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Integrating recent scientific breakthroughs and emerging technologies into basic medical education: A focus on histology and embryology

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Highlights

Integrating cutting-edge scientific advancements and new technologies into histology and embryology education not only enriches traditional teaching methods but also aligns the curriculum with the needs of the modern era. It broadens students' perspectives, fosters greater interest in scientific research, and lays a solid foundation for cultivating interdisciplinary medical professionals in the new era.

Abstract

Basic medical education is the cornerstone of healthcare development, directly impacting the well-being of a nation's population. The advancement of modern medicine has raised increasing demands on the research capabilities of medical students. Therefore, it is crucial to foster their research interests and cultivate their research skills early in their education. As core components of basic medical science and introductory courses to immerse medical students in the intricate microscopic world of the human body, histology and embryology are indispensable in medical education, igniting their curiosity. Incorporating cutting-edge research into education courses can effectively stimulate medical students' research interests. This article primarily focuses on histology and embryology to explore how the latest scientific advancements and emerging technologies can be incorporated into basic medical curricula, offering insights and suggestions for future developments in medical education.

Keywords: Medical education, histology and embryology, progress in science, new technologies

Introduction

Basic medical education serves as the foundation of a nation's healthcare development, directly influencing the health and well-being of its citizens. Over the years, China has established a higher education-based system to accelerate the advancement of medicine [1]. However, traditional basic medical education methods no longer meet the demands of rapidly evolving scientific and technological developments, nor do they fulfill the curiosity and broadening perspectives of modern students. Medical students often emphasize textbook learning over practical experience, which in turn hampers the progression of medical expertise. Therefore, improving the methods, practices, and levels of medical education has become a crucial issue.

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This paper reflects on the need to integrate cutting-edge scientific advances and new technologies into histology and embryology education to cultivate research-oriented medical professionals. It highlights the evolving role of these subjects in bridging basic anatomy with molecular medicine, emphasizing how current curricula often fall short in incorporating recent research and technological progress. By introducing innovative tools such as digital microscopy, spatial transcriptomics, and gene-editing techniques into both theoretical and practical components of the curriculum, educators can inspire students to engage in research, fostering the development of the next generation of medical researchers. The paper argues that this pedagogical shift is essential for preparing students for the challenges of future medical practice and scientific discovery, ensuring that they are equipped not only with clinical skills but also with a strong foundation in research and innovation.

Cultivating research-oriented medical students for future healthcare demands

Evolving research competencies in modern medical practice

With the rapid advancement of science and technology, the medical education system in China is also undergoing rapid reform, particularly in areas such as medical education, residency training, specialist training, continuing medical education, and graduate education. Within this transformative landscape, two critical challenges emerge: the modernization of pedagogical approaches and the integration of scientific innovation into medical education [2, 3]. For medical students entering any medical-related profession, research competency is a key determinant of long-term career success. Modern medical professionals must combine teaching, clinical practice, and research skills, in line with the national strategy to cultivate talent for a technologically advanced nation. Therefore, it is imperative to introduce cutting-edge scientific knowledge early in undergraduate medical education.

Disparities between current curricula and future research requirements

Universities aim to cultivate well-rounded talents by integrating basic education with innovative research. However, medical undergraduates predominantly acquire knowledge through textbooks, and there is often a significant lag in integrating scientific research into these educational materials. As a result, students who rely solely on current coursework may fall behind in understanding contemporary scientific progress. It is crucial for students to stay informed about latest research development that has not yet been included in textbooks. While some students with an interest in research may join faculty research groups, this is only a small subset of the student body and does not reflect the broader educational goals of universities [4]. Given the vast scope of medical molecular sciences and the absence of standalone courses on recent scientific advances, it is neither practical nor feasible to establish a separate course solely dedicated to research advancements. Instead, integrating relevant scientific progress into existing courses is a more feasible approach. This would broaden students' perspectives, stimulate their interest in research, and motivate them to participate in research teams, thus fostering their research skills and preparing them for future postgraduate education.

Developing research competencies through histology and embryology education

Fundamental role of histology and embryology in medical education

As crucial subjects in medical education, histology and embryology play a foundational role in understanding human anatomy at the microscopic level. These subjects bridge gross anatomy with cellular and molecular physiology and pathology, forming the foundation for more advanced medical disciplines. Additionally, histology and embryology heavily rely on cutting-edge research tools and techniques, which continue to evolve with advancements in technology. The rapid advancement of information technologies has led to the creation of innovative tools that deepen our understanding of histology and embryology, further driving progress in medical science. Therefore, histology and embryology are indispensable components of medical education [5].

Fostering research interest in medical students through histology and embryology education

Histology and embryology are introductory subjects, in which medical students explore the microscopic world of the human body, offering an ideal opportunity to ignite curiosity about medical research. The complexity and beauty of microscopic structures, combined with the latest scientific discoveries, can inspire students to pursue research careers. By introducing new advances and technologies into the curriculum, educators can foster students' research interests and enhance their understanding of

current medical developments. For instance, educators can highlight which fundamental problems have been solved, which are currently being addressed, and which remain unresolved. This dual focus on both clinical practice and research helps cultivate future medical scientists and physicians equipped with research skills necessary to meet evolving healthcare needs [6].

Incorporating scientific advances and new technologies into histology and embryology education

Current landscape of histology and embryology theory education

Histology and embryology consist of two major components: histology, which studies the microscopic structures and functions of tissues, and embryology, which focuses on the development and growth patterns of the human body. As fundamental courses in medical education, they serve as introductory subjects for further study. Traditionally, the teaching of these subjects has relied heavily on textbook-based knowledge, with students often memorizing content through lectures. However, textbooks frequently fail to integrate the latest technological advancements, leading to a gap between students and current scientific progress. This reliance on outdated materials can dampen students' interest in research and hinder the development of innovative thinking.

Modernizing theoretical education through scientific and technological integration

As students engage in the study of disciplines related to the structure and function of the human body at the microscopic level, they will discover that the fields of histology and embryology are rapidly advancing and progressing. Many new discoveries and research findings can enrich students' understanding of these fields. For example, traditional methods such as paraffin sectioning and hematoxylin-eosin staining are commonly taught in textbooks, enabling students to observe cellular arrangements and functions under a microscope. However, newer technologies, such as spatial transcriptomics and single-cell sequencing, which allow for RNA expression mapping within tissue slices, are not mentioned in most textbooks [7-9]. These advanced techniques provide insights into gene expression at subcellular levels, significantly enhancing their understanding of tissue architecture. Introducing such technologies during lectures on research techniques can spark students' interest and encourage their engagement in hands-on practice.

Enhancing practical education through research integration

Traditional histology and embryology practical sessions often rely on outdated equipment, with students using optical microscopes to examine tissue sections. These methods can be time-consuming, and variations in slide quality can lead to confusion, leaving limited time for in-depth exploration of the subject. However, with the rapid advancement of science and technology, new tools and methods are emerging, making interactive digital microscopy systems a promising trend in histology education. These systems combine intelligent terminals, wireless communication, and digital imaging, providing high-resolution images and interactive features [10]. Such technology enables more efficient collaboration between students and instructors, as well as greater flexibility in learning [11-13]. Data can be stored on portable devices and synced to the cloud, enhancing both student engagement and teaching efficiency. By incorporating relevant scientific advances and new technologies into histology and embryology courses, educators can broaden students' horizons, keep their knowledge up to date, and better prepare them for careers in both medical practice and research. Some students may even become leading figures in the medical field, contributing to the advancement of healthcare.

Examples of integrating scientific advances and new technologies into histology and embryology education

As introductory courses for medical students, histology and embryology cover the study of four major tissue types, eight systems, and embryonic development. During classroom instruction, educators can leverage advanced tools like the interactive spatial transcriptomics system to enhance students' efficiency in learning and identifying anatomical structures. Additionally, theoretical lessons should incorporate cutting-edge advancements to stimulate students' interest in scientific research and lay the groundwork for future exploration.

For instance, an introduction to spatial transcriptomics and single-cell technologies can be incorporated into the introductory section to demonstrate their relevance to histology and embryology [14, 15]. In the chapter on the circulatory system, educators can introduce the concept of extracellular vesicles to deepen students' understanding of blood components and

highlight the limitations of traditional textbook knowledge [16]. Furthermore, adding discussions on gene editing technologies and their role in the research and treatment of hereditary blood diseases can provide students with insight into how these innovations are transforming healthcare and shaping potential future treatments for various conditions [17-20].

In the section on the nervous system, educators can present findings from the department's research on neuroinflammatory diseases, giving students an opportunity to connect their theoretical learning with specific ongoing research within the institution [21]. Similarly, in the study of the skin, introducing recent research findings on skin injury, including contributions from the research lab and university, would broaden students' perspectives on this field [22, 23].

For the digestive, immune, and urinary systems, incorporating the latest advancements in liver research, along with the university's contributions to these fields, will keep students informed of current developments. In the embryology curriculum, instructors could introduce recent innovations in developmental biology, such as embryonic stem cells, induced pluripotent stem cells, and tissue engineering, highlighting breakthroughs in these fields and the contributions of the university's research teams. This approach not only expands students' knowledge but also stimulates their interest in research, laying a strong foundation for developing multi-talented medical professionals capable of thriving in the new era of healthcare.

Feasibility exploration

Integrating new technologies and methods into histology and embryology education enhances students' structural recognition efficiency and exposes them to novel knowledge, techniques and theories beyond standard textbooks. While this approach significantly contributes to the professional development of medical students, its implementation faces several challenges. A primary limitation is the demand for comprehensive and in-depth knowledge frameworks, which substantially elevates the requirements for instructors' teaching and research capabilities. The establishment of an interactive slice learning system requires substantial financial support. It is crucial to draw upon successful case studies from other institutions and secure adequate preparation funding. Establishing an effective teaching framework is equally important. Given that educational reform is a gradual process, implementation should follow a structured approach encompassing conceptualization, preparation, staff training, system application, framework establishment, and feedback evaluation.

Conclusion

As universities serve as the primary institutions for cultivating well-rounded medical professionals, it is essential to keep pace with the rapid advancements in modern medicine. While new knowledge, technologies, and theories emerge at an unprecedented pace, their integration into standard textbooks often experiences significant delays. Modernizing traditional pedagogical approaches through the systematic incorporation of these advancements into the curriculum can substantially enhance the professional competencies of medical students.

Furthermore, the development of exceptional medical professionals requires not only clinical proficiency but also robust research capabilities. Scientific research and innovation have become indispensable attributes for future medical practitioners. Contemporary medical education must therefore emphasize the cultivation of scientific research foundations and innovative thinking to address the increasingly complex challenges of healthcare [24, 25]. As a leading medical institution, the strategic integration of theoretical knowledge, clinical skills, and research literacy represents a crucial approach to fostering the scientific acumen and innovative spirit essential for students' professional development. Enhancing foundational medical education through these measures will undoubtedly yield more effective results in developing medical professionals capable of meeting future healthcare challenges.

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