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Patterns in the Evolution of the Conceptual Framework of Histology and Cytology (17th–21st Centuries)

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ABSTRACT

The conceptual framework of the morphological sciences began to develop on a scientific basis in the 18th century. Histological structures were described using terms already applied in other biological fields, such as *tissue*, *cell*, *fiber*, *sheath*, *plexus*, *node*, *membrane*, *nucleus*, *colloid*, and others. In addition, new terms emerged through the combination of existing concepts with clarifying modifiers. At the same time, entirely new terms were introduced, such as *centrosome*, *mitochondrion*, *endoplasmic reticulum*, alongside numerous eponyms in histology and cytology. For many of these terms, the authorship remains unknown or is the subject of ongoing debate.

The modern conceptual framework of histology was largely formed by the mid-20th century and officially formalized in its second half. The culmination of the evolution of histological terminology was the development of the International Histological Nomenclature, later renamed the International Histological Terminology, where eponyms were virtually excluded. Based on this international terminology, several countries developed national histological terminology, which continue to be periodically reviewed and updated. Today, histology is considered one of the most systematically organized scientific and educational disciplines.

Keywords: history of histology and cytology; conceptual framework; terminology; eponyms.

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Закономерности эволюции понятийного аппарата гистологии и цитологии (XVII–XXI вв.)

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АННОТАЦИЯ

Разработка понятийного аппарата морфологических наук стала проводиться на научной основе начиная с XVIII века. Для обозначения гистологических структур стали применять термины, уже использовавшиеся в других областях биологии, такие как «ткань», «клетка», «волокно», «оболочка», «сплетение», «узел», «мембрана», «ядро», «коллоид» и др. Кроме того, в обиходе появились термины, образованные путём сочетания уже известных понятий с уточняющими дополнениями. Одновременно с этим создавались и новые термины, например «центросома», «митохондрия», «эндоплазматическая сеть» и другие, а также возникло много гистологических и цитологических эпонимов. Для большого количества терминов авторство неизвестно, либо является предметом дискуссий.

Современный понятийный аппарат гистологии в основном сложился к середине XX века и был официально оформлен во второй половине XX века. Результатом эволюции системы гистологической терминологии стало создание Международной гистологической номенклатуры, впоследствии переименованной в Международную гистологическую терминологию, в которой эпонимы практически отсутствовали. На основе созданной Международной терминологии в ряде стран появились национальные гистологические терминологии, которые периодически пересматриваются и дополняются. В настоящее время гистология является одной из самых системно организованных научных и учебных дисциплин.

Ключевые слова: история гистологи и цитологии; понятийный аппарат; терминология; эпонимы.

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组织学与细胞学概念体系的演变规律 (17—21世纪)

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摘要

自18世纪起,形态学相关学科的概念体系逐步建立在科学基础之上。在组织学结构的命名中,开始引入其他生物学领域已有的术语,如“组织”“细胞”“纤维”“包膜”“网状结构”“结节”“膜”“细胞核”“胶体”等。同时,亦出现由已有术语与限定词组合形成的新术语。与此同时,还创造出诸如“中心体”“线粒体”“内质网”等全新术语,并形成大量组织学与细胞学的专有名称(eponyms)。许多术语的首创者已无从考证,或在学术界尚存在争议。

当代组织学的概念体系主要于20世纪中期确立,并在下半叶得到正式规范化。其重要成果之一,是制定了《International Histological Nomenclature》,后更名为《International Histological Terminology》,其显著特征为基本取消了专有名称。在此基础上,多国相继建立本国的组织学术语体系,并定期进行修订与补充。目前,组织学已发展为概念体系最为系统严谨的科研与教学学科之一。

关键词: 组织学与细胞学史; 概念体系; 术语学; 专有名称。

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INTRODUCTION

Although ideas about many biomedical objects and concepts had been forming for millennia, the intensive scientific development of the conceptual apparatus of biomedical sciences, including the morphological sciences, began only in the 18th century [1–10].

The conceptual framework of any scientific discipline has developed on the basis of several approaches. The first approach was the creation of a corpus of terms derived from definitions already used in other scientific disciplines. Since histology as a scientific specialty emerged long ago (mainly forming as a discipline from the second half of the 18th to the early 19th century), many histological structures were designated by terms already used for non-histological structures: *tissue*, *cell*, *fiber*, *membrane*, *plexus*, *node*, *nucleus*, *colloid*, and others. Some terms arose from existing concepts with clarifying additions. Thus, the terms such as *basement membrane*, *nerve fiber*, *collagen fiber*, *connective tissue*, *adipose tissue*, and several others were introduced in this manner [3, 5–7].

Simultaneously with the enrichment of the terminological arsenal of histology by definitions borrowed from other scientific fields, many new terms were created in the course of the discipline's evolution. For example, to designate intracellular components discovered in the 19th–20th centuries, new terms such as *centrosome*, *mitochondria*, and *endoplasmic reticulum* were proposed [4].

It is important to note that, as the beginning and early stages of histology took place in Europe, and until the 19th century the language of science was Latin, new scientific terms were created using Latin (less frequently, Greek) roots. When foreign textbooks were translated into Russian, translators used Russian equivalents of foreign terms, and in the absence of such equivalents, retained the original word. As a result, most histological and cytological terms are borrowings from foreign languages, whereas terms of Russian or pan-Slavic origin are relatively few, such as *волокно* (*fiber*), *железа* (*gland*), *ядро* (*nucleus*), *язык* (*tongue*), *яичко* (*testis*) [2, 4, 11–17].

For many terms, the authorship is unknown or remains controversial; however, there are terms for which the authorship is not disputed. For example, many publications indicate that the term *biology* was introduced by Burdach (1776–1847) in 1800 [9]. In other sources, Lamarck (1744–1829) and Treviranus (1776–1837) are also mentioned to have introduced the term, although they proposed it later, in 1802 [8, 9]. One of the earliest scientific definitions of *life* (1800) was formulated by Bichat (1771–1802): “life is the sum of functions that resist death” [18]. The authorship of the term *morphology* (1800) is attributed to both Goethe (1749–1832) and Burdach [9, 19]. The term *histology* was proposed by the German naturalist Mayer (1786–1870) in 1819 [8]. The term *cell* was first introduced by Hooke (1635–1703) in 1665 [8–10].

In 1682, Grew (1641–1712) introduced the terms *tissue* and *parenchyma* into botany [1, 2, 8–10]. Subsequently, these terms became widely used in zoology, anatomy, and histology to designate structures of animal and human bodies. In medicine, the term *tissue* was introduced by Bichat in 1800 [9]. The use of the term *protoplasm* for animal cells was initiated by Purkyne (1789–1869) in 1825, and for plant cells by Mohl (1805–1872) in 1846 [8].

In 1888, Waldeyer (1836–1921) introduced the terms *neuron* and *chromosome* [11]. The terms: *gene*, *genotype*, and *phenotype* were proposed by W.L. Johannsen (1857–1927) in 1909 [4, 8–10, 18]. Mitochondria were first described by the German anatomist and histologist R. Altmann (1852–1901) in 1894 under the name *bioblasts*. The currently used term *mitochondrion* was introduced into scientific usage by the German histologist and pathologist Benda (1857–1932) in 1898 [4, 11–12]. The term *epigenesis* was first applied by Harvey (1578–1657) in 1651 [4]. The term *virus* was proposed by the Dutch botanist and microbiologist Beijerinck (1851–1931), according to some sources in 1898 [8], and according to others in 1899 [4]. The term *stem cell* is associated with the Russian histologist Maksimov (1874–1928). To designate the progenitor of all blood cells, he introduced the term *hemocytoblast* in 1909, and later replaced it by *stem cell* [20–21]. The term *parthenogenesis* was proposed by the English zoologist Owen (1804–1892) in 1849 [8].

During the creation of the conceptual framework of the morphological sciences, a significant number of histological and cytological eponyms emerged. A particularly large number of eponyms apply to the names of different cell types: Alzheimer cell, Anitschkow cell, Aschoff cell, Betz cell, Gegenbauer cell, Hensen cell, Golgi cell, Deiters cell, Gianuzzi cell, Dogiel cell, Ito cell, Cajal cell, Clara cell, Claudius cell, Corti cell, Kulchitsky cell, Kupffer cell, Langerhans cell, Langhans cell, Leydig cell, Martinotti cell, Marchand cell, Merkel cell, Paneth cell, Purkinje cell, Renshaw cell, Sertoli cell [20–21]. The emergence of eponyms was most often associated with the fact that a particular scientist discovered and described in detail the morphofunctional characteristics of a given structure. At present, histology is arguably one of the most systematically organized scientific disciplines. Except for anatomy and embryology, no other discipline possesses such a structured conceptual framework, enabling scientists from different countries to articulate their concepts using universally recognized, officially approved terminology.

EMERGENCE AND DEVELOPMENT OF CONCEPTS OF THE CELL

The term *cell* was first introduced by the English scientist, physicist, astronomer, and botanist Hooke in his work *Micrographia*, or *Some Physiological Descriptions of Minute Bodies* in 1665 [22–24]. Since its introduction into scientific discourse, the meaning of the term has undergone substantial changes. Hooke, who primarily studied plant objects in the

late 17th and early 18th centuries, used the term *cell* only to denote the wall of a plant cell, defining it as a vesicle with a dense envelope filled with fluid content [22–27].

Various terms were proposed to designate the internal contents of cells. In 1835, the French biologist Dujardin (1801–1860) used the term *sarcode* to describe the internal substance of cells. In 1825, Purkyne (1789–1869) introduced the term *protoplasm* for the contents of animal embryonic cells. In 1846, the German-Swiss botanist Mohl (1805–1872) started using the term *protoplasm* to designate the liquid contents of plant cells [10, 22].

The discovery of the cell nucleus was a crucial advance in the development of concepts of cellular structure in plants and animals, and in the creation of morphological terminology. In 1827, Brown (1773–1858) described the nucleus in plant cells, and in 1825 Purkyne identified nuclei in avian oocytes [10].

A definition of the *cell* close to its modern understanding was proposed by Schultze (1825–1874), who characterized the cell as a mass of protoplasm containing a nucleus, in 1863 [18, 28].

The fundamental principles of cell structure and function were formulated by the German biologist Schwann (1810–1882) in his cell theory (1838). It should be noted, however, that Schwann's concept of the cell differed significantly from modern views. For example, he considered the nucleus to be a transient structure present only in young, developing cells [22].

One of the central problems of cell and tissue biology has been that of cell reproduction. As a result of studies of cell proliferation, terms such as *mitosis* and *meiosis* were introduced into scientific usage. For a long time, the issue of cell generation remained controversial. By the second half of the 19th century, the idea of cells arising from "living matter" was abandoned, and the principle of new cells originating from pre-existing ones gained wide acceptance. Nonetheless, in the 20th century, there were revivals of the concept of cell generation from "living matter," for example in the theory of Lepeshinskaya [10, 29]. The leading role in establishing the postulate *omnis cellula e cellula* ("every cell originates from another cell") belongs to Virchow (1821–1902) [24, 25]. The process of plant cell division was first described in 1838 by the botanist Mohl [8]. The research on plant cell division by Hofmeister (1824–1877) in 1867 and Strasburger (1844–1912) in 1870 was crucial in clarifying the role and significance of the nucleus. The studies of animal cell division were conducted by Schneider (1831–1890) and Flemming (1843–1905) between 1879 and 1882 [8]. In 1873, the German zoologist and embryologist Schneider described indirect nuclear division in oocytes, later termed mitosis [8, 22]. Subsequently, mitosis was observed by the German zoologist Bütschli (1848–1920), the Polish botanist Strasburger, and others. In 1900, Strasburger described the reduction division of plant cells, later termed meiosis [4].

A major contribution to the introduction of the term *cell* into the medical and biological literature was made by the work of the pathologist Virchow, who studied pathological processes in the organism from the standpoint of cell theory in the mid-1850s [24, 25].

The conceptual framework of histology was substantially enriched by the research of the Russian histologist Maksimov, the author of the unitarian theory of hematopoiesis: the concept that all blood cellular elements originate from a single lymphocyte-like progenitor. Although the idea of the existence of stem cells was proposed by Maksimov more than a century ago, objective evidence for their existence was presented only in the 1960s through the studies of Till (b. 1931) and McCulloch (1926–2011), who demonstrated the capacity of hematopoietic cells to form colonies in the spleens of lethally irradiated mice.

The conceptual apparatus of morphology expanded further in the 20th century with the emergence of research in biochemistry and molecular biology devoted to the ultrastructure of cells and the role of DNA and RNA as molecules carrying and transmitting hereditary information. These initially biochemical terms, along with others, became an integral part of histological terminology. Although the concept of nucleic acids was introduced by the Swiss biochemist Miescher (1844–1895) as early as 1869 [8–10], their true role and significance in cellular activity were elucidated only in the 20th century.

In 1928, the English biochemist and geneticist Griffith (1879–1941), studying pneumococci, hypothesized the existence of substances in cells responsible for hereditary properties. In 1944, American biochemists Avery (1877–1956), MacLeod (1909–1972), and McCarty (1911–2005), also using pneumococci as a model, established that DNA was the material responsible for the realization of hereditary traits in the cell [8].

A significant contribution to concepts of cell structure and physiology was made by the Russian biologist Koltsov (1872–1940). In 1928, based on his research, he formulated the hypothesis of the molecular structure and template reproduction of chromosomes, which anticipated the principal postulates of modern molecular and cell biology in many respects [4, 8].

In 1931, the German scientists Ruska (1906–1988) and Knoll (1897–1969) constructed the first electron microscope. By the 1940s, electron microscopy started being applied to the study of cells. Thanks to the work of numerous researchers: Palade (1912–2008), Claude (1899–1983), De Duve (1917–2013), among others, the ultrastructure of the cell was systematically investigated and described. To designate newly discovered subcellular structures, many new terms entered the practice of scientific research. For the development of electron microscopy, its application to biomedical research, and the subsequent discoveries, the Nobel Prize was awarded to Ruska in 1986, and to Palade, Claude, and De Duve in 1974.

In 1952, using the X-ray diffraction method developed by Franklin (1920–1958), the English biophysicist Wilkins (1916–2004) presented his vision of the DNA structure. A year later, in 1953, based on Wilkins' findings, the American biochemist Watson (b. 1928) together with the English physicist Crick (1916–2004) proposed the double-helix model of DNA, consisting of two polynucleotide chains. Deciphering the structure of DNA laid the foundation for the concept of protein synthesis, proposed by French researchers Lwoff (1902–1994), Jacob (1920–2014), and Monod (1910–1976) based on the studies of bacterial cells. This concept was later confirmed in eukaryotic cells as well. In the mid-20th century, a series of Nobel Prizes were awarded to the scientists working in the field of molecular biology and cell physiology: Watson, Crick, Wilkins, Lwoff, Jacob, Monod, Khorana (1922–2011), Yamanaka (b. 1962), Edwards (1925–2013), among others. Unfortunately, the name of Franklin is absent from the list of Nobel laureates, as she died four years before the prize was awarded for the discovery of the DNA structure [30, 32].

As a result of decades of research by both international and Russian histologists, cytologists, and molecular biologists, the number of terms related to the cell has steadily increased. For example, the *Terminologia Histologica*, published in 2009 [33], contains nearly 700 terms, including synonyms. There are more than 200 terms are listed in the section Cytoplasm, including: 182 in "Organelles and Cytoplasmic Inclusions" section; 37 in "Cytoskeleton" section; 79 in "Nucleus" section; 83 in "Mitosis" section; and 49 in "Meiosis" section.

EVOLUTION OF CONCEPTS OF TISSUES

Since the term tissue was first applied to biological objects, its meaning has undergone substantial changes. In his *Anatomy of Plants* published in 1682, Grew (1641–1712) first employed the term *tissue* [10] to describe fibrous interwoven structures, aggregations of tubules, and vesicles visible under the microscope that resembled woven fabrics used in clothing. Subsequently, the term came to denote various systems of cells and noncellular structures in plants, animals, and humans [13, 16–17, 33].

The concept of tissue has a long history, and its content evolved with scientific progress. Several examples illustrate the development of its interpretation, based on different methodological approaches. The earliest definitions relied primarily on structural and functional analysis.

In 1865, Kölliker (1817–1905) defined tissue as "a definite arrangement of elementary parts (cells), repeated in the same way throughout identical regions" [34].

According to Maksimov [35], tissue represents "a complex of cellular elements that have developed in a specific direction, possess a common basic form and structure, and perform similar general functions".

In the Textbook of Microscopic Anatomy, Stöhr (1849–1911) characterized tissue as an aggregate of uniformly differentiated cells [36].

Karpov [37] considered tissue as "an aggregate of cells, connected to each other and modified in the same way to perform a particular function within the organism". A similar definition was given by Nemilov [38], who described tissue as "a collection of cells joined together to perform the same function in the organism, having correspondingly altered their structure in a uniform manner".

In the definition of tissue formulated by Stöhr and Mellendorf [39], the primary emphasis was placed on the interrelationship and interdependence of biological systems at the cellular, tissue, and organismal levels: "tissue is a manifestation of living matter that governs the cell while being subordinate to the organism".

According to Bykov [40], "tissue is a system of cells and their derivatives specialized in the performance of specific functions".

Perhaps the most comprehensive modern definition was given by Pekarsky and Zakharov in 2014 [41]: "tissue is a historically established complex of cells and their derivatives, specialized in the performance of organismal functions, each of which corresponds to one of the essential properties of living matter: separation from and exchange with the external environment (epithelia); internal exchange (internal milieu)—connective tissues; excitability—nervous tissue; motility—muscular tissues."

The formulation of the germ layer theory by Russian researchers Wolff, Pander, Baer, Kovalevsky, and Mechnikov contributed to the introduction of several terms related to morphogenesis and histogenesis by both Russian and foreign scientists, thereby substantially enriching the conceptual framework of histology and embryology. These included *ectoderm*, *mesoderm*, *endoderm*, *differentiation*, *determination*, *presumptive material*, and others [29, 42–47].

In the 1920s, Russian scientists expanded the concept of *tissue* beyond structural and functional perspectives to include ontogenetic and phylogenetic aspects. A large body of work devoted to morphogenesis and histogenesis in ontogeny and phylogeny was carried out in the mid- and late 20th century [22, 28, 46–53].

The conceptual framework of histology was further advanced by theories addressing the evolutionary dynamics of tissues, notably the theory of parallel evolution of tissues proposed by Zavarzin and the theory of divergent evolution of tissues formulated by Khlopin in the 1920s–1930s. According to Zavarzin [53], "tissue is a system of histological elements subordinate to the whole but, to a certain degree, balanced within itself, united by a common function, and developing from a common primordium in a defined direction". In the definition by Khlopin [52], "tissues represent integrated subsystems of the organism that change throughout evolutionary processes, exist in complex correlative relationships, and, in their development, remain subordinate to the organism as a whole".

Subbotin [54] proposed the following definition: "tissue is a system of cells and extracellular material characterized

by a common phylogenesis, morphology, and function.” Danilov and coauthors [28] formulated an alternative definition: “tissue is a system of cellular differentia and their extracellular derivatives, established through phylogeny and ontogeny, whose function and regenerative capacity are determined by the histogenetic properties of the leading cellular differential.” It should be noted that, despite the wide variety of proposed definitions of tissue, there is still no consensus definition accepted by all, or even most, morphologists [55–56].

The diversity of definitions was further reflected in the development of tissue classification systems. For example, more than 20 tissues, many of which were in fact organs, such as hair, were listed in the classification proposed by Bichat. By contrast, several dozens of distinct tissue types were recognized in the classification based on histogenetic principles proposed by Khlopin [52].

Differences in the understanding of the essence of the object of study have often led to controversial generalizations. For example, Hertwig [22] defined the concept of the *germ layer* as “a sheet of cells that are connected to one another in a manner similar to an epithelium and serve to delineate the surfaces of the body”. This analogy of the germinal cell sheet to epithelium subsequently contributed to the emergence of the concept of the epithelial–mesenchymal transition, developed by the American researcher Hay. However, this concept remains a matter of debate and requires further substantiation.

FORMATION OF THE SYSTEM OF HISTOLOGICAL AND CYTOLOGICAL TERMINOLOGY

The rapid accumulation of terms used in histology, along with the frequent use of multiple terms to describe the same structures, necessitated their systematization and the creation of a normative framework. In the 1960s, efforts to compile and standardize histological and cytological terminology were undertaken internationally, ultimately leading to the development of the International Histological Terminology. The first compendium of Latin terms was discussed, approved, and adopted on August 22, 1970, at the 9th World Congress of Anatomists held in Leningrad (USSR). Due to the location of its adoption, this terminology was informally referred to by histologists as the Leningrad Histological Nomenclature [57–58].

One distinctive feature of this nomenclature was the absence of eponymous terms, which had been widely used by morphologists worldwide. Exceptions were made only for a few terms, such as Golgi apparatus. The exclusion of eponyms from histological terminology was met with regret, as eponymous terms continue to be widely used in clinical medicine and practice. Moreover, in zoology, the majority of species names traditionally incorporate the names of researchers.

Like any complex system, histological terminology must evolve to remain relevant. Accordingly, the terminology was repeatedly revised, supplemented, and reapproved as the official International Histological Terminology at subsequent international congresses (typically every five years). Notably, Soviet and Russian scientists played an active role in the systematization of histological terminology since the 1960s. In 1970, the International Anatomical Congress recommended that national morphological associations prepare national versions of the International Histological Terminology (Nomenclature). In the USSR, the first Russian-language version, based on the 1970 International Histological Nomenclature, was prepared and published in 1973 [57]. A substantial contribution to the creation of the Russian version was made by V.G. Eliseev, Yu.N. Kopaev, A.N. Studitsky, Yu.I. Afanas'ev, A.G. Knorre, V.P. Mikhailov, S.I. Shchekunov, N.G. Khrushchev, A.A. Voitkevich, K.A. Zufarov, N.I. Zazybin, L.S. Sutulov, A.Ya. Friedenstein, N.I. Grigor'ev, A.A. Klishev, N.A. Yurina, Yu.S. Chentsov, M.G. Shubich, V.V. Banin, V.L. Bykov, V.V. Semchenko, R.P. Samusev, T.K. Dubovaya, M.Yu. Kapitonova, V.B. Zaitsev, A.L. Zashikhin, A.A. Stadnikov, V.E. Torbek, S.L. Kuznetsov, Yu.A. Chelyshev, V.I. Nozdrin, T.A. Belousova, and I.R. Kilachitskaya [58]. The Russian version was subsequently revised, expanded, and republished in 1980 [59]. In post-Soviet Russia, updated versions of the International Histological Terminology were published in 1999 and 2009 [33, 60]. The 2009 edition [33], developed on the basis of the 2008 international edition [61], remains the most comprehensive. In 2014, a Russian-language version of the International Embryological Terminology was also published [62].

In the *Terminologia Histologica* 2008 and 2009, an attempt was made to integrate modern terminology from cytology, cell biology, and histology. However, it should be noted that the recommendations of *Terminologia Histologica* [61] regarding the exclusion of eponymous terms have not been consistently followed in international textbooks and journals in the morphological sciences. Eponyms continue to appear both in journal articles and in educational publications. For example, in the eighth and ninth editions of Textbook of Histology by Singh (1930–2014) [63–64], more than 100 eponyms are cited. A similar situation is observed in many other foreign histology textbooks [65–66]. This has led several international researchers to argue that the recommendations of *Terminologia Histologica* have not been sufficiently taken into account in scientific and educational literature [67–68]. Russian publications have not completely abandoned the use of eponyms, which raises the question of whether rejecting them entirely is justified.

Nearly two decades after the publication of *Terminologia Histologica*, advances in tissue biology, molecular biology, and cell biology have resulted in the emergence of numerous new terms not included in this compendium. In addition, certain inconsistencies among the terminological definitions

of histology, cytology, pathology, molecular biology, and cell biology still require resolution.

CONCLUSION

The modern conceptual framework of histology was largely established by the mid-20th century and was formalized in the second half of the century. Progress in scientific research, particularly in cytology and molecular biology, has significantly enriched the terminological system. The evolution of histological terminology ultimately led to the creation of the International Histological Nomenclature, later renamed the International Histological Terminology, which served as the foundation for the development of national histological terminologies in several countries. Today, histology is considered one of the most systematically organized scientific and educational disciplines. Although the foundations of histological and cytological terminology were laid in European countries, the contributions of Soviet and Russian scholars to its creation and refinement should not be underestimated.

ADDITIONAL INFORMATION

Author contributions: The author confirms that his authorship complies with the international ICMJE criteria (the author developed the article design, collected and processed the material, prepared the text and illustrations, and reviewed and approved the final version prior to publication). The author also agrees to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. Автор разработал дизайн статьи, собрал и обработал материал, подготовил текст, прочёл и одобрил рукопись (версию для публикации), а также согласился нести ответственность за все аспекты работы, гарантируя надлежащее рассмотрение и решение вопросов, связанных с точностью и добросовестностью любой её части.

Источник финансирования. Автор заявляет об отсутствии внешнего финансирования при проведении поисково-аналитической работы.

Раскрытие интересов. Автор заявляет об отсутствии отношений, деятельности и интересов за последние три года, связанных с третьими лицами (коммерческими и некоммерческими), интересы которых могут быть затронуты содержанием статьи.

Доступ к данным. Редакционная политика в отношении совместного использования данных к настоящей работе не применима, новые данные не собирали и не создавали.

Генеративный искусственный интеллект. При создании настоящей статьи технологии генеративного искусственного интеллекта не использовались.

Рассмотрение и рецензирование. Настоящая работа подана в журнал в инициативном порядке и рассмотрена по обычной процедуре. В рецензировании участвовали два внешних рецензента, член редакционной коллегии и научный редактор издания.

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