White Paper

Conceptualize the most difficult anatomy and physiology topics with 3D technology

Anatomage™

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Preface

Providing essential knowledge to many medical areas, anatomy and physiology, beyond a doubt, help students gain significant insights into the anatomical structures and functions in keeping our bodies alive. As one of the most significant components in medical learning is cadaveric dissection, medical educators and trainers pay special attention to ensure the accuracy and efficiency of dissection materials, including cadaveric specimens and anatomy models.

In the early 20th century, cadaveric dissection was often used as the main tool for human life science discovery and education. Given the limits of physical cadavers, digital cadavers were developed which allowed students and trainers to simulate anatomy functions while manipulating human bodies without the pressure of making an irreversible mistake.

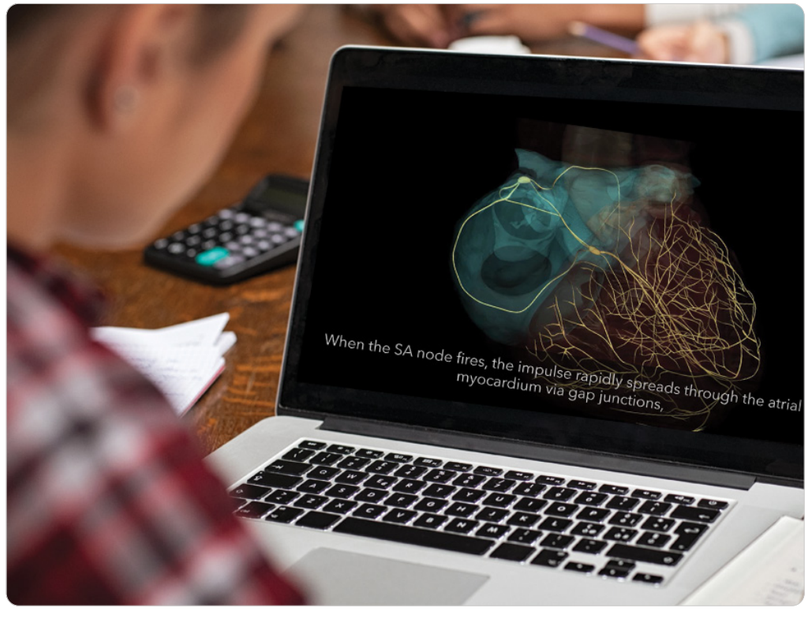
Recently, an emerging issue around the lack of human specimens and cadavers has raised concerns about the accessibility of learning materials for teaching life science. This concern also pushes for a quest to look for technologies that help students to visualize, interact with and study human bodies accurately.

> *I profess to learn and to teach anatomy not from books but from dissections, not from the tenets of Philosophers but from the fabric of Nature.*
>
> **— William Harvey**

Problem statement

Under the influence of the pandemic, a shortage of cadavers has been observed. In a survey published by BMC Medical Education[1], 78.4% of course directors reported that COVID-19 negatively impacted student learning. Specifically, 44.4% attributed the impact to the lack of dissection, while 62.4% believed it was caused by a lack of interactive experience.

Lack of dissection and interactive learning sessions have prevented students from visualizing human anatomy and its functions accurately, producing negative impacts on student learning and their learning attitude.



Without visualization, students:

Fail to conceptualize bodily structures and functions correctly

Digital cadavers, 3D anatomy models, and interactive simulators allow students to visualize intricate anatomy and functional responses that would not be possible with physical cadavers.

Experience lower engagement

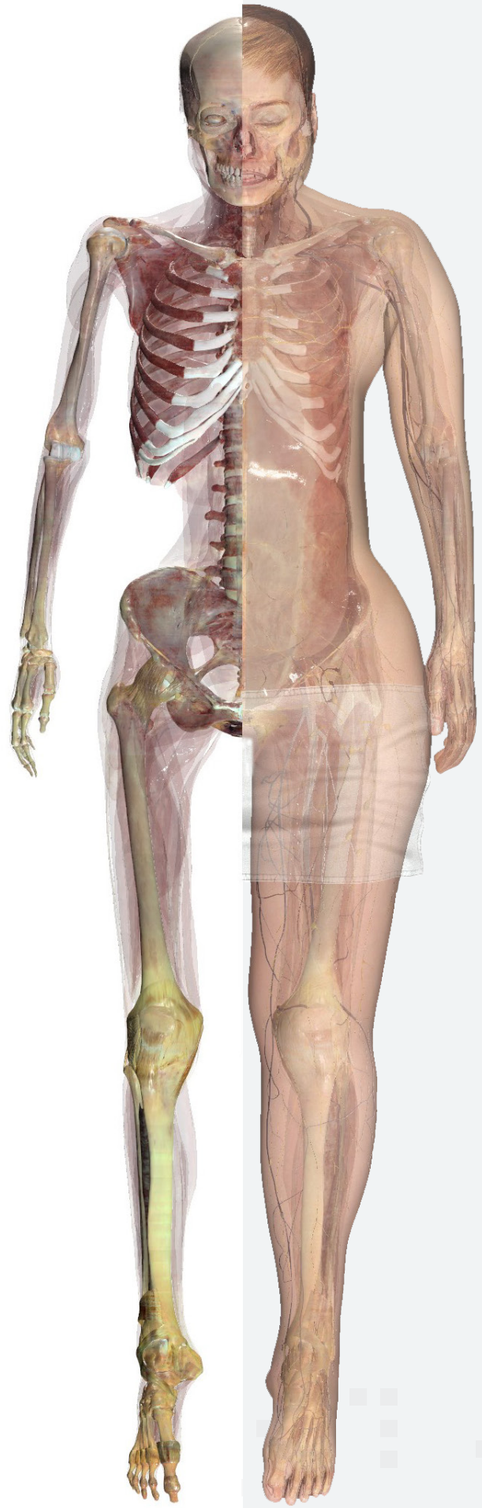
Visual learning helps students store information better while stimulating their intellectual and positive emotional responses to the subjects.

Fail to receive hands-on learning experience

Students that engage in dissection can gain hands-on experience in learning anatomical variations and functions, leading to a deeper understanding of physiology.

Visualizing challenges in anatomy and physiology

Visualization is an important process in medical learning. For many years, the human body has been deciphered through the use of cadaveric dissection, anatomy illustrations, and plastic models. These approaches, though academically beneficial, are often debated for the delivery of clinical accuracy, student safety, and failure to portray physiological responses.



Introduction to digital modeling and simulation

Modeling

- Provides a visual representation of data
- Magnifies complex structures for a better view
- Accurately illustrates spatial relations of anatomical structures

Simulation

- Generates an interactive experience of real-world processes
- Demonstrates real-world clinical scenarios for medical insights
- Allows students to acquire knowledge about real-life clinical processes

> One of the limitations of cadaveric dissection is its susceptibility to damage or decay, hindering students from visualizing living anatomy or structures in the original state.

Exposure to formaldehyde also creates adverse effects on student health such as eye irritation, coughing and a burning sensation in the skin. Prolonged exposure can cause severe choking in the throat and even death.

Like cadaveric dissection, static anatomy illustrations or plastic models lack the capabilities to simulate functional responses. With functional anatomy continuing to be the foundation in many clinical areas (i.e., sports medicine, physical therapy, and kinesiology), it's critical for students to visualize how anatomy structures interact with each other.

As traditional methods of studying anatomy may pose visualization challenges, the demand for a solution that allows students to visualize both gross and functional anatomy concepts is formed. To understand these challenges deeper, we asked a group of medical educators to list three anatomy and physiology concepts that students have trouble visualizing.

After analyzing the data, we devised a solution leveraging 3D simulation and modeling technology.

How we conducted the survey

Phase 1 Launched a survey targeting 6,000+ medical educators and asked them to identify three anatomy and three physiology topics that students have trouble visualizing. Specifically, we asked them to rank particular anatomy and physiology concepts from 1 to 5, with 1 being the easiest and 5 being the most difficult.

Phase 2 Randomly selected 100+ responses from the segment to analyze the data.

Phase 3 Devised a solution approach to help students conceptualize the challenging topics better.

Phase 4 Formed a conclusion that inspires and guides educators to adopt appropriate technology to combat academic challenges in medical education.

Methodology

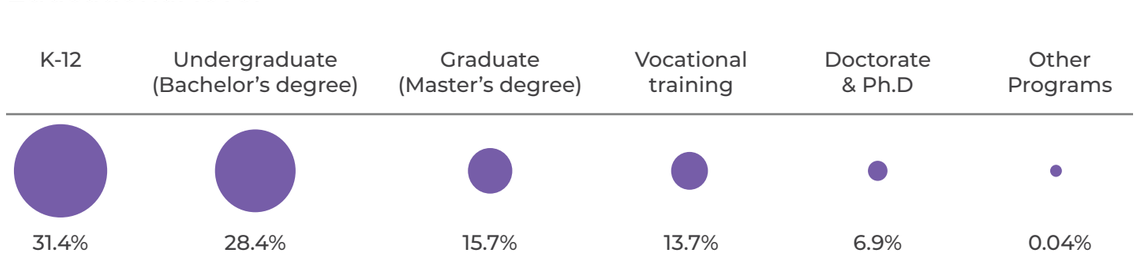
Cracking the code of visualization challenges can't be done without insights from medical educators. To investigate the challenges, Anatomage launched an outreach campaign to 6,000+ medical professionals across the United States. We asked them to identify the most challenging anatomy and physiology concepts. The goal was to develop solutions to combat the associated academic challenges.

Survey audience

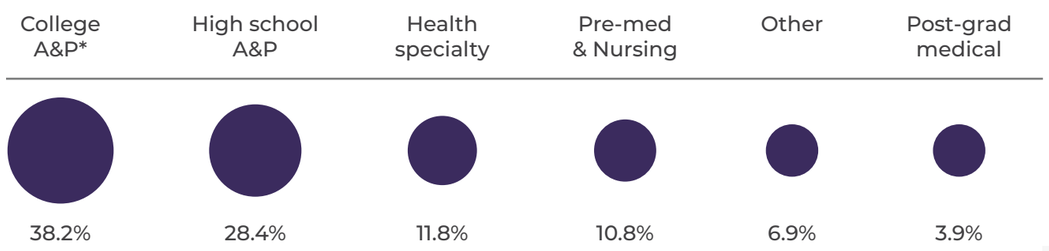
The survey's target audience comprises more than 6,000 individuals from the medical education and healthcare industries. Their industry segments range from K-12 to post-graduation. In an effort to diversify the survey data, we gathered pedagogical insights from education and medical professionals whose job titles and curricula vary primarily in their scope of work and course emphasis.

With a diverse audience, we ensured the quality and credibility of the survey's data thereby allowing us to understand that the named challenges have been persistent across various medical programs and are not exclusive to a particular educational level or specialty program.

Educational level



Course breakdown



* Anatomy & Physiology

Survey results

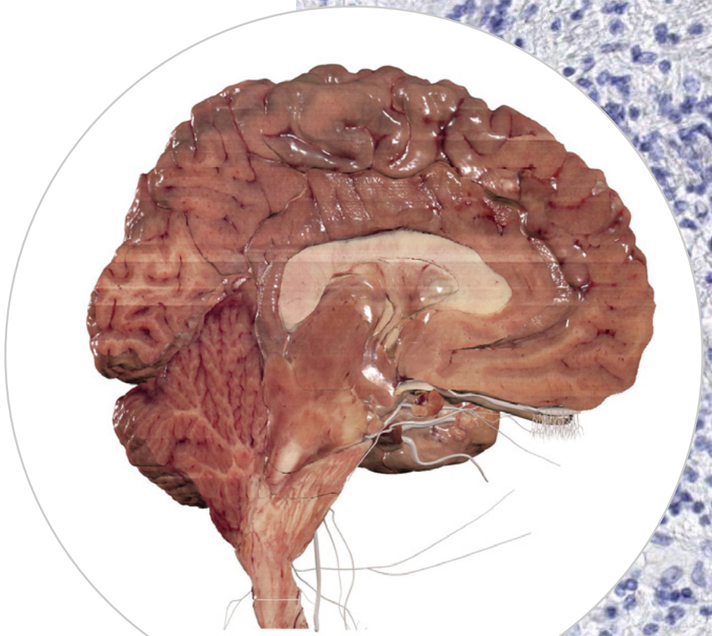
According to the survey's final data, the following topics were identified as the most challenging anatomy and physiology concepts to visualize. For anatomy concepts, the brain (39.2%), nerves (33.3%), and histology (31.4%) were selected as the most difficult concepts, while the integumentary system (4.9%) was chosen as the least challenging concept. These results were expected as the brain is often regarded as the most complex organ, and the integumentary system is known for having a small number of terms[2] or structures required to study (37 terms compared to 370+ terms in the nervous system).

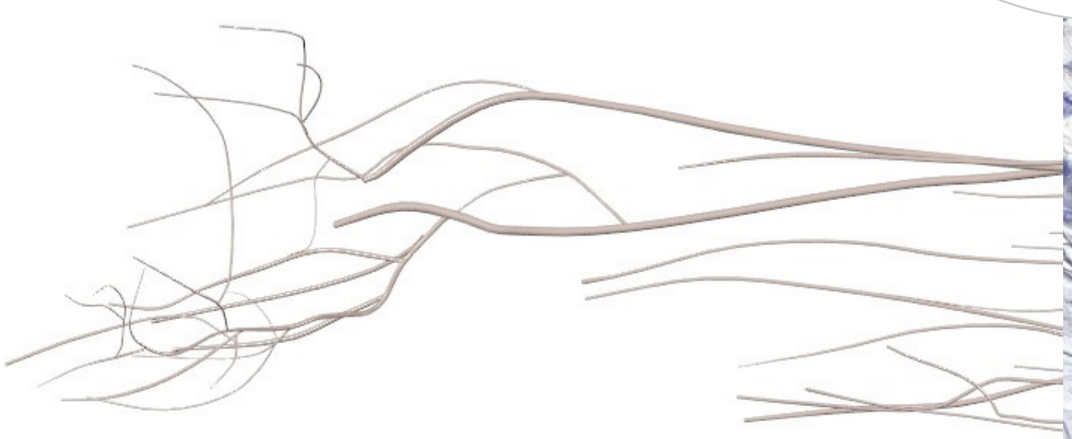
For physiology concepts, 51.0% of the respondents chose neural pathways as the most challenging physiology topics to visualize, followed by cellular respiration (32.4%), and renal function (30.4%). Surprisingly, the least challenging physiology topic named was kinesiology (7.8%). This contradicts our assumption that students may find it tough to visualize kinesiology as it often requires more than 300+ terms to memorize[2], and without visualization tools, studying the kinesiology terminology can pose a challenge.

Most difficult anatomy concepts

Cracking the code:

- Brain
- Nerves
- Histology





> Composed of at least 100 billion nerves to process a trillion different communications, the brain is undoubtedly the most complex organ.

Cracking the code: Brain

The more complicated an organ system is, the higher amount of time it requires for students to read, memorize, and review the key concepts. This can explain the rationale behind selecting the brain as the most challenging concept to visualize by 39.2%. The data corroborates the results from another survey conducted by HAPS[2], the Human Anatomy and Physiology Society, which concluded that the central nervous system (comprising the brain and spinal cord) was rated as the top three difficult organ systems to learn.

39.2%

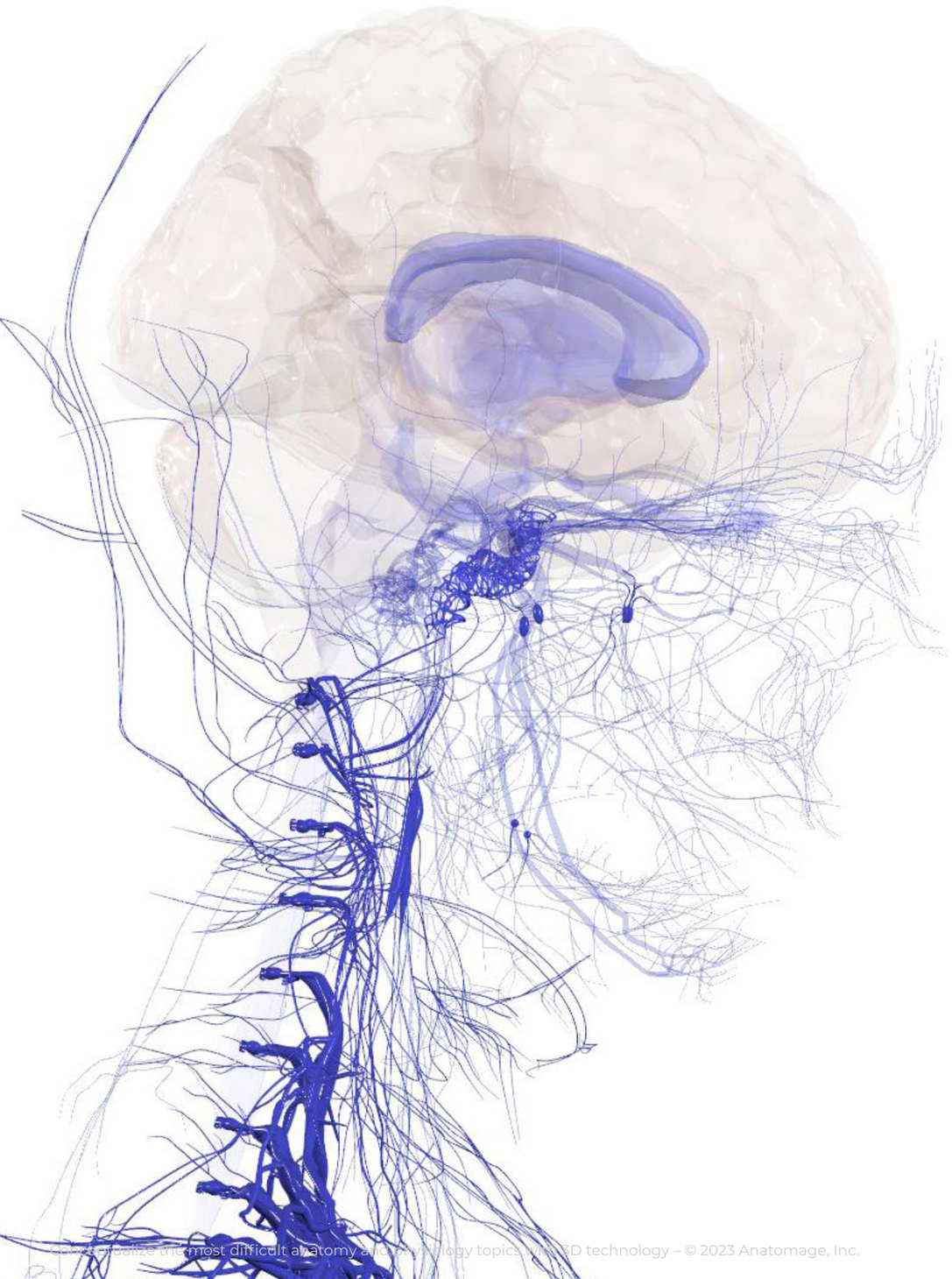
identified the brain as the most challenging anatomy concept to visualize

(Source: Anatomage)

26.8%

identified the central nervous system as the most challenging organ structure to learn

(Source: HAPS)

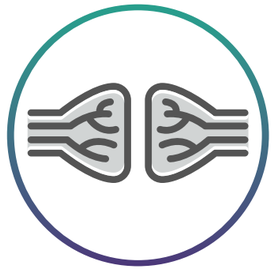


Widely regarded as the most complicated system in the human body, learning about the nervous system involves immense knowledge of the terminology of different structures and functions.

Cracking the code: Nerves

Given its critical role in helping all body parts communicate and process almost all internal and external activities, the nervous system is undoubtedly a highly important learning topic for medical students. Its extensive network and functions also make it the most demanding concept to learn.

With that said, it's not surprising that 33.3% of the survey's respondents selected nerves as the most challenging anatomy concept to learn. Our data from the in-house survey once again confirms the data from the HAPS survey, in which the entire nervous system (Central, Peripheral, and Autonomic nerves) was rated by 72.2% as the most challenging structure.



33.3%

identified the nerves as the most challenging anatomy concept to visualize

(Source: Anatomage)

33.3%
central nervous

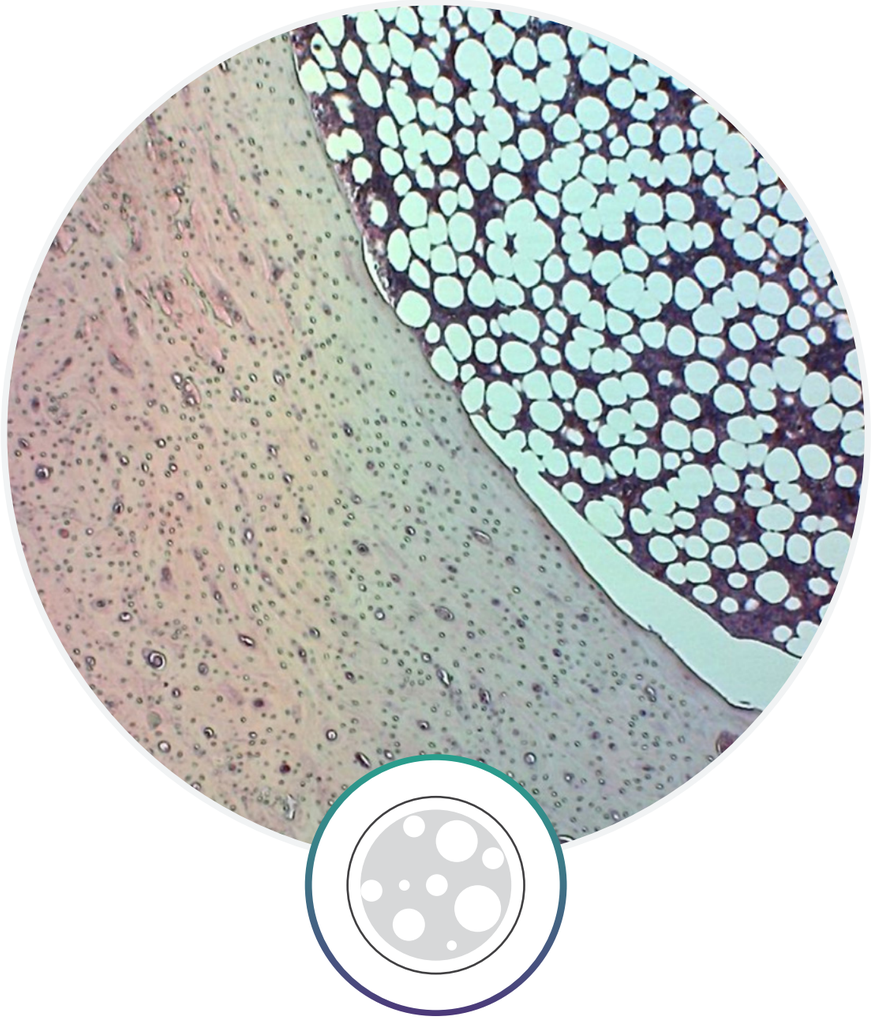
30.8%
peripheral

26.6%
autonomic

identified as the most challenging organ structures to learn

(Source: HAPS)

Learn & visualize the most difficult anatomy and physiology topics with 3D technology – © 2023 Anatomage, Inc.



31.4%

identified histology as the most challenging anatomy concepts to visualize

(Source: Anatomage)

> In simple terms, histology, or microanatomy, is the study of small “anatomical” things.

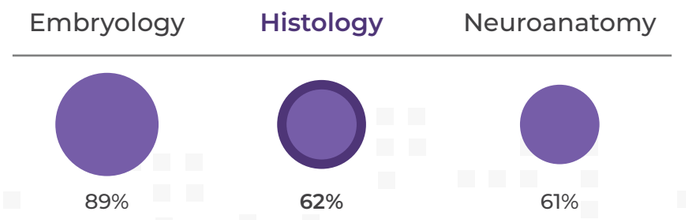
Cracking the code: Histology

Biological tissues, cells and microscopic organs are often the learning subjects in histology. And as the structures of cells and tissues are too small that they can only be observed through a microscope, visualizing histological concepts isn’t a simple task. With the high associated costs to purchase and maintain microscopes, in addition to the dependency on the availability of histology slides, many teachers may face difficulties in teaching histology.

Our Anatomage survey indicates that 31.4% of medical professionals found histology as the toughest anatomy concept for students to visualize At the college level, histology has been reported to be the most difficult topic to study.[6] Specifically, the difficulty of learning histology was attributed to the differentiation of tissues. To overcome the difficulty, virtual microscopic solutions[3] were suggested then adopted. As a result, student perception of histology was enhanced and expanded.

Army Medical College Survey

Most difficult anatomy concepts to learn by undergrad med students



Solutions: 3D modeling

After analyzing the top most challenging anatomy concepts, we perceived that the common rationale behind such selection could be related to (1) the complexity of the mentioned system, (2) the visibility of the system's anatomical structures, and (3) the function of the structures and how clinically significant the structures are compared to the rest of the body. We believe that these challenges can be addressed by the use of 3D modeling.

Ways that 3D modeling can be leveraged to better visualize complex anatomical structures:

Simplifies intricate structures through 3D segmented anatomy

3D modeling of segmented anatomy enables multi-view visualization of deep structures within the organs. Traditionally, students would need to perform a craniotomy on the skull to access deep structures inside the brain, such as the hypothalamus, thalamus and pineal gland. Nowadays, 3D platforms can produce virtual brain models allowing users to easily visualize segmented structures located deep inside the brain. Advanced segmentation technology[4] successfully replicates the entire human nervous system into a 3D model depicting a full network of nerves.

Increases the visibility of the microscopic structures

As cells and tissues are invisible to the naked eye, teaching histology depends on the accessibility of microscopic devices and histological slides - which sometimes are unattainable due to economic barriers. 3D modeling platforms with histology content can provide easy access to the microscopic slides, assisting students in visually differentiating various types of tissues.

Provides additional anatomical context into pathology

Complex structures tend to pose diagnostic and treatment challenges. For instance, brain surgeries are often associated with serious risks and post-procedure complications. Many hospitals and healthcare facilities are implementing 3D anatomy for visualizing the tumor location and improving surgical outcomes. In 2018, the Mayo Clinic revealed to the press that it had successfully removed a lime-sized tumor from a patient's brainstem. While other institutes had believed such a procedure was not a viable option, Mayo Clinic utilized a virtual dissection table to map out the surgical steps then effectively detached the tumor from the patient's spinal cord.

Most difficult physiology concepts

Cracking the code:

- Neural pathways
- Cellular respiration
- Renal function

> Neural pathways, a critical concept in neuroanatomy, can be simultaneously interesting and puzzling.

Cracking the code: Neural pathways

Acting as a bridge that exchanges information through neurons within a nervous system, neural pathways can create up to 25 quadrillion connections. Like the brain, neural pathways can be classified into simple or extremely complex types depending on their responsibilities for processing a specific set of behaviors, habits, and senses. With these said, the function of neural pathways may be too ambiguous to conceptualize with just reading.

Expectedly, in Anatomage's customer survey, more than half of the medical educators (51.0%) also agreed that visualizing neural pathways is the toughest task. The difficulty level of neural pathways seems to correlate with the challenges faced in visualizing the brain (39.2%) and nerve structures (33.3%). We, therefore, speculated that these findings might be due to the lack of available technology that simulates neural pathways, students' limited understanding of the nervous system (including brain), or the inefficiency of the pedagogical approach to teaching the pathways.

51%

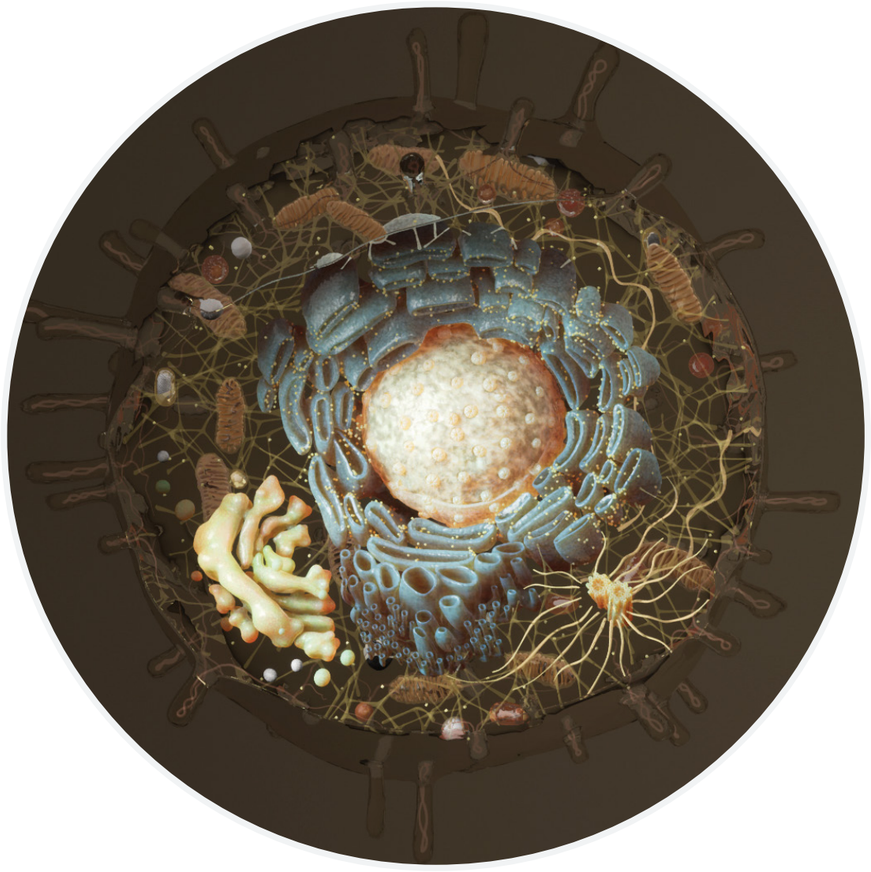
indicated neural pathways as the most challenging physiology concept to visualize

(Source: Anatomage)

33.3%

indicated the nervous system as one of the most challenging anatomy concepts to visualize

(Source: Anatomage)



> Though not conventionally emphasized in fundamental anatomy & physiology courses, cellular respiration is still an important topic for students who want to apply histological knowledge to biology.

Cracking the code: Cellular respiration

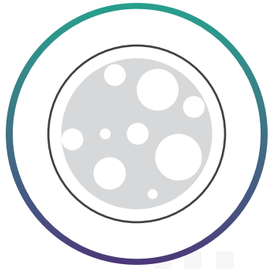
Since having a basic understanding of cells, biological tissues, and biochemistry is the prerequisite, students may find it challenging to integrate and apply all these concepts into comprehending the cellular respiration process.

According to our survey, 34.3% of the respondents reported that cellular respiration is the hardest physiology topic to visualize. This data reinforced the previous responses indicating histology as one of the most challenging anatomy topics (31.4%). And because cellular respiration involves the inner workings between cells and other histological tissues, students' failure to visualize histology may contribute to struggling in learning the topic.

34.3%

indicated metabolic (cellular) respiration as the most challenging physiology concept to visualize

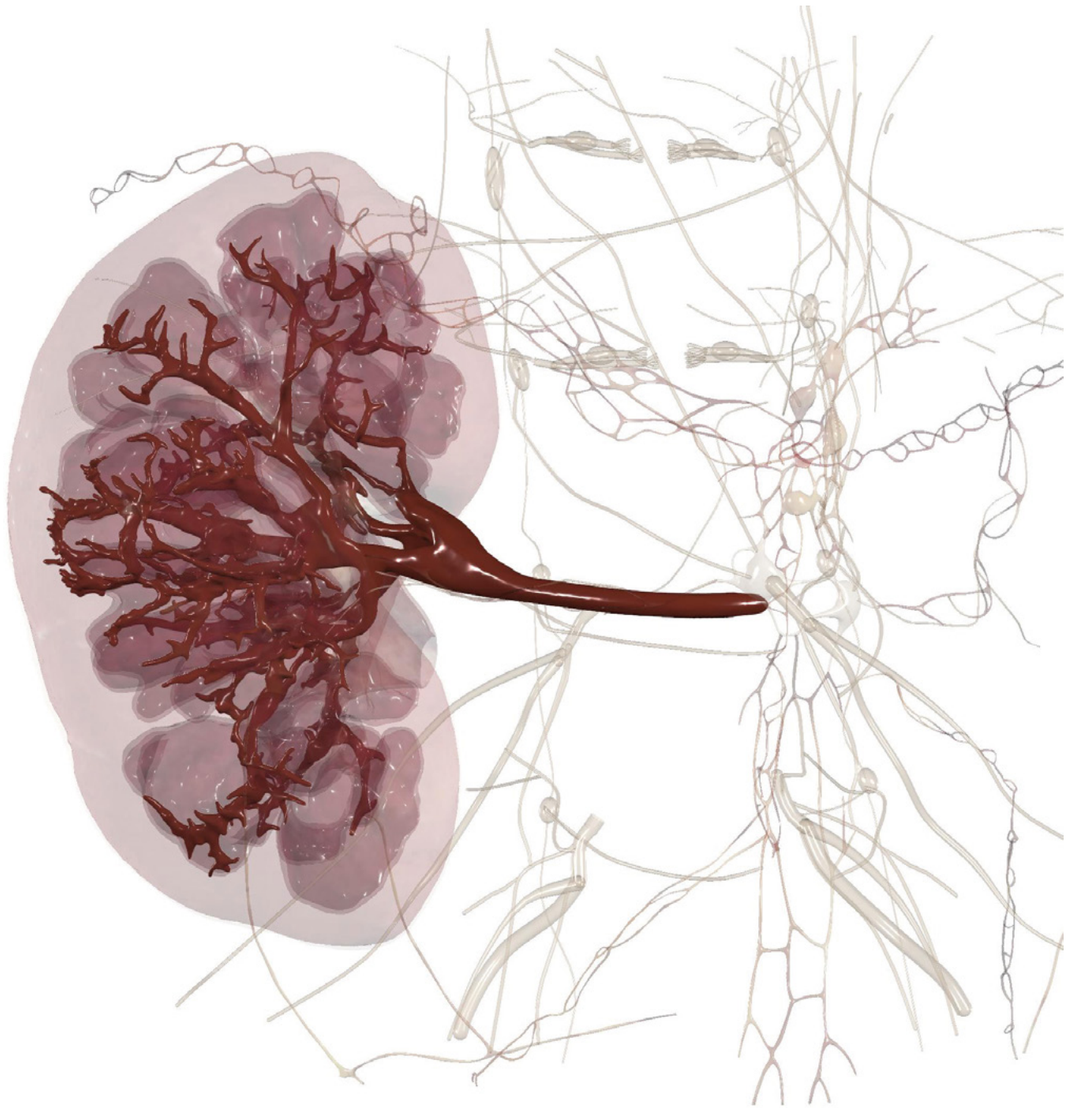
(Source: Anatomage)



31.4%

indicated histology as one of the most challenging anatomy concepts to visualize.

(Source: Anatomage)



> Anatomage's customer survey denotes that 30.4% of medical professionals found renal function as one of the most challenging physiology concepts.

Cracking the code: Renal function

Findings from Anatomage's customer survey could be influenced by the difficulty in visualizing the renal regulation of different substances and actions produced by various physiological phases (i.e., filtration, reabsorption, etc). Students' lack of core chemistry knowledge could also be a factor.

Comparisons across many surveys show that the urinary system is often rated as one of the least difficult anatomy concepts. For instance, HAPS ran a study to determine the most difficult organ systems and found that the urinary system was found among the least challenging concepts. One of the correlators with the difficulty level, as reported by HAPs, was that the required number of terms to learn about the kidney system (39) in the course was much less than other systems such as the nervous (371), skeletal (317) and muscular systems (102). Anatomage's in-house survey also specified that the kidney structures (19.6%) weren't perceived as the top most challenging anatomy concepts by medical professors.

These contradicting findings could be potentially shaped by the difference in priorities between learning anatomy versus physiology. Terminology fluency is often prioritized in anatomy while physiology demands integrative knowledge across science disciplines (i.e., chemistry, biology, and math). Understanding these priorities can improve student success in both anatomy and physiology courses.

30.4%

indicated renal function is the most challenging physiology concept to visualize

(Source: Anatomage)

19.6%

Conversely, the kidney was identified one of least challenging anatomy concept to visualize.

(Source: Anatomage)

Solutions: 3D simulation

Successfully studying physiology relies on the comprehensive knowledge of anatomical sciences, chemistry and biology. The ability to conceptualize different functional mechanisms in the human body is highly subject to the accessibility of proper technology, hands-on activities, and resources to stimulate student learning.

The common theme for why medical professionals found neural pathways, cellular respiration and renal function as the most difficult physiology concepts was potentially due to (1) the complexity of physiological and chemical processes (2) students' failure to retrieve anatomy, chemistry and biology knowledge and (3) the inadequate usage of simulation technology for hands-on clinical experience.

With the versatility of today's simulation technology, simulating functional responses is no longer a challenge.

Ways that 3D simulation can be used to conceptualize complex physiology concepts better:

Simulates physiological processes in 3D

3D simulation translates complicated physiological reactions into interactive experiments for students to easily see how different parts of the anatomical systems work with each other. Virtual labs can simulate chemical reactions and even allow students to run tests to assess the function of human systems.

Offers visual guides to apply other life science concepts to physiology

Today, medical instructors use digital cadavers to teach gross anatomy as it illustrates a complete anatomical map of human body systems. Selected digital cadavers are equipped with interactive simulation features that produce functional responses providing a complete picture of how the human body orchestrates anatomical structures to keep it alive.

Enables a clinically-relevant learning environment

A major benefit of 3D simulation is its capacity to simulate clinical scenarios for students to practice patient treatment. For example, instead of actual people, students and medical professionals can practice clinical diagnoses and surgical simulations on virtual patients. This will allow students to acquire real-life patient care experience and doctors to reduce medical errors.

Visualizing life with Anatomage Table

The goal of science is to allow us to discover, study and understand life to preserve, maintain, and advance it.

Concepts to reality

To understand life, we rely on the information that the human body offers us - from its structures, systems, and functions. Learning anatomy helps us to absorb these details academically.

The human body contains tremendous information that can't be digested efficiently using one medium. Whether it's books, cadaveric dissections, virtual anatomy, or physiology simulation, many approaches aim for one goal: turning learning concepts into reality.

Fostering this idea, Anatomage has invented the Anatomage Table, a 3D visualization and simulation platform that allows students to dive deeper into gross anatomy, and visually discover the clinical significance behind every anatomical structure.

From when the body moves and functions to when it suffers from diseases, the Anatomage Table transforms anatomy concepts into reality, enabling learners to visualize, study, and understand life better.

Anatomage Table Use Case Scenarios

3D anatomy enhances visualization of complicated clinical concepts.

Ways to incorporate Anatomage Table into your classroom to help students visualize difficult anatomy concepts:

Learn

Anatomy visualization
3D anatomy and virtual dissection allow students to examine deep structures inside complex organs such as the brain and nerves.

Simulation lab
Simulation tools enable interactive views of bodily functions, providing visual details of how anatomical systems work with each other.

Microscope experiments
Real-tissue histology slides let students accurately study the microscopic structures of various organs.

Experience

Disease studies
Instructors can illustrate how diseases affect anatomical structures with real-anatomy clinical cases.

Virtual surgeries
Students can perform surgeries on virtual patients, exploring location and spatial relations between anatomical structures.

Radiology reading
Visualizing abnormal anatomy through DICOM images assists students in determining the physiological impact of illness.

Anatomage Table Case Study

Topic:

Structure Identification[7]

Background:

Research conducted at Sidney High School assessed the impact of the Anatomage Table on learning skeletal and muscular systems.

Framework

22 students from an Anatomy and Physiology class at Sidney High School were split into two groups:

Comparison
(without access to the Table)

Experiment
(with access to the Table)

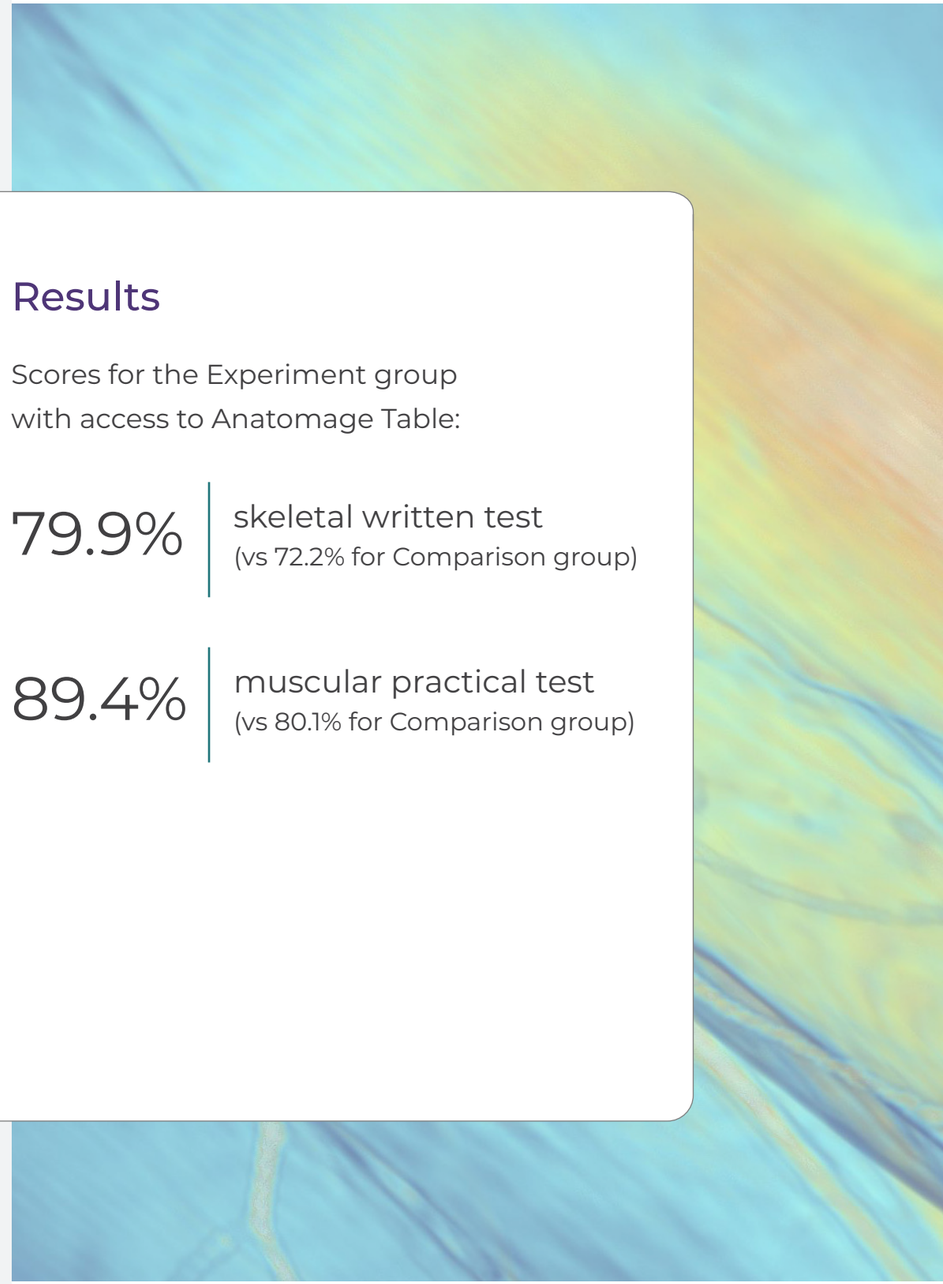
The Comparison group utilized 2D diagrams and images for skeletal and muscle identification. The Experiment group used the Anatomage Table to look at cadaveric structures, pathology case studies, microscopic slides, and functional anatomy in 3D.

Results

Scores for the Experiment group with access to Anatomage Table:

79.9% | skeletal written test
(vs 72.2% for Comparison group)

89.4% | muscular practical test
(vs 80.1% for Comparison group)



Anatomage Table Case Study

Topic:

Understanding Spinal Anatomy[8]

Background:

Life University coordinated a study to compare the academic effects of lessons taught with the Anatomage Table, physical cadavers, and anatomical models.

Framework

The study's audience consisted of 1st-year chiropractic musculoskeletal anatomy students whose lecture and lab exam scores were evaluated in a three-year period. The students were divided into three groups:

- **Cohort 1** practiced dissection on physical cadavers in addition to anatomical models and atlas
- **Cohort 2** utilized anatomical models and atlas
- **Cohort 3** used models and had access to the Anatomage Table

Results

Cohort 3, the group that had access to the Anatomage Table, outperformed the other two groups on laboratory examinations.

85.1%	Cohort 3
81.4%	Cohort 2
76.4%	Cohort 1

Anatomage Table Case Study

Topic:

Peripheral Nerve Blocks[9]

Background:

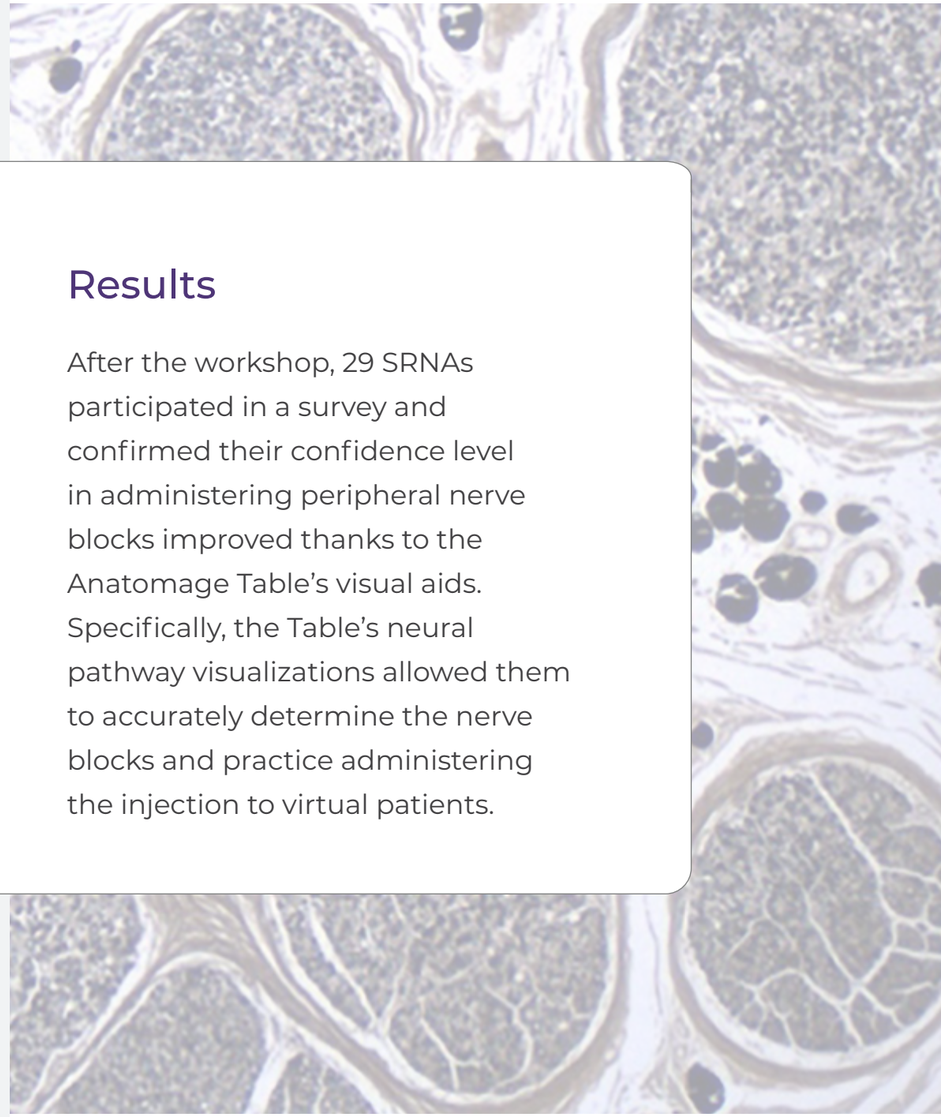
Southern Illinois University-Edwardsville (SIUE) Nursing Anesthesia program hosted a workshop where second-year student registered nurse anesthetists (SRNAs) utilized the Anatomage Table to understand anatomy associated with peripheral nerve blocks.

Framework

During the workshop, SRNAs were asked to identify landmarks with the Anatomage Table. The students were able to visualize the corresponding structures' locations and positions better by using the Table's technology to isolate the landmarks.

Results

After the workshop, 29 SRNAs participated in a survey and confirmed their confidence level in administering peripheral nerve blocks improved thanks to the Anatomage Table's visual aids. Specifically, the Table's neural pathway visualizations allowed them to accurately determine the nerve blocks and practice administering the injection to virtual patients.



Conclusion

A crucial part of learning gross anatomy, 3D modeling, and simulation enable both educators and students to engage with the anatomy materials interactively. In addition to providing in-depth visualization of the human anatomy, it also offers visual insights into functional anatomy which cannot be accomplished with physical cadavers.

Most importantly, 3D modeling and simulation technology simplifies the most complicated learning concepts by turning them into reality, allowing trainers to gain real-world clinical knowledge.

Appendix

Academic advantages of Anatomage Table’s 3D visualization and simulation

Features

Interactive anatomy simulation
Visually conceptualize challenging functional anatomy concepts that can’t be obtained through cadaveric dissections

Clinical applications
Interact and manipulate real-patient MRI/CT scans to inspect pathological responses from natural human bodies

3D dissection
Orchestrate virtual dissection on real human bodies to explore more than 2,950 anatomical structures within 11 human body systems

Impact

Accurate perception
Delivers a highly insightful and accurate perspective into how anatomical systems work with each other

Comprehensive anatomy
Amplifies student learning experience with extensive anatomy and pathology content authenticated by experts

Technological leadership
Helps institutions establish technological leadership within their community, improving student application rates

About Anatomage

Anatomage is a digital healthcare platform dedicated to improving the quality of life for all people. We specialize in bringing accurate medical solutions to healthcare providers and inspiring the next generation of health professionals across the globe.

Through our 3D visual technology, we provide the most diverse, complete and accurate digital anatomy of the human body. Our products and services are used for education, product development, and clinical applications, including the diagnosis and treatment of medical conditions. Our customers range from teachers and their students to prestigious medical schools and healthcare systems.

To learn more:

Visit anatomage.com

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