7]

Literature search strategy

Relevant literature was identified through systematic searches of PubMed and Scopus, supplemented by targeted searches in Google Scholar and Google. Citation tracking of included studies was also performed to identify additional sources. Searches were conducted from 1 April to 30 November 2023 and updated on 2 July 2025. A flow diagram of the search process is provided in the supplementary material. The search covered publications from 1 January 1990 to 2 July 2025. Keywords included "anatomy", "anatomy education", "medical student", "cadaveric dissection", "prosection", "ultrasound", "computed tomography", "magnetic resonance imaging," "3D-printing," "virtual reality", "augmented reality", "Problem-based learning", "ChatGPT", and "artificial intelligence". As a narrative review, inclusion was guided by thematic relevance to the evolution of anatomy education.[7,8] Eligible publications met at least one of the following criteria: early seminal works or highly cited studies, reports of notable educational outcomes, or credible grey literature offering conceptual or contextual value. Only English-language sources were considered. Studies were excluded if they duplicated content without providing new insights.

Changes in Cadaver-based Learning

Cadaveric Dissection

The shift towards hands-on study emerged during

the Renaissance period. Before this, students primarily observed dissections, as evidenced by a 13th-century painting.[9,10] Hands-on cadaveric dissection became standard practice following William Hunter's adoption of the Paris method in the 18th century, which involved providing each pupil with an entire body for dissection and periodically inspecting their work.[11] This paradigm began to change after the publication of the Flexner Report in 1910, which emphasized the integration of basic sciences into medical education.[12] Several factors have contributed to the gradual shift away from cadaveric dissection in modern pedagogy. These factors include the development of alternative teaching methods and supplementary learning tools, which are discussed later in this review, and the adoption of systems-based curricula with increased emphasis on clinical applications.[13,14] Additional challenges include a shortage of trained anatomy educators[15], the considerable costs associated with cadaver management[15,16], heightened ethical concerns regarding body donation, such as the requirement for informed consent from the donor and the recommended practice of obtaining co-signature from the next of kin[17,18], cadaver shortage in some countries[19,20], and health risks related to formaldehyde exposure.[21,22] A 2019 survey of anatomy education in the United Kingdom and the Republic of Ireland reported an average teaching time of 85 ± 6 hours dedicated for gross anatomy, with only one out of 39 medical schools using dissection as the primary teaching method.[23] In contrast, the use of cadavers in residency training has increased in parallel with the rise of minimally invasive surgery, a trend that began with the first laparoscopic cholecystectomy in the 1980s and continues to shape modern surgical practice.[24-26] Minimally invasive surgery presents a unique anatomical perspective compared to open surgery, employing modern surgical tools such as microscopes and endoscopes. Since the 1990s, cadaver-based procedural training has expanded beyond core techniques to advanced surgeries.[27-29] Training with cadavers has been shown to enhance competency and confidence among future surgeons.[30-32] Globally, institutions have integrated cadaver labs into their residency curricula.[33-35]

Prosection

Prosection, the use of pre-dissected cadaveric specimens, serves as an alternative to student-performed dissection.[36] A renowned prosection collection from the Enlightenment era was developed by William Hunter in the 18th century and has been preserved to the present day.[37,38] By the 19th century, the British General Medical Council had removed the requirement for whole-body dissection, prompting evaluations of prosection's efficacy as an alternative.[39] A search of MEDLINE, Embase, Scopus, and Google Scholar identified only two randomized controlled trials (RCT) comparing the effectiveness of prosection and dissection. The search strategy focused on the core concept of prosection, dissection, RCT, and comparative effectiveness. The first RCT comparing cadaveric dissection and prosection in teaching applied surgical anatomy assessed instruction in truncal anatomy through 6 clinically relevant procedures: inguinal hernia repair, cholecystectomy, laparotomy, right hemicolectomy, and Hartmann's procedure. The dissection group achieved significantly higher post-course test scores (69.8% ± 10.8%) than the prosection group (62.3% ± 10.6%; $p < 0.05$), as well as higher one-year retention scores (59.8% ± 10.4% vs. 49.8% ± 10.1%; $p < 0.05$). However, after adjusting for the time spent in sessions, these differences were no longer statistically significant.[40] Another study reported higher practical and multiple-choice question (MCQ) scores in the dissection group (169 ± 1.99) compared to the prosection group (142 ± 1.78), though it lacked a pre-intervention assessment and used only 2 cadavers for 50 students.[41] A meta-analysis comparing anatomy laboratory pedagogies found no significant difference in outcomes between traditional cadaveric dissection and prosection across 4 studies, with a pooled standardized mean difference (SMD) of –0.33 (95% confidence interval [CI], –0.76 to 0.11, $p = 0.15$). However, the included studies varied widely in focus, ranging from human limb anatomy to canine thoracic limb dissection, and included comparisons involving computer-assisted instruction versus traditional methods.[42] These findings suggest that it remains inconclusive whether prosection is more effective than dissection for learning human anatomy, underscoring the need for more rigorous research.

Changes in Applied Clinical Anatomy: Surface Anatomy, Physical Examination, Ultrasound, and Imaging Modalities

Surface anatomy

The observation of living humans is one of the simplest methods for learning clinical anatomy. Leonardo da Vinci documented surface anatomy through detailed sketches during the 15th century.[43,44] Evidence of anatomy instruction using live subjects is also depicted in 18th-century paintings.[45] These methods have been reintroduced in the 21st century through methods such as body painting and peer physical examination in clinically integrated anatomy courses.[46,47]

Ultrasound

Ultrasound enhances anatomy education by illustrating the relationship between surface anatomy and underlying structures and by demonstrating real-time physiology and organ function. In 1990, Hannover Medical School became the first institution to implement ultrasound into anatomy education, with 48.7% of first-year medical students reporting improved topographical knowledge of abdominopelvic organs.[48] Subsequent studies have consistently reported positive student feedback on ultrasound-based learning.[49,50] A randomized study comparing prosection and ultrasound found both methods to be equally effective in improving cardiac anatomy test scores.[51] At Mayo Medical School, an outcome-based ultrasound course trained students in echocardiography using handheld devices. Over the course of 3 weeks, students' accuracy in labeling ultrasound anatomy improved from 3.7% to 91.0%, while satisfactory image quality increased from 57.1% to 78.6%, p=0.04.[52] A 2023 non-randomized study reported that students who participated in additional point-of-care ultrasound (POCUS) sessions scored significantly higher on cardiovascular anatomy exams compared to those in the standard curriculum (92.1 vs. 88.5, $p < 0.05$). However, no significant differences were observed for gastrointestinal anatomy exams or in USMLE Step 1 and clinical examination scores.[53] Recent publications have explored the use of ultrasound in teaching head and neck, musculoskeletal, and limb anatomy.[54] Despite its expanding applications, the role of ultrasound as a supplement to or substitute for cadaver-based learning remains unclear in much of the existing literature. One RCT addressed this question by comparing cardiac anatomy instruction using ultrasound versus cadaveric prosection in first-year medical students who had not received prior training in cardiac anatomy. Post-test scores showed no significant difference between the groups (cadaveric 85% ± 15.7, ultrasound 85.1% ± 13.5, $p = 0.95$).[51] Despite its demonstrated benefits, gaps remain in understanding the optimal integration of ultrasound into anatomy curricula and its long-term impact on knowledge retention and clinical performance.

Imaging modalities in anatomy teaching

Wilhelm Röntgen discovered X-rays in 1895 and published the first radiograph, an image of his wife's hand, in 1896.[55,56] During World War I, Marie Curie developed the Radiological Ambulance to offer surgical guidance on the battlefield, laying the groundwork for portable X-ray machines.[57] In 1971, inspired by the idea of visualizing the contents of a closed box, Sir Godfrey Hounsfield invented the computed tomography (CT) scanner, which enabled detailed cross-sectional imaging of internal body structures.[58] Around the same time, magnetic resonance imaging (MRI) was being developed.[59]

The use of imaging to enhance anatomical understanding was first introduced at McMaster University in 1969 as part of its Problem-based learning (PBL) curriculum.[60] A 1990 study evaluating the integration of diagnostic imaging into dissection laboratories reported an improvement in student performance, with correct responses increasing from 16.7% (pre-test) to 88.1% (post-test), and a retention rate of 73.5% retention after 14–17 weeks.[61,62] Subsequent studies investigating the incorporation of imaging modalities into anatomy education support these findings. In a five-year study, Chew et al. reported higher anatomy MCQ scores during the two academic years in which radiology was integrated into small-group sessions. These sessions included brief radiologic anatomy lectures and rotating quiz stations focused on clinically relevant pathology aligned with weekly anatomical content. Student performance improved considerably, with mean anatomy scores rising to 68.97% in 2017 and 73.77% in 2018, compared to 65.85% in 2015 and 62.23% in 2019, when no radiology instruction was provided.[63] Similarly, Larsen and Engle examined the impact of integrating radiologic content into anatomy education through lectures, laboratory sessions, and assessments. Students were evaluated using a 12-question anatomy test incorporating imaging modalities such as X-ray, CT, and MRI. Across the 2016 and 2017 cohorts, mean pre-test scores increased from 12.05% to 41.3% following the intervention.[64] Integrating imaging-based anatomy early in medical education, particularly alongside cadaveric dissection, has shown promise in enhancing the clinical applicability of anatomical knowledge. However, further research is needed to evaluate student-perceived confidence in diagnosis and the long-term educational outcomes associated with this approach

Changes in Medical Education

In 1870, Christopher Columbus Langdell, Dean of Harvard Law School, pioneered a new learning approach by encouraging students to analyze and discuss cases to understand underlying principles.[65,66] This initiative laid the foundation for the Harvard Business School's Case Method, introduced in 1921, which emphasized real-life scenario analysis to develop problem-solving skills beyond textbook knowledge and conventional ideas.[65,67,68] A similar shift occurred in medical education when, in 1900, a Harvard Medical School student criticized reliance on didactic lectures and advocated for a Case System involving

real patient data and analytical discussions.[69] By 1906, the Case System had been implemented in the United States medical education.[70] A major transformation came in 1969 when Howard Barrows at McMaster University introduced PBL, which encouraged students to analyze clinical scenarios and develop solutions independently, with instructors serving as facilitators to support self-directed learning.[60,71] A 1990 publication described an educational reform at Harvard Medical School that replaced formal lectures with problem-oriented, case-based tutorials and small group activities, aiming to integrate basic and clinical sciences by eliminating their temporal separation.[72]

Despite its widespread adoption, studies evaluating its effectiveness have reported mixed outcomes. A 2005 meta-analysis reported no significant benefit for acquiring basic factual knowledge, with a weighted effect size (ES) of –0.04. In contrast, PBL showed a strong positive effect on understanding underlying principles (ES= +0.75), and a moderate, though not statistically significant, benefit in applying knowledge to real-world problems (ES = +0.34).[73] A 2010 systematic review of 30 studies, conducted primarily in North America and Western Europe over 22 years, found that 73.3% of included studies reported no significant difference in examination performance between PBL and traditional teaching methods.[74] In contrast, a 2022 scoping review that included studies from a broader international context reported that 69% of publications found PBL to be superior to Lecture-based learning in terms of learning outcomes and knowledge acquisition.[75]

In the context of anatomy education, findings have been similarly mixed. One study compared anatomy test scores between two institutions with different teaching approaches. Institution A employed a traditional model, including lectures, guided dissections, and weekly small-group discussions. Institution B implemented a PBL approach with unguided dissections and a single weekly integrated preclinical-clinical session without lectures. Students in the traditional curriculum scored significantly higher (mean 37.5, range 25–46) than those in the PBL curriculum (mean 32.35, range 18–45, $p < 0.001$).[76] A 2014 systematic review focusing on anatomy education included studies from Western countries and the Middle East and evaluated active learning strategies such as PBL and Team-based learning (TBL). Among these, 40% of the studies reported improved examination performance, while 50% found no significant difference when compared with traditional teaching.[77] Taken together, these findings indicate that conclusions about the effectiveness of PBL remain inconclusive, which may be due in part to differences in the geographical representation of the studies included. In the context of anatomy education, there remains a need for further analysis focusing specifically on the isolated impact of PBL. At present, it is difficult to conclude that PBL is superior to conventional methods for teaching anatomy. However, existing evidence indicates that active learning approaches are more effective than traditional Lecture-based instruction.[77]

Beyond method-level evaluations, broader curricular trends raise additional concerns for the future of anatomy education. An analysis of Association for Medical Education in Europe (AMEE) guides published between 1992 and 2025 revealed that only one guide directly addresses anatomy education.[78] Additionally, AMEE's movement toward Lecture-free curricula and the growing shift toward online learning may further deprioritize hands-on anatomical training,[79,80] which itself constitutes a form of active learning. These changes raise critical questions. Is the current trajectory of anatomy education optimal? Can PBL or online methods fully replace hands-on skills gained through dissection? How should effectiveness be measured, and what defines sufficient anatomical knowledge for medical students? Most importantly, how can educators ensure that students are well-prepared to meet real-world clinical demands?

Changes in technology: digital anatomy, 3D-printing, the internet era to mobile technology, and artificial intelligence

In the 1930s, Alan Turing laid the foundation for modern computing by developing the theoretical principles of digital computation.[81,82] He later proposed the concept of AI, envisioning machines capable of autonomous thought.[83,84] By the 1970s, technological advances had produced smaller and more affordable computers, making them accessible to household user[85,86] and driving rapid changes across multiple fields.

Digital anatomy

A pivotal development in digital anatomy was the launch of the Visible Human Project (VHP) in 1988. The initiative aimed to address the limitations of traditional dissection, which restricts learners to a single perspective and does not allow for review of the dissection process.[87] Utilizing CT, MRI, and 3D rendering technologies, the VHP produced a detailed digital cadaver dataset that can be viewed from multiple angles, virtually dissected, and used to simulate clinical procedures such as colonoscopy.[88,89] Modern 3D models now incorporate virtual reality (VR), augmented reality (AR), and mixed reality (MR), further enhancing immersive learning. A 2025 systematic review

reported that VR improved anatomical knowledge in 50% of studies assessing learning outcomes and outperformed traditional methods, including lectures, prosections, two-dimensional models (2D), 3D-printing, cadaver dissection, and AR, in 75% of comparative studies.[90] A 2024 meta-analysis found that, compared with traditional methods overall, VR and AR showed a significant benefit (SMD = 0.40, $p < 0.001$), with the greatest effect when used as complementary tools (SMD = 0.52, $p < 0.001$). Cybersickness, resulting from sensory conflict between visual and vestibular systems, was reported in 25% of studies but was generally mild and transient.[91] However, a 2021 meta-analysis reported no significant difference in anatomical test scores between AR and control groups. Student motivation and engagement outcomes also remained inconclusive due to variability in the assessment tool.[92] Based on current evidence, VR and AR appear most effective when used to complement rather than replace traditional teaching methods. Importantly, none of the reviewed studies were conducted in low-income countries, suggesting limited access to these technologies in resource-constrained educational settings.[93]

3D-printed

The origins of 3D-printing date back to 1980, when Hideo Kodama proposed using ultraviolet light to form 3D objects from photosensitive resin, laying the foundation for stereolithography (SLA). In 1984, Charles Hull developed the first functional SLA printer.[94] Shortly thereafter, Scott Crump invented fused deposition modeling,[95] a technique in which heated filament is extruded layer by layer. Since the 1990s, 3D-printed models have been used in surgical planning.[96] In anatomical education, a 2016 RCT comparing painted cadaveric skulls, 3D-printed models, and 2D atlases found that students using 3D-printed models achieved the highest median post-test scores (31.5 vs. 29.5 and 27.75, $p = 0.04$).[97] Another RCT at Monash University reported significantly higher scores in the 3D-printed cardiac model group compared to those using prosected specimens or combined materials (60.83% vs. 44.81% and 44.62%, adjusted $p = 0.01$).[98] In functional simulation, a study in Singapore found that students using a 3D-printed knee joint simulator achieved higher spatial understanding scores compared to those using text and skeletal models (85.03% vs. 70.71%, $p < 0.05$).[99] A 2020 systematic review found that 3D-printed models improved learning outcomes in neuroanatomy, cardiac, and abdominal domains, with SMD of 0.69 compared to cadavers and 1.05 compared to 2D resources ($p < 0.05$).[100] With ongoing advances and falling production costs, 3D-printing continues to show promise in anatomy education. Reported learning gains fall within the medium to large effect size range, supporting its educational value. These developments also parallel broader clinical applications, including surgical simulation models, patient-specific prostheses, and emerging work in bioprinting.[101-103]

Internet and mobile technology

The internet's foundation was the Advanced Research Projects Agency Network (ARPANET), developed in the 1960s to enable connectivity among universities.[104] Following expanded public access in the 1980s, internet service providers began offering individual users connectivity via modems in the 1990s. In 1997, the University of Washington developed a web-based atlas featuring 2D images, 3D animations, and interactive quizzes, which became a globally recognized resource.[105]

The 2000s marked the advancement of smartphones, which integrated mobile phone functionality with computing capabilities such as user-friendly web browsing, email, and multimedia applications.[106] The launch of the iPhone, the introduction of Android smartphones, and the debut of mobile application platforms, including the App Store and Android Market in the late 2000s, along with the release of the iPad in 2010, accelerated the integration of mobile computing into daily life and educational practice.[106-108] Evidence from the early 2010s indicates that pre-clinical students most often preferred self-directed learning tools, with study notes as the most frequently used resource, followed by textbooks, atlases, websites, videos, and educational software.[109] A decade later, a shift in preference was reported toward anatomy websites, followed by interactive sessions, lecture notes, textbooks, and computer-assisted tools.[110] Social media has also contributed to interactive learning environments, with platforms such as Facebook, YouTube, Twitter, and Instagram used to share anatomy-related content and encourage student engagement through content creation.[111-114]

The COVID-19 pandemic highlighted the critical role of online learning, as lockdowns necessitated a rapid shift from traditional classrooms to digital platforms globally.[115-117] By 2024, improvements in infrastructure and affordability had enabled 66% of the global population to access the internet.[118] In the post-pandemic era, a 2024 study found that 51% of students identified the Visible Body application, an interactive 3D anatomy and physiology platform available on the web and tablet, as the most beneficial self-study tool. Other frequently used resources included Kenhub, Noted Anatomist, and AnatomyZone.[119]

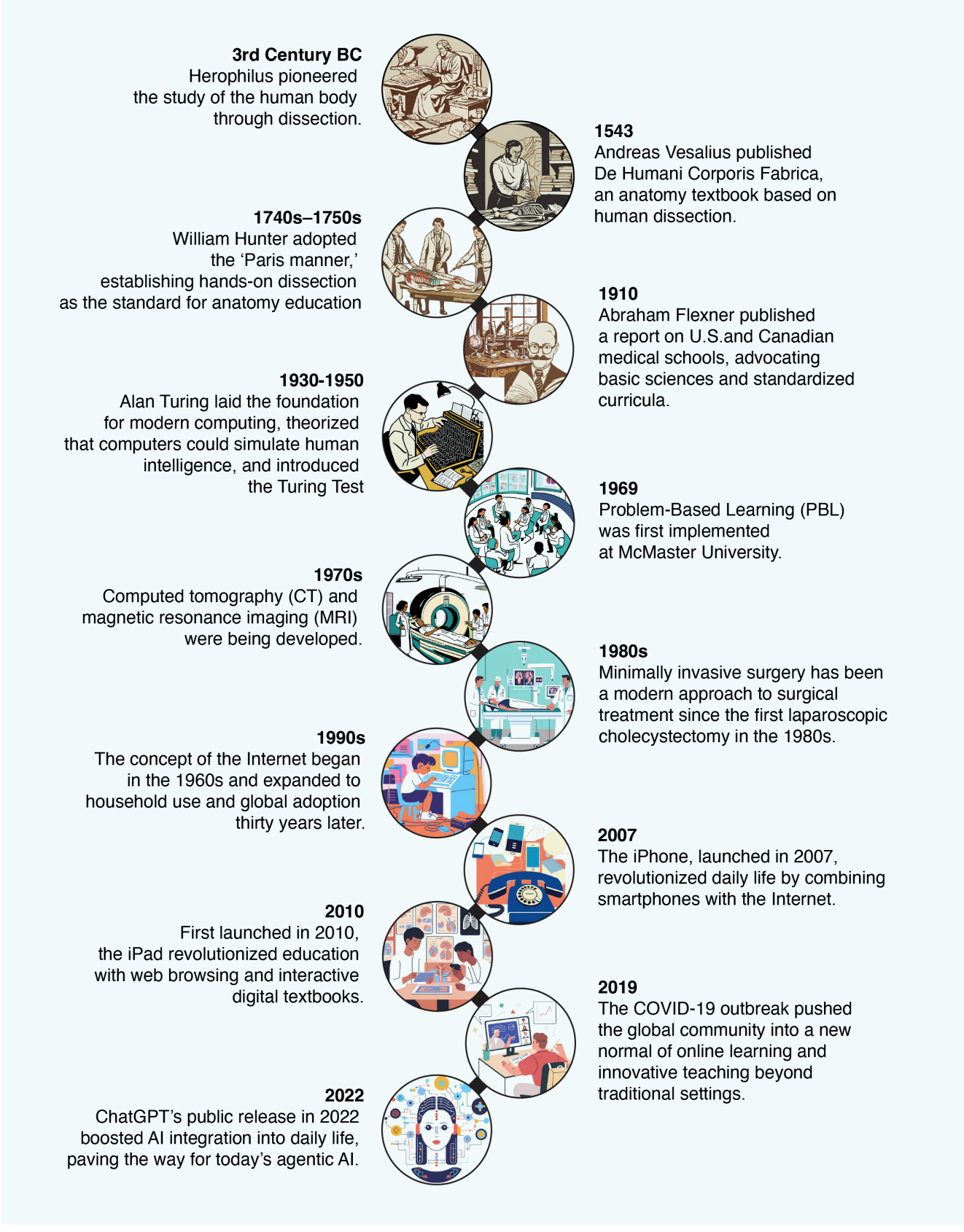


Fig 1. Timeline of the Evolution of Anatomy Education: From Cadaveric Dissection to Artificial Intelligence. The illustrations featured in this timeline were created using Canva's AI-powered image generator, Magic Media. (https://www.canva.com/apps/generate_image/magic-media).

Artificial intelligence

In the 1940s, Turing proposed the idea that machines could learn like children and gradually develop independent thinking[83,84], which was later termed AI.[120] To assess whether a machine possessed such intelligence, Turing introduced the "imitation game", suggesting that a machine could be considered intelligent if its responses were indistinguishable from those of a human.[83]

Since the 1990s, AI has shown transformative potential in medicine, initially through tasks such as interpreting electrocardiograms and detecting breast cancer via imaging.[121] By the 2010s, AI matched or exceeded physician-level performance in diagnosing conditions including skin cancer, diabetic retinopathy, colonic polyps, and various radiologic pathologies.[122] It has also been assessed for surgical decision-making and intraoperative anatomical guidance.[123,124] By the 2020s, AI had been integrated across the continuum of care, from triage to outpatient follow-up.[125-127]

AI applications in anatomy and medical education have grown rapidly, with momentum accelerating after ChatGPT's public release in November 2022, driving widespread engagement with large language model (LLMs) technologies.[128,129] In 2021, Li et al. developed the Artificial Intelligence Support System (AISS), a chatbot trained on syllabi from the UK Anatomical Society and the Chinese University of Hong Kong. Designed to enhance anatomy learning and student–teacher communication, AISS could answer questions, generate quizzes, and provide instant feedback. Although accuracy metrics were not reported, students who used the system during a one-hour session on upper limb anatomy reported increased confidence, with self-assessment scores rising from 2.10 to 3.84 on a 5-point Likert scale.[130] In 2023, Fries et al. demonstrated AI's ability to monitor learning and predict academic performance by analyzing student interactions with a virtual microscope. Their model accurately predicted practical exam outcomes in first-year medical and dental students by identifying key learning behaviors, including time spent on specific regions, study sequence, and session duration.[131] At McMaster University, researchers explored AI's potential to automate grading in anatomy practical examinations, achieving an average accuracy of 94.49% across 54 questions.[132] Another study applied AI to analyze students' reflective writing about themselves and body donors, using sentiment and emotional tone analysis to better understand student attitudes toward human anatomy.[133] These findings highlight the growing role of AI in medical education as a study companion, a tool for performance monitoring, a mechanism for early identification of students needing support, and a means of personalized learning. AI also offers the potential for reducing educator workload and generating new insights from large-scale data.

Recent advancements in 2025 LLMs, such as Google's Gemini, ChatGPT, and Perplexity, allow them to generate outputs ranging from simple explanations to full research papers.[134-136] However, several concerns about using AI have been reported since its wide adoption. A study conducted between 2022 and 2023 evaluating medical references generated by various LLMs identified fabricated or erroneous citations across multiple providers.[137] A 2023 case report showed that LLMs can fabricate healthcare-related content, highlighting hallucination risks with potential implications for scholarly integrity and clinical decision-making.[138] Accordingly, AI ethical guidelines emphasize the importance of maintaining a "human-in-the-loop" approach, whereby the user is responsible for monitoring and evaluating the results generated by AI.[139,140] Bias in AI-generated outputs has also been pointed out, reflecting the nature of its training data and algorithms.[139,140] Moreover, the World Health Organization (WHO) has raised concerns about AI's unpredictable behavior and the unclear processes behind its outputs, highlighting the importance of robust data protection and security.[139,141] Despite these concerns, AI has also been recognized as a valuable tool for idea generation, content refinement, literature synthesis, data analysis, and manuscript preparation.[142] Transparent disclosure of AI use in academic work is recommended to promote accountability.[142] In conclusion, the rapid adoption of AI in academia is unavoidable, making it essential to be aware of both its transformative potential and inherent risks.

CONCLUSION

Cadaveric dissection has been the cornerstone of anatomy teaching for nearly seven centuries, yet the three decades since the early 1990s have brought unprecedented and rapid transformation. Advances in medical imaging technologies, the development of cadaveric 3D models and AR/VR/MR, and affordable 3D printing have coincided with the rise of minimally invasive surgery, PBL curricula, financial constraints in maintaining cadaver-based systems, and evolving ethical considerations around body donation as well as safety standards in anatomy laboratories. Together, these factors have shifted many programs away from a dissection-only paradigm. Current evidence suggests that cadavers remain the gold standard for surgical simulation, spatial understanding, whereas prosection allows more time-efficient coverage but has not shown

equivalence across all body regions. Early integration of diagnostic imaging with gross anatomy enhances short-term clinical reasoning, though its long-term impact on practice remains unclear. Similarly, PBL and TBL foster self-directed inquiry, but whether these approaches can fully replicate the psychomotor and affective gains of dissection remains unresolved, particularly in an era where AI delivers information rapidly yet cannot replace hands-on skills. Immersive VR and AR, together with increasingly affordable 3D prints, show promise as complementary tools within blended learning environments. AI tutors offer potential for personalized and scalable feedback, supporting instructors by automating repetitive, non-instructive tasks, though risks of hallucinations, bias, and data governance challenges require careful oversight. To conclude, 5 key gaps warrant attention in the coming years. 1. Determining which anatomical regions and competencies require cadaveric dissection versus those that can be taught effectively through alternative pedagogies. 2. Identifying clinically applied imaging modalities that, when integrated early, reinforce anatomical knowledge, support long-term retention, and enhance diagnostic reasoning and procedural skills. 3. Developing cost-effective, globally accessible solutions to democratize advanced anatomy education. 4. Exploring, monitoring, and keeping pace with rapid AI advancements 5. Defining learning outcomes aligned with healthcare system needs for future undergraduate medical graduates and identifying pedagogical strategies to achieve them in an era where AI rapidly generates and delivers knowledge. Addressing these priorities will help shape anatomy curricula that preserve the enduring value of cadaveric heritage while embracing 21st-century innovation, ensuring graduates are clinically proficient, ethically grounded, and globally prepared.

Data Availability Statement

This study is a narrative review and did not generate any primary datasets. All sources cited in this review are publicly available in the published literature and can be accessed through the referenced journals and databases.

Limitations

While this review selectively incorporates key RCTs, systematic reviews, and grey literature, it is structured as a narrative synthesis to provide a broad, historically informed perspective that complements the focused scope of systematic reviews and meta-analyses. Future studies should assess the comparative educational efficacy of traditional and emerging modalities to build on this historical synthesis.

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Author Contributions

The sole author was responsible for all aspects of the work, including conceptualization, data curation, formal analysis, reviewing, project administration, resources, software, supervision, validation, visualization, writing the original draft, review, and editing.

Use of Artificial Intelligence

The author used Canva's AI-powered image generator, Magic Media (https://www.canva.com/apps/generate_image/magic-media), to create the illustration in Fig 1. Timeline of the Evolution of Anatomy Education: From Cadaveric Dissection to Artificial Intelligence.

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