Foundations And Progress In Microscopy, Histology And Embryology

Altan ARMUTAK
Istanbul University - Cerrahpasa

Ayça ÜVEZ
Istanbul University- Cerrahpasa

Elif İlkay ARMUTAK
Istanbul University- Cerrahpasa

To Cite This Chapter:
Armutak, A., Uvez, A., & Armutak, E. I. (2025). Foundations and progress in microscopy, histology and embryology. In S. Erten & C. A. Aksoy (Eds.), *Current studies in basic sciences, engineering and technology 2025* (pp. 315–338). ISRES Publishing.

Summary

The microscope ranks among the most important inventions in the history of science, its discovery leading to the birth and development of numerous scientific disciplines. After the light microscope was developed, it was used for a long time for curiosity and entertainment purposes. However, the microscope later became an indispensable instrument used for scientific purposes, particularly in the fields of biology and medicine, where it is utilised clinically. With the help of microscopes, a scientific 'Cell Theory' was developed, and under the influence of this theory, the scientific fields of Histology and Embryology were born and developed. As can be seen, Histology and Embryology are among the scientific disciplines that owe their existence to the microscope. During this process, many new microscopic techniques for examining tissues under the microscope found their place. In parallel, new types of microscopes were developed, primarily the electron microscope. This section focuses on the development of the scientific fields of Histology and Embryology in light of the use of microscopes. In this way, the impact of microscopes on the scientific world is evaluated against a historical background, and the effects of this impact on both the present and the future are interpreted through the lens of the disciplines of Histology and Embryology.

Microscope

A microscope is a viewing and magnifying device developed based on the principles of light and optics for the purpose of identifying and evaluating objects that cannot be seen with the naked eye. The word microscope is derived from the Greek words mikros

(small) and skopos (to look, to see) (Skinner, 1949; Anonymous, 1957).

The invention of the microscope actually marks the birth of many scientific disciplines. Some scientific fields gained meaning with the invention of the microscope, while others developed rapidly thanks to it. For the sciences that use microscopes today, the period before the invention of the miCroscope is a deep darkness. Considering the point reached by microscopes today, which have been in use for over 400 years worldwide, it is evident that these devices have influenced societies not only scientifically but also socially, economically, and culturally (Armutak, 2000).

Prior to the invention of the microscope, knowledge in the biological sciences, medicine, and veterinary medicine was always obtained at the macroscopic level. After the invention of the microscope, information could only be obtained at the microscopic level, and in this way, much more detailed and surprising results were revealed. The sciences that use the microscope have developed rapidly, and in this way, the darkest secrets of nature have been illuminated by microscopes. The sciences that began their development with the microscope at their centre and have continued to do so for centuries include Histology and Embryology, Pathology, Microbiology, Virology, Parasitology, Zoology and Botany. However, Histology and Embryology have been the fields that use the microscope most extensively and intensively. This is because the microscope is the sole fundamental tool for obtaining knowledge in the field of Histology and Embryology. This discipline is a fundamental science that examines the pre-natal development of cells, tissues, and organs in living organisms, as well as their post-natal structure and function, at a microscopic level through comparative analysis (Armutak, 2000).

The microscope is essentially an optical system consisting of magnifying lenses called lenses (Wolf, 1950). In fact, the existence of glass, the fundamental element of the microscope, has been known since 4000 BC. However, for thousands of years, glass was considered merely an ornamental object. Magnifying glass, which would later be used in microscopes and called lenses, was known to the ancient Egyptians around 2500 BC. As can be seen, the history of lenses is much older than that of the microscope. It is known that glass was blown into shape in Syria in the 1st century BC and that the first transparent glass was produced there. Transparent glass then spread across Asia and Europe via Egypt and Syria. During this process, the ancient Greeks succeeded in making simple magnifying lenses using rock crystal, which they called ‘Berillos’ or ‘Kristallos’. In the Roman Empire, in the 1st century AD, a lens was developed by filling a spherical piece of glass with water, and this lens was named after the Roman philosopher Seneca (3 BC-65 AD). Since it was possible to place Seneca’s Lens in front of a light source to increase the light and spread it around, this lens is also considered the ancestor of simple magnifying glasses (Kirkpatrick, 1976; Ergin, 1997).

Copyright © 2025 by ISRES Publishing

Ibn al-Haytham (965–1040), one of the scholars of the Islamic civilisation era, conducted research on the magnifying properties of lenses, and his views influenced many Western scientists who worked on microscopes and telescopes. One of these Western scientists was the renowned English philosopher Roger Bacon (1214–1294). Bacon added to the book of the aforementioned Islamic scholar, provided practical interpretations, and was also the first to propose the idea that lenses could be used as spectacles (Sarton, 1950; Bradburry & Turner, 1967).

Again, during the Islamic Civilisation era, it was determined that writing appeared larger when viewed through a lens, and lenses were used like magnifying glasses, equipped with frames and handles, to enable those with poor eyesight to read. These early lenses were again made from transparent stones, particularly beryl, rather than glass. Some time later, separate lenses were made for each eye and placed in a frame, creating the first spectacles (Bernal, 1995). The first silicate glass was produced in Italy in the 13th century, and in the 14th century, lenses began to be used as spectacles and quickly became widespread. Salvino d'Armato degli Armati is credited as the inventor of spectacles. However, it is still not known for certain who first used spectacles. Nevertheless, it is known that ordinary magnifying glass-like lenses were used for reading or entertainment purposes (Dobell, 1960).

The Invention of the Microscope and the First Microscopists

The question of who invented the microscope and where it was invented has always been a subject of debate. It is thought that the microscope was first invented in Holland. This is because jewellery crafting techniques were highly developed in this country. Jewellers, who also crafted lenses to make spectacle lenses, may have led to this result. The Zacharias family, who lived in Middelburg, Holland, and were spectacle makers, were pioneers in this field. Zacharias Jansen, a member of this family, was working with lenses in water to make spectacles in the late 16th or early 17th century, when he noticed that a combination of a pair of convex and a pair of concave lenses magnified objects in water. In this way, he developed the first compound microscope by chance (Wolf, 1950; Dobell, 1960; Purtle, 1974). Until then, only the magnifying properties of a single convex lens had been utilised, but Zacharias Jansen laid the foundation for the first compound microscope by placing two convex and two concave lenses inside a tube. Galileo Galilei also took advantage of this discovery and succeeded in developing the binoculars, telescope and microscope (Uzluk, 1959; Boorstin, 1996; Merdivenci, 1975).

Shortly after the invention of the telescope, people began using this device to magnify small objects in their vicinity. Even Galileo Galilei used his telescope like a microscope (Boorstin, 1996). While microscopes were being produced in Holland in the first decade of the 17th century, a new form was independently developed in Italy (Dobell,

1960). Developed by Jansen, these microscopes, capable of magnifying an object nine times, became one of the most popular devices of the period and were even sold to the Dutch Royal Family. The fame of the microscope quickly spread from the Netherlands throughout Europe, and the number of microscope makers increased rapidly. One of these new microscope makers, Cornelius Van Drebbel, developed a new microscope model in London in 1619, with two convex lenses at one end and a concave objective at the other (Wolf, 1950; Erbengi, 1988; Eren, 1996).

The Use of the Microscope for Biological Observations

The microscope was also used for biological observations by Galileo Galilei in 1610 or earlier. Galileo Galilei examined the sensory and locomotor organs of small animals and the compound eyes of insects; by making some modifications to the microscope developed by Drebbel, he ensured that the device could be used both as a microscope and a telescope. The Italian word 'Occhialino' and the Latin word 'Perspicillum' were used at that time to mean both telescope and microscope (Wolf, 1950; Boorstin, 1996). Giovanni Faber, a physicist and natural scientist who was one of the first members of the Lincei Academy, used the word 'Microscopio' (microscope) for the first time in history in a letter he wrote to his friend Federico Cesi on 13 April 1625. In his letter, Faber stated: 'After the model of the telescope, I thought of calling this invention "microscope", because this instrument allows us to perceive the images of very small objects' (Dobell, 1960; Boorstin, 1996). Federico Cesi and members of the Lincei Academy were among the scientists who played a very active role in these early microscopic investigations (Mettler, 1947). Also in 1625, Italian researcher Francesco Stelluti published his book 'Apiarium,' in which he used the microscope for scientific purposes and drew detailed illustrations of the head and mouth parts of bees. Stelluti stated in his work that he used the microscope to examine the body parts of bees (Wolf, 1950; Westfall, 1987; Lyons & Petrucelli, 1987). The first medical study based on the microscope was the work entitled 'Historiarum et Observationum Medicophysicorum' published in 1653 by the French physicist and philosopher Pierre Borel (1620–1689). Although Borel mentioned creatures resembling whales or dolphins floating in blood in 1655, he also described one of the earliest examples of a compound microscope. The first microscopes were quite simple and could only magnify objects 100–200 times (Dunlop & Williams, 1996).

Leeuwenhoek and the Golden Age of Microscopic Observation

Antony Van Leeuwenhoek (1632–1723), a Dutch merchant and self-taught scientist, was one of the most remarkable figures in 17th-century biology and one of the most important early microscopists. In his spare time, he made lenses for microscopes, and the lenses he produced continued to be influential until the 19th century. Although he could not directly follow contemporary scientific publications because he did not know Latin, his extraordinary powers of observation and diligence enabled him to make numerous

Copyright © 2025 by ISRES Publishing

independent discoveries. He made 247 microscopes and 419 lenses from precious metals such as gold and silver; using two small concave lenses together, he created his best microscopes, which could magnify objects approximately 270 times (Ünver, 1943; Dobell, 1960; Lyons & Petrucelli, 1987). Leeuwenhoek did not actually use a compound microscope in the modern sense, but rather simple lens systems. He placed a lens on a flat silver or brass plate and used a concave mirror to focus the light onto the object (Wolf, 1950; Dobell, 1960). Before his death, Leeuwenhoek sent some of his microscopes and observation reports to the Royal Society in London; these studies were published, and he was elected a member of the Royal Society in 1680 (Uzluk, 1959). In 1674, Leeuwenhoek observed spermatozoa, protozoa, and bacteria under the microscope for the first time and named them 'Animalcules', meaning 'tiny animals' (Ünver, 1943; Uzluk, 1959; Dobell, 1960; Ural, 1998). He also examined human skin, tongue papillae from oxen, lens crystalline and urinary bladder, pig liver, hair structures of various animal species, and the microscopic anatomy of insects (Dobell, 1960). He was the first to correctly identify the blood cells that Malpighi had described as 'fat globules'; he noted that the erythrocytes observed by Swammerdam were round in mammals and oval in fish and amphibians. Leeuwenhoek, who also examined rainwater and dental plaque under the microscope, was the first to show skeletal muscles under the microscope, defining the striated structure of muscles; he discovered capillaries in the tail of a frog tadpole, demonstrating the connection between arteries and veins. He thus supported Malpighi's views on the circulatory system (Ünver, 1943; Wolf, 1950; Uzluk, 1959; Erbengi, 1988).

Dutch physician Jan Swammerdam (1637–1682) studied insects and small creatures, performing extremely delicate dissections under the microscope. In 1658, Swammerdam observed frog erythrocytes for the first time and prepared his work Bibel der Natur, in which he drew detailed illustrations of the internal organs of insects. In his studies, Swammerdam injected coloured liquids into insects to enhance the visibility of their organs (Wolf, 1950; Uzluk, 1959; Ünver, 1943; Erdemir, 1994). Italian physician and professor of physiology Marcello Malpighi (1628–1694) was one of the scientists who used the microscope most effectively in his research. Malpighi examined plants and insects under the microscope and identified structures in organs such as the kidney, spleen, liver, and skin that would later be called 'Malpighi bodies' (Wolf, 1950; Erk, 1978). Malpighi developed new methods for preparing tissues to be examined under the microscope (Lyons & Petrucelli, 1987). Due to his work in the field of histology, considered the 'sister science' of pathology, Malpighi is recognised as the 'Founder of Biological Microscopy' (Long, 1965). Leeuwenhoek, who made significant contributions to the accumulation of biological knowledge, is also considered one of the 'Founders of Histology' alongside Malpighi (Westfall, 1987; Boorstin, 1996; Theodorides, 1993). Johannes Hevelius (1611–1687), who lived during the same period, developed the 'micrometre' screw used for fine adjustment in microscopes in 1673 (Erbengi, 1988).

The Birth of Cell Theory and the Formation of Histology

Following these developments, new microscopists emerged in England. The earliest and most famous of these was the botanist Robert Hooke (1635–1703) (Wolf, 1950; Purtle, 1974). Hooke's early scientific work was based entirely on microscopic observations, demonstrating how effective the use of microscopes could be in scientific research. In his famous work Micrographia, published in 1665, Hooke first used the term 'cellula' (cell), meaning 'air-filled cavity'. Using a compound microscope with limited magnification power, he examined seedless, honeycomb-shaped fungal cells and named them 'Cellula' (Cell). In his work, he included 57 remarkable microscopic images of plants and insects, accompanied by his own drawings (Wolf, 1950; Sencer, 1998). While Leeuwenhoek and Malpighi worked with simple lenses, Hooke used one of the most advanced examples of a compound microscope. Hooke's microscope is a system in which the object to be observed is fixed with a needle protruding from the base, screwed onto a movable platform, and light is provided by a lamp with a spherical condenser (Wolf, 1950). Hooke increased the clarity of the image by adding a third lens, which he called the 'middle glass,' in addition to the objective and eyepiece lenses (Ergin, 1997; Wolf, 1950). Furthermore, in 1678, Hooke dipped the objective lens in water, thereby testing the 'wet immersion' technique for the first time and succeeding in improving image quality (Erbengi, 1988). Hooke's Micrographia became the most renowned work in this field. Hooke's descriptions of the structure of fungal cells, his observations of eels in vinegar, his studies of insect anatomy and various small objects were enthusiastically pursued by subsequent microscope users (Wolf, 1950). However, Hooke failed to grasp the significance of his observations, and as a result, the 'Cell Theory' was only proposed in the 19th century by Rudolf Virchow (Uzluk, 1959).

The first person to use a microscope in disease research was the physiology professor Athanasius Kircher (1602–1680). In 1646, Kircher claimed to have observed plague microbes in blood using a simple microscope with a low-power lens at one end and a flat glass plate at the other, but his claim was met with scepticism (Wolf, 1950; Lyons & Petrucelli, 1987). Similarly, Schelftrateus, an official at the Vatican Library, published an illustrated study on the use of the microscope in medicine in the 1680s (Mettler, 1947). Simple microscopes were mostly used for examining insects, which is why they were referred to as 'flea glasses' or 'fly glasses' at the time (Wolf, 1950).

However, despite the more intensive use of microscopes from the 17th century onwards, this invention did not influence the medicine of the period (Erk, 1978). The physicians of the time remained indifferent to the microscope and the discoveries made with it, continuing to practise their art traditionally. Consequently, no significant progress was made throughout the 18th century towards the scientific definition of the cell. However, at the end of the century, Marie François Xavier Bichat (1771–1802) realised, without

Copyright © 2025 by ISRES Publishing

using a microscope, that organs were composed of tissues and proposed that there were 21 different tissues in the body. Bichat likened these tissues to a 'spider's web' or 'cloth weave' and used the term "tissu" (tissue) for the first time. Thus, the concept of 'histology,' derived from the Greek word 'histo' (spider's web or cloth weave), was born. Bichat demonstrated that diseases affect the vital properties of tissues and is therefore recognised as the 'Founder of Modern Histology' (Erk, 1978; Şan, 1994; Theodorides, 1993). However, due to optical errors in the lenses at that time, the magnification power of microscopes remained limited (Karasszon, 1988). Although Bichat did not give the microscope the importance it deserved, the microscope has now become an indispensable tool in biological research (Long, 1965). G. Hertel (1683-1743) began using a flat mirror for light in microscopes in 1716, and in 1738, J. N. Lieberkühn (1711-1756) developed and began using a ring-shaped mirror. John Cuff (1708-1772) worked on a microscope with a sliding stage (carriage) and a fine adjustment knob (micrometer) in 1738, while George Adams developed a microtome for sectioning in 1770, and J. Bleuler (1757-1829) used a condenser assembly capable of moving focus in the 1780s. Meanwhile, J. N. Lieberkühn injected a coloured substance into blood vessels in 1748 to achieve staining in tissues and described the 'Lieberkühn Glands' in the intestines, which are named after him (Erbengi, 1988).

Robert Brown (1773–1858) was the first to identify the nucleus in plant cells and named it the 'nucleus.' Anatomy professor Jacob Henle (1809–1885) built upon the foundations of histology laid by Bichat, introducing new structures. Henle defined the cellular structure of tissues, establishing 'microscopic anatomy' based on cytology, and proposed that living organisms could only be formed by living cells. Henle demonstrated the presence of smooth muscle in the middle layer of arteries, the 'Henle Layer' in hair follicles, the 'Henle Loop' in the kidneys, the connections of the hippocampus in the brain, and the character of the posterior lobe of the pituitary gland. He provided the first accurate histological description of the corneal layer of the eye, studied the urinary bladder, and also focused on the development and structure of the larynx, introducing the term 'epithelium' for the first time (Mettler, 1947; Dunlop-Williams, 1996). Henle also published his books entitled 'Allgemeine Anatomie' in two separate editions in 1837 and 1841, and 'Handbuch der Systematischen Anatomie des Menschen' in three volumes between 1856 and 1873. These books contain illustrations of the macroscopic and microscopic structure of the entire body, an excellent classification of tissues, and a history of descriptive microscopy and histology (Mettler, 1947; Uzluk, 1959; Lyons-Petrucelli, 1987). It has been argued that Henle's histological findings were more significant than those of the renowned anatomist Vesalius (Long, 1965).

Biologist Matthias Jacob Schleiden (1804–1881) succeeded in establishing the concept of the plant cell and, in doing so, conducted microscopic studies on plants, focusing on

plant cells and their reproduction. He determined that the nucleus is naturally present in flowering plants and demonstrated the nucleolus (Theodorides, 1993). Accepting that the cell produces its own similar form through a process similar to crystallisation in chemistry, Schleiden examined cells in different parts of both angiosperms and gymnosperms, stating that the cell is the smallest independent unit in living organisms, that it exists in harmony with the entire structure, and that it performs its assigned tasks within the organism (Tekeli et al., 1999).

Influenced by Schleiden's views, Theodor Schwann (1810-1882), who accepted his ideas on plant cells and attempted to adapt them to animal cells, stated that he aimed to demonstrate that even the most complex animal tissues are composed of cells. In 1839, Schwann published his famous book 'Mikroskopische Untersuchungen' (Microscopic Investigations), which revealed the microscopic structure of plants and animals. In this book, the cell was accepted as the basic unit of life, and this theory revolutionised biology, leading to the emergence of modern concepts related to embryology, genetics, and evolution (Theodorides, 1993). Schwann defined the 'Schwann Cells' named after him in the nervous system and also discovered the striated muscle structures in the upper part of the oesophagus (Mettler, 1947). Schwann, who conducted detailed research on cells, summarised his work as follows: "All plants and animals are composed of cells. Cells have an individual life. Cells have their own unique lives and perform specific functions within the whole" (Tekeli et al., 1999).

Schwann's 'cell theory,' which posits that the animal body is composed of cells that have been specially modified for specific purposes or of substances formed by these cells, remains valid today. By studying animal cells on chicken eggs and observing their developmental stages, Schwann classified tissues into five groups based on his findings (Tekeli et al., 1999).

1-Cells that are separate from each other, such as blood cells.

2-Cells that are arranged side by side, such as skin cells.

3-Cells that are needle-shaped, such as muscle cells.

4-Cells whose cell membranes have thickened and hardened, such as bone and cartilage cells.

5-Cells whose cell membranes and spaces are adjacent to each other, such as nerve cells.

Although the development of cell theory is associated with Schleiden and Schwann, René-Joachim-Henri Dutrochet (1776-1847) surpassed these researchers in many respects. At least 15 years before Schwann's work, Dutrochet focused on the role of the cell as a physiological unit, pointing out that the basic unit in plant and animal tissues

Copyright © 2025 by ISRES Publishing

was the cell, observing that dead structures such as hairs were actually composed of living cells, proposing that growth was dependent on the formation and development of new cells, discovered migrating leukocytes, and first used the term ‘osmosis’ (Mettler, 1947).

Apart from Schwann, many scientists during his time and afterwards conducted research on cells and determined the properties and physical and chemical characteristics of the cell nucleus, membrane and protoplasm. The main focus of research on the nucleus has been on ‘cell division’. Thanks to these studies, research on mitosis, amitosis, and meiosis yielded results at the beginning of the 20th century. Similarly, studies on protoplasm made it possible to determine the chemical building blocks of living organisms, thereby making the structure of living organisms more understandable. These studies ensured that the subject of cells took shape as an independent field of research within biology (Tekeli et al., 1999).

The current understanding of cells is the product of observations made by various scientists who lived in the 19th century and conducted studies using microscopes, and some of these scientists contributed to the formulation of cell theory (Theodorides, 1993). One of the first to suggest that organs must be composed of cells, the Czechoslovakian scientist Johannes Evangelista Pürkinje (1787-1869) first became closely interested in the living entity of the cell in 1837 or 1839 and named it ‘protoplasm’ (Mettler, 1947; Theodorides, 1993; Dunlop-Williams, 1996). Pürkinje was also the first researcher to use the ‘microtome’ for sectioning and ‘Canada balsam’. Pürkinje, who also discovered the sweat glands in the skin, defined the ‘Pürkinje Cells’ in the cerebellum, named after himself, and the ‘Pürkinje Fibres’ in the heart muscle and uterus (Mettler, 1947). Pürkinje, who also used new achromatic lenses that yielded good results under the microscope, put forward his hypothesis showing the functional hierarchy between nerve cells, which could form a stepping stone for the ‘Neuron Theory’ (Dunlop-Williams, 1996).

The anatomist Max Johann Sigismund Schultze (1825–1874), who worked on cells and whose research was almost entirely histological, was the first to correctly define the cell in 1854, stating that ‘the cell is a small mass of protoplasm containing a nucleus and surrounded by a rigid cell membrane.’ He conducted successful studies on nerve endings in sensory organs and on the nose and retina. Schultze, who also developed the tissue staining technique using osmic acid, founded the journal ‘Archiv für Mikroskopische Anatomie’ in 1865 and served as its editor until his death (Mettler, 1947; Dampier, 1957; Theodorides, 1993). Rudolf Wagner (1805-1864) also conducted detailed studies on nerve cells in the brain of the electric fish (Mettler, 1947). The resulting understanding of cells soon had a profound impact on histology and embryology studies (Erk, 1978).

Rudolf Virchow (1821-1892), a student of Johannes Müller (1801-1858), one of the first to use the microscope in pathology, reported that all vital events and disease

symptoms occur in the cells that make up the body, and conducted research on the phases of karyokinesis. Virchow also opposed the view previously put forward by Schwann, concluding that cells are not formed in tissue fluids but are the product of division. In his book 'Cellular Pathologie', published in 1858, Virchow summarised his view as 'omnis cellula e cellula', meaning 'every cell originates from another existing cell' (Mettler, 1947; Dampier, 1957; Lyons-Petrucelli, 1987; Theodorides, 1993).

In plants, cell division was demonstrated in the true sense in 1875 by the German botanist E. Strasburger (1844-1912), who observed mitotic division in plant cells and the division of the cell into two parts that could be stained. Another German physician, W. Flemming, demonstrated mitosis in diploids and further deepened and explained his research by studying the phases of karyokinesis, as did Virchow. Flemming named the stainable particles of the nucleus 'chromatin' (Mettler, 1947; Theodorides, 1993). Wilhelm Waldeyer (1836-1921) named the structures he observed in cell nuclei 'chromosomes' in 1891 and the cells found in the nervous system 'neurons' (Mettler, 1947; Lyons-Pettrucelli, 1987).

One of the leading microscopists of his time was the Swiss scientist Rudolph Albert von Koelliker (1817–1905). He made countless contributions to histology, embryology, and morphology. His work demonstrated that spermatozoa originate from testicular tissue. Further detailed Henle's studies on the muscle structure of blood vessels, made observations on neuroanatomy, and wrote the first organised histology textbook, Mikroskopische Anatomie, in light of the new cell theory (Mettler, 1947; Lyons-Petrucelli, 1987). Published in Germany in 1851, this first histology textbook in the world also covered the details of the nervous system, the smallest structures of the eye and ear, and the importance, functions, and classifications of various types of blood cells. Koelliker's histology textbook was translated into English in 1852, and the tissue and organ diagrams included in both language editions are still noteworthy today (Carleton-Short, 1954).

Researchers who studied the microscopic details of the nervous system in laboratories and demonstrated staining methods for nerve cells and their filaments have greatly benefited clinical neurology. One of the pioneers of this movement, Camillo Golgi (1844-1926), first isolated nerve tissue cells in 1873 using silver nitrate. Another Spanish researcher working in the field of neurohistology, Santiago Ramon Y Cajal (1852-1934), together with Camillo Golgi, used the metal impregnation method in neurohistology and won the 1906 Nobel Prize for their findings obtained from the central nervous system (Uzluk, 1959; Erbengi, 1988). Furthermore, the experimental principles of nerve cell degeneration developed by Auguste-Henri Forel (1848-1931), who also worked on neurohistology, replaced the old views on this subject (Mettler, 1947).

Copyright © 2025 by ISRES Publishing

Russian scientist Elie Metchnikoff (1845-1916) drew attention to the fact that certain cells in the body eliminate foreign particles and microorganisms by ingesting them, and named these cells 'phagocytes'. Consequently, by distinguishing between 'macrophages' and 'microphages' in blood and tissue cells, he laid the foundation for the cellular theory of immunity (Dampier, 1957; Erk, 1978). Meanwhile, the renowned physician Joseph J. Lister (1827-1912) developed a modern type of compound microscope with an achromatic objective (Long, 1965). Furthermore, in 1907, H. Harrison conducted important studies on tissue culture (Erbengi, 1988; Karasszon, 1988).

Following the formulation of cell theory, the development of cytology continued with the emergence of new techniques, enabling the acquisition of tissues that could be cut into thin sections using microtomes and stained with various substances such as plant dyes and mineral salts. The impact of cell theory on biology has been immense (Theodorides, 1993).

Microscope Errors and Their Correction

From the outset, all microscopes produced have been affected by chromatic and spherical aberrations (deviations), leading to misinterpretations. Newton, in particular, conducted important work on eliminating these aberrations (Merdivenci, 1975; Boorstin, 1996). Chromatic aberration arises when each colour, which makes up white light and has a different wavelength, is refracted at a different angle as it passes through the lens and converges at different focal points. As a result, a coloured halo forms around the image. Spherical aberration, on the other hand, arises from the lens thickness not being the same at the edges and the centre. As rays pass through thick and thin areas, they exhibit different refraction properties and converge at different focal points. Consequently, the image field cannot be completely sharpened (Artan, 1988).

By conducting research specifically aimed at eliminating chromatic aberration, work began on developing the achromatic lens in 1807 by H. Deijel (1738-1809) J. L. V. Chevalier (1770-1840) and C. L. Chevalier (1804-1859) in 1824, and Giovanni Battista Amici (1786-1863) in 1829.

Andrew Ross (1798-1859) and his son Thomas Ross (1819-1870) produced the first classical binocular microscope in 1862 (Merdivenci, 1975). Despite the research conducted by the 'Oberhauser' and 'Hartnack' companies, no progress was made in eliminating chromatic aberration until Ernst Abbe (Karasszon, 1988). However, Ernst Abbe (1840-1905) and Carl Zeiss (1816-1888) successfully used the apochromatic objective lens they developed to eliminate spherical and chromatic aberrations for the first time in 1886. In this way, they achieved technical perfection in magnification by eliminating both spherical and chromatic aberrations and improved the eyepieces and objectives. Ernst Abbe also completed his development work on the condenser, one of the most important parts of the microscope, in 1873, and in 1878, together with Carl

Zeiss, used the first homogeneous oil immersion lens (Long, 1965; Merdivenci, 1975; Erbengi, 1988; Karasszon, 1988).

The Development of New Microscopic Techniques

Joseph Janvier Woodvard was the first to investigate the possibilities of taking photographs under a microscope in 1883-1884, and is therefore considered the 'pioneer of microphotography'. Moritz V. Rohr (1868–1940) also conducted research in the field of microphotography in 1904 (Merdivenci, 1975). Meanwhile, in 1887, H. S. Greenough made significant contributions to the development of the binocular microscope (Erbengi, 1988).

Advances in histological techniques by researchers have enabled the discovery of productive and unexplored microscopic areas. General histological practices in the 19th century were based on the immediate examination of frozen fresh tissue sections cut with a razor. All tissues except cartilage and bone are too soft for sectioning, making it extremely difficult to obtain sections from them. This difficulty could only be overcome by freezing the tissues to be sectioned. The general method consists of placing the cut material in a container and immersing it in a freezing saltwater mixture. After a short time, the tissues can be easily cut with a razor. Pieter de Riemer (1760-1831) from the Netherlands was one of the first to use this method. Benedict Stilling (1810-1879) successfully used the freezing method, particularly in his classic studies on central nervous system histology (1843). Later, physiologist Gabriel Gustav Valentina (1810-1883) discovered double-edged blades and used them to obtain thin sections from tissues (Mettler, 1947; Long, 1965).

Work on microtomes gained momentum towards the end of the 19th century, and French-made microtomes, in particular, became more popular due to their simplicity and affordability. Numerous scientists working at universities developed new and improved forms of microtomes, while the mechanical details of microtomes were perfected by technical staff at universities. A new microtome invented by German pathologist Richard Thoma, which served as a model for much more modern microtomes, came into use from 1881 onwards (Long, 1965).

Particularly from the mid-19th century onwards and in parallel with these developments in light microscopy and microscopy techniques in the 20th century, entirely new methods and techniques were developed and began to be used in the field of histology. In this way, significant advances were made in cytology, histology, and microscopic anatomy. Meanwhile, numerous newly synthesised chemical substances began to be used in histology laboratories. The vast majority of these methods are staining techniques used to determine the presence of tissues and cells. Microscope techniques, which have advanced over time, have become the most important part of the discipline of microscopic anatomy

Copyright © 2025 by ISRES Publishing

and have formed a fundamental infrastructure for histochemical research today. These developments in histology were naturally and rapidly applied in the field of pathology as well (Long, 1965; Pearse, 1968; Lyons-Petrucelli, 1987).

Danish scientist Adolf Hannover (1814-1894) used chromic acid solutions to fix tissues, and German physicist F. Blum used formaldehyde as a fixing solution in 1893. In addition, Carl Kayserling and Rudolf Virchow jointly developed the 'Kayserling Solution' in 1897, which was used for fixing and preserving large tissue specimens. In 1894, Konrad Zenker developed the 'Zenker Solution,' which contained potassium dichromate and mercuric chloride. Tissues to be embedded in paraffin require solidification and dehydration, so alcohol has long been used for this purpose.

Salomon Stricker used a mixture of beeswax and oil for embedding, while Edwin Klebs, in 1869, first described the method of embedding tissue in paraffin and used this method in his own laboratories a few years later. Matthias Duval (1844-1915) first developed collodion, and shortly afterwards, its commercial form, 'Celloidin', was introduced to the market and is now used in conjunction with paraffin. Transparent solutions of carmine and gelatin were first injected into tissue vascular systems in 1847 by Joseph Gerlach (1820-1896). This was one of the first significant staining procedures. Alum-Haematoxylin, a nuclear stain still used today, was first used by F. Böhmer in 1865. The discovery of aniline dye created great opportunities in staining. Furthermore, Paul Ehrlich played a major role in this field and proved through his work that living tissues could also be stained with a group of dyes (Long, 1965). However, at the beginning of the 20th century, histology was not limited to the examination of normal tissues; it also focused on studies aimed at understanding the cellular basis of pathological changes. The staining methods used during this period became a fundamental tool not only for distinguishing tissue types but also for diagnosing diseases. In this context, Haematoxylin-Eosin (H&E) staining began to be used as the standard method for evaluating the general morphology of tissues. Additionally, special methods such as Van Gieson, Masson Trichrome, PAS (Periodic Acid-Schiff), and Sudan stains have been developed; it has become possible to selectively demonstrate different cellular components such as connective tissue, muscle, fat, and carbohydrate content, by staining them. The widespread use of these techniques has transformed histology from a morphological field into a diagnostic and analytical science.

The Development of New Microscopes and Modern Histology

The limitations of the light microscope became even more apparent in the mid-20th century, resulting in a need for higher resolution images. This requirement led to the development of the electron microscope in the 1930s. Electron microscopes, which use electron beams instead of light beams to make invisible living or non-living entities

visible, were developed and began to be used in the first half of the 20th century.

Numerous researchers, chief among them K. F. Braun (1850–1918) and J. J. Thomson (1856–1940), conducted studies on cathode rays and the relationship between cathode rays and electrons in the final years of the 19th century. The concept of the electron microscope originated with the 'Wave Mechanics Theory' (1924) of the world-renowned French physicist Louis de Broglie (1892-1987). The most significant difficulty encountered in research on electron microscope optics was the ability to form an image with electrons. This problem was solved, in particular, by adapting Abbe's views on image formation in optical microscopes to the electron microscope, and only then was it possible to achieve rapid progress in the construction of electron microscopes (Bradburry & Turner, 1967; Larsen, 1975; Erbengi, 1988).

Meanwhile, Hans Busch's discovery in 1926-1927 that an electromagnetic field deflects electron beams constituted an important step in the construction of the electron microscope. As a result of systematic work in this direction, the renowned physicists Max Knoll (1897) and Ernest Ruska (1906-1988) established the basis for the first electron microscope in 1931. Approximately one year later, in November 1932, the first electron microscope was built in Berlin and entered service in 1933. The first biological research using an electron microscope was conducted in 1934 (Bradburry & Turner, 1967; Larsen, 1975; Merdivenci, 1975; Erbengi, 1988). Tissue sections of sufficient thinness for electron microscopy were first obtained by Von Ardenne in 1939. Latta and Hartmann were the first to use glass blades in 1950 (Reid, 1970). Ernest Ruska, who invented the electron microscope in 1933, won the Nobel Prize in Physics in 1986, and his first reaction to this event was to say, 'I am very happy. I thought I had been forgotten' (Erbengi, 1997).

Thus, the detailed structure of organelles such as mitochondria, ribosomes, endoplasmic reticulum, cell membrane, and nucleolus could be observed for the first time with the electron microscope. The electron microscope revolutionised cell biology and histology, providing molecular-level explanations for morphological information. With this development, histology redefined itself as a molecular morphology science that studies the structure and function of living tissues at the microscopic level, independent of anatomy.

Additionally, the Ultraviolet Microscope, which allows for the examination of cellular elements that absorb ultraviolet rays, such as nucleic acids, was developed in 1903 by R. Zsigmondy and H. Siedentopf in 1903, the Polarisation Microscope, which can examine double-refracting materials, was developed by W. J. Schmidt in 1924, the Fluorescence Microscope was developed by Carl Reichert in 1911, and the first Phase Contrast Microscope, which can examine living, moving materials, was developed by

Copyright © 2025 by ISRES Publishing

Fritz Zemnike in 1932. In addition to all these, the Confocal Microscope was developed starting in the 1980s and, thanks to its optical sectioning feature, made it possible to examine the three-dimensional structure of tissues at high resolution. This microscope has enabled the detailed examination of neural networks, vascular structures, cytoskeletal organisation, and intracellular transport mechanisms in modern cell biology (Erbengi, 1988; Karasszon, 1988). Finally, the cryo-electron microscope began to be used in the 21st century as a microscope that allows the atomic-level examination of proteins, viruses, and macromolecular complexes in their natural state. Here, samples are rapidly frozen with liquid nitrogen and imaged in an electron microscope before ice crystals form. This method enabled the observation of cell structure without damage and earned researchers Jacques Dubochet, Joachim Frank, and Richard Henderson the Nobel Prize in Chemistry in 2017.

Thus, histology has evolved beyond being merely a discipline that studies cell and tissue morphology since the mid-20th century; today, it has become a multifaceted field of research that integrates with biochemistry, molecular biology, and genetics. During this process, rapid advances in microscope technology have enabled the study of the three-dimensional, dynamic and functional structures of living cells. At the same time, these developments have enabled microscopic-level investigations in cell biology and have brought histology closer to physiology (histophysiology) and molecular biology.

These developments have transformed histology from merely the ‘structural examination of tissues’ into a discipline that unravels the dynamic organisation of living systems. Thus, modern histology has elevated itself to the status of a scientific discipline that pioneers the understanding of life at the microscopic level by integrating morphology with molecular biology, genetics, biochemistry, and biophysics.

Embryology

The Origins of Embryology

People have been interested in embryonic development since ancient times. In antiquity, embryological studies were conducted in Ancient Egypt, Babylon, Assyria, and India. It is known that embryological studies were particularly well developed in India. In India, Susruta, in the 6th century BC, proposed that the embryo was formed from semen and blood, and that the origin of these two was a white fluid found in the intestines. He focused on the development of the child in the womb according to months and reported that the soft parts of the body came from the mother and the hard parts from the father. In Egypt, systematic embryology studies were conducted, and artificial incubators were developed for bird eggs. Similarly, artificial incubation was successfully applied in China (Needham, 1934).

Embryology in Ancient Greek Science

Later data on embryology can be found in ancient Greek. Alcmaeon, Hippocrates, Empedocles, and Aristotle contributed to knowledge on this subject (Petorak, 1988; Kayalı, 1989; Theodorides, 1993). Hippocrates (460-377 BC) proposed that the embryo was nourished by the mother's blood, which flowed towards the foetus, coagulated there, and shaped the embryo's flesh. He stated that the white part of the bird's egg is edible, while the yolk is used for structural purposes in the body. Parmenides (540-450 BC) reported that the female embryo forms on the right side of the body, while the male embryo forms on the left side (Needham, 1934).

Aristotle (384–322 BC) observed chick development from the earliest days in the egg, investigated the early development of the heart and major blood vessels, examined the first heartbeats of the embryo, and ultimately advanced thinking on circulation, thereby creating an advantage for those who came after him (Smithcors, 1958). Aristotle proposed that the heart was the first organ to differentiate, that foetuses did not breathe, and that male and female embryos did not develop in different parts of the uterus (Needham, 1934; Lyons-Petrucelli, 1987).

One of his most notable works is his research tracking placental development in sharks. Aristotle also observed the development of fish and emphasised the similarities between fish and placental mammals (Singer-Underwood 1962). Aristotle was the scientist who grouped animals into three embryological groups: 'oviparous' (those that hatch from eggs), "viviparous" (those that give birth to live young), and 'ovo-viviparous' (those that hatch from eggs and give birth to live young). Similarly, he also conducted studies based on comparative observations of the reproduction and development of vertebrates and invertebrates (Bertier-Aristot, 1998). Aristotle is recognised as the 'Founder of Embryology' due to these early and important works in the field of embryology (Kayalı, 1989). Aristotle reported that the germ (seed) is formed from the mixture of male and female reproductive fluids, and thus the spirit from the male and the body from the female shape the foetus (Sarton, 1950). Aristotle theoretically indicated that the new life formed within the female organism, suggesting that all reproductive material came from the female and stating that the reproductive materials in the female were contained within the menstrual blood, which was released at intervals (Sarton, 1950; Erk, 1978; Petorak, 1988).

Herophilus (375–280 BC) described the ovary and oviduct, while much later Galen (129–199 AD) reported that a fluid formed in the female's ovaries was transported to the uterus, where it mixed with the seminal fluid to result in pregnancy. Contrary to Aristotle, he proposed that male seed was both the material and the cause of reproduction (Petorak, 1988). Galen, who conducted more detailed embryological studies, also provided anatomical descriptions of the allantois, amniotic membrane, placenta, and

Copyright © 2025 by ISRES Publishing

membranes. According to Galen, embryonic life consisted of four stages: 'the unformed seminal stage, the stage in which the brain, heart, and liver are formed, the stage in which all organs are formed, and the stage in which the formed organs are clearly visible'. Parallel to these developments, Galen also proposed that the embryo transitions from the life of a plant to the life of an animal (Needham, 1934).

Embryology in the Middle Ages and the Modern Era

During the Middle Ages, theological theories were also developed concerning embryonic development and the formation of life (Sarton, 1953). Furthermore, in the baytarnames written during the Islamic civilisation, the foetal development of young animals in the womb was frequently discussed (Dinçer, 1973). Throughout the Middle Ages and until the early 17th century, the views of Aristotle and Galen generally remained dominant in the field of embryology. During this period, two important embryological works by physicist and anatomy professor Hieronymus Fabricius d'Aquapendente (1533-1619), who inherited the legacy of Leonardo Da Vinci's (1452-1519) studies and drawings, stand out in the field of embryology in the 1600s. His first book, 'De Formatione Ovi et Pulli,' which describes chick development, is considered to be in line with Aristotle and Galen's views. His second work, 'De Formatio Foetus', covers domestic mammals as well as mice and sharks (Dunlop-Williams, 1996). In addition, research prepared by Pierre Belon of Le Mans (1517-1564) in 1551, showing the characteristic mammalian foetus in the uterus, was published.

As can be seen, the 17th century did not inherit a unified and common theory of reproduction from the Old World. Different theories exist for each class of living beings. It is clearly evident that reproduction in mammals differs from that in oviparous animals. The first research attempting to provide a common explanation for the reproduction of all animals was conducted by Doctor of Medicine William Harvey (1578-1657), who also discovered blood circulation and is considered one of the first great embryologists of the modern world (Mettler, 1947; Singer-Underwood, 1962; Westfall, 1987).

Harvey, in his embryology book titled 'Exercitationes De Generatione Animalium,' published in 1651 during his later years, determined that the first product of pregnancy is always a type of egg. He attempted to prove that viviparous animals also hatch from eggs and expressed this view with the famous maxim 'ex ovo omnia' (every living thing is born from an egg) (Hunter, 1931; Erk, 1978; Westfall, 1987; Theodorides, 1993). Continuing Fabricius' work, Harvey also studied the blastoderm, maturation, and the origin of blastocysts, using magnifying glasses/lenses during his work (Wolf, 1950; Dunlop-Williams, 1996). However, Harvey did not fully understand the ovum, mistaking the larva or pupa in insects and the membranes or chorion in mammals for the small embryo. His studies on deer led him to propose the view that the offspring originated

solely from the female seed, with the male merely serving to facilitate its formation, like a magnet or a stimulant.

Embryological Theories

In the second half of the seventeenth century, since the ovum had not yet been discovered, Harvey is recognised as the founder of the 'ovist theory' (ovism), a theory stating that the embryo originates solely from the female animal (Erk, 1978; Westfall, 1987; Theodorides, 1993). However, Harvey also appears to have accepted the theory of 'spontaneous generation' for such creatures, as the eggs of insects, being very small creatures, are too small to be seen. Harvey also studied blood circulation in foetuses, demonstrated that the mother's blood provides nourishment for the foetus, and emphasised the similarities between the blood circulation of adult fish and foetuses (Needham, 1934; Erk, 1978). Harvey is one of the proponents of the 'epigenesis' (sequential formation) theory in embryology. According to this theory, the 'embryo' (foetus) is formed by the sequential addition of developing segments (Lyons-Petrucelli, 1987; Theodorides, 1993).

With the development of the microscope, from the first half of the 17th century onwards, old views gradually gave way to new ones (Petorak, 1988). Antony Van Leeuwenhoek (1632-1723) first observed human and animal spermatozoa under a microscope in 1677-1678 and illustrated them. As a result, the 'animalculist theory' began to emerge in opposition to Harvey's ovist theory. Contrary to the ovists, the animalculists argued that offspring were formed solely by male seed (Wolf, 1950; Westfall, 1987; Theodorides, 1993). Louis van Hamm, in 1677, proposed that the egg, which was immobile and therefore considered lifeless, was merely a storehouse of nutrients (Kayalı, 1989).

Another Dutchman, Niklaas Hartsoeker (1656-1725), published a small work showing drawings of male spermatozoa he observed under the microscope after Leeuwenhoek (Lyons-Petrucelli, 1987). Another Dutchman working in the field of embryology, Jan Swammerdam (1637-1687), examined the eggs of various animals (lice, ants, butterflies, frogs). As a result of these studies, he adopted the theory of 'preformation'. According to this theory, there is a very small embryo inside the egg, and this embryo contains the entire being of the animal in miniature form and gradually emerges by growing and developing from the membranes surrounding it. Supporters of the preformation theory also oppose the theory of epigenesis proposed by Harvey (Lyons-Petrucelli, 1987; Theodorides, 1993).

As can be seen, scientists living at the end of the 18th century were divided into two camps: those who accepted that the embryo underwent a preformation within the egg, known as 'preformation' or 'epigenesis', and those who attributed the fundamental role in the development of the organism to the egg or sperm, known as "ovists" or 'animalculists'. (Bernal, 1976; Lyons-Petrucelli, 1987; Theodorides, 1993).

Copyright © 2025 by ISRES Publishing

New Developments in Embryology

Perhaps the greatest embryologist of the century, Marcello Malpighi (1628-1694), developed the technique of peeling the membrane of a newly laid egg and spreading it on glass, thereby enabling the use of the microscope in embryological studies (Westfall, 1987). With the aid of a simple microscope, he was able to see details that Harvey could not and made observations on reproduction, particularly in chickens and insects (Mettler, 1947; Theodorides, 1993). In his work, he defended the view that all animals are produced from eggs, based on the identification and development of the chicken egg. Malpighi's embryological study, published in 1666 under the title 'De formatione pulli in ovo', is of great importance (Mettler, 1947).

Thomas Wharton (1610–1673) was the first to describe the 'Wharton's jelly,' a loose embryonic connective tissue located in the umbilical region, which bears his name. Meanwhile, the Danish anatomist N. Stenon (1638–1686) conducted studies on the ovum in mammals and fish. while Dutchman Regnier de Graff (1641-1673) described the 'Graffian follicle' and the 'corpus luteum' in rabbits, dogs, cattle and human ovaries in 1672, and demonstrated the spermatic vessels using mercury injection. De Graff did not oppose Aristotle's views on reproduction, but stated that the embryo was solely a male product and that the mother had no function beyond nourishment and protection (Mettler, 1947; Wolf, 1950; Westfall, 1987; Theodorides, 1993). Furthermore, Italian Francesco Redi (1618-1676) attempted to disprove the theory of spontaneous generation through his experiments, which was one of the most significant developments of the century (Uzluk, 1959; Westfall, 1987; Sari, 1994). Nevertheless, by the mid-17th century, the problem of fertilisation and embryonic development was still far from being resolved (Theodorides, 1993).

The Scottish anatomist Alexander Monro (1687–1767) studied the uterus, the membranes surrounding the foetus, foetal circulation, the cotiledon and the allantois in cattle and in various animal species; his son, the anatomist Alexander Monro –secundus– (1733-1817), demonstrated that there is no relationship between foetal blood and maternal blood in mares and cows in the placenta. One of the most famous comparative anatomists, physician, and surgeon John Hunter (1728-1793), conducted studies on freemartinism, oestrus in animals, unilateral ovariectomy in young animals, and the structure of the placenta. He laid the foundations of placental anatomy by demonstrating that the maternal and foetal circulations are independent of each other (Mettler, 1947; Erk, 1978). Father Lazzaro Spallanzani (1729-1799), who clearly rejected the theory of spontaneous generation through his experiments, performed artificial insemination in frogs for the first time in 1777 and drew attention to the necessity of contact between sperm and egg for fertilisation (Erk, 1978; Theodorides, 1993). For approximately two hundred years, fierce debates took place between supporters of the preformation and epigenesis theories

(Wolf, 1950; Bernal, 1976; Kayalı, 1989; Theodorides, 1993).

However, the embryological studies of the German scientist Caspar-Friedrich Wolf (1733-1794) held an important place in the middle of the century. Wolf published his fundamental scientific observations in his works 'Theoria Generationis' in 1759 and 'De Formatione Intestin' in 1768. In these works, he demonstrated that organs are not preformed but gradually take shape during the formation of the embryo, providing strong support for the theory of epigenesis. He also studied the development of the intestines in chicks (Needham, 1934; Erk, 1978). The physiologist Albrecht von Haller (1708-1777), although initially accepting the theory of epigenesis, vehemently opposed Wolf's work, believing that his studies around 1760 proved that the chick embryo was preformed within the egg. He conducted original studies on the growth rate of the embryo, demonstrating that it grows at an incredible speed in the uterus and arguing that no organ can develop before another, but that they all take shape simultaneously (Needham, 1934).

The renowned Czech scientist Johannes Pürkinje (1787–1869) published a study in 1837 proposing that the animal organism consists of three primary forms: liquid, granular, and fibrous. He also demonstrated the structure of the vesicula germinativa in the embryo (Mettler, 1947; Dunlop-Williams, 1996). In the early nineteenth century, Swiss physician Jean-Louis Prevost (1790-1850) and French chemist Jean-Baptiste Dumas (1800-1884) conducted important research on fertilisation. In their work, building on Spallanzani's discoveries, they established the relationship between the presence of spermatozoa in seminal fluid and fertilisation capacity. The two scientists proposed that spermatozoa entered the egg and formed certain organs (such as the nervous system), while other organs originated from the egg and the egg membrane (Theodorides, 1993).

The German biologist Carl Ernst von Baer (1792–1876) first described and identified the egg cell within the tertiary follicle in dog ovaries in 1827. Furthermore, in his work published in 1828, he laid the foundation for knowledge about embryonic germ layers. For these reasons, von Baer is recognised as the founder of modern embryology. The embryonic germ layers mentioned by Baer were classified by Robert Remak (1815-1865) in 1845 according to their embryonic origins and named ectoderm (outer), mesoderm (middle) and endoderm (inner) (Dampier, 1957; Lyons-Petrucelli, 1987; Petorak, 1988; Theodorides, 1993). Physiologist Johannes Müller (1801-1858) also conducted numerous studies in the field of embryology and discovered the 'Müllerian duct,' named after him (Uzluk, 1959; Erdemir, 1994).

Rudolf Virchow (1821–1892) explained that all vital events and disease symptoms occur in the cells that make up the body, and that cells are the common building blocks of all living organisms. It was then understood that although both the ovum and the spermatozoon differ from other cells in shape and function, they are still cells. With

Copyright © 2025 by ISRES Publishing

Oscar Hertwig's 1875 discovery that the spermatozoon enters the egg, the event of 'fertilisation' has been accepted as the beginning of life. Hertwig fully defined and explained this by observing the fertilisation of female and male germ cells for the formation of living organisms (Lyons-Petrucelli, 1987; Theodorides, 1993). In his work between 1883 and 1887, Belgian biologist E. van Beneden demonstrated that the egg and spermatozoon contain equal numbers of chromosomes and carry half the number of chromosomes of the germ cells from which they originate (Theodorides, 1993). The most important work of anatomy professor Wilhelm His was in embryology, and his first article on tissue layers and body cavities was published in 1865. This new classification of tissues became standard in embryology. He focused on structures originating from the mesoderm and conducted research on chick embryology in 1868. He completed his most important work, 'Anatomie Mensclier Embryonen,' in 1885, becoming the first scientist to work on a complete human embryo. (Mettler, 1947). As a result of his research, Walter Fleming reported in 1882 that the embryo grows, organs develop, and tissues can be renewed with the help of the cell division mechanism (Lyons-Petrucelli, 1987).

Modern Embryology

On the one hand, the cellular structure of gametes has been determined; on the other hand, cell theory has made it possible to definitively link all the formation processes of living organisms to divisions, transformations, or the displacement of cells. These new ideas have also influenced embryology (Theodorides, 1993). Meanwhile, the first histology textbook, written by Albert von Kölliker (1817-1905), also covered embryonic development in light of the new cell theory (Lyons-Petrucelli, 1987).

Following the definition of fertilisation, the morphological examination of the embryo continued throughout the 19th century and continues today. Although the main features of this reality are known, there are still many important points that need to be clarified today (Kayalı, 1989). A. Fischel first used vital staining in embryology research in 1903, while W. Wogt, in 1925, used vital stains to mark sections of the egg cell and showed where the cells that would develop from the blastomeres formed as a result of the 'segmentation' event would later migrate (Erbengi, 1988; Petorak, 1988). On the other hand, zoologist Hans Spemann (1869-1941) and his colleagues initiated experimental embryology studies.

Recently, with the understanding of the importance of DNA in reproduction and development, developmental events have also been approached from a molecular biology perspective, changing researchers' perspective on developmental events. New types of microscopes developed during this process have further strengthened the scientific foundations of this change. (Petorak, 1988). The importance of embryology has gained even more significance today, particularly with the proliferation of techniques such as

IVF, in vitro fertilisation, and cloning. In this way, embryology has begun to transform from a basic science into a discipline that is closer to clinical sciences and more applied.

References

Armutak, A. (2000). Türkiye'de veteriner hekimliğinde histoloji ve embriyoloji tarihi üzerinde araştırmalar (Doktora tezi, Ankara Üniversitesi Sağlık Bilimleri Enstitüsü). Ankara.

Artan, M. E. (1988). Histoloji. İstanbul Üniversitesi Veteriner Fakültesi Yayınları.

Bernal, J. D. (1995). Modern çağ öncesi fizik (ss. 121–123). TÜBİTAK Popüler Bilim Kitapları.

Boorstin, D. J. (1996). Keşifler ve buluşlar (F. Dilber, Trans.). Türkiye İş Bankası Kültür Yayınları.

Bradbury, S., & Turner, G. (1967). Historical aspects of microscopy. Royal Microscopical Society.

Carleton, H. M., & Short, R. H. D. (1954). Schaeffer's essentials of histology. Longmans, Green and Co.

Dampier, W. C. (1957). A shorter history of science (pp. 113–129). Meridian Books.

Dobell, C. (1960). Anthony van Leeuwenhoek and his little animals. Dover Publications.

Dunlop, E., & Williams, P. (1996). Veterinary medicine: An illustrated history. Dunlop & Williams.

Erbengi, T. (1988). Dünyada ve Türkiye'de 1850 yılından sonra tıp dallarındaki ilerlemelerin tarihi (ss. 208–219). İÜ Cerrahpaşa Tıp Fakültesi Vakfı Yayınları

Erbengi, T. (1997). Elektron mikroskopi kongresinden izlenimler. Tekser Koll. Şti.

Erdemir, A. D. (1994). Tıp tarihi ve deontoloji dersleri (s. 75). Uludağ Üniversitesi Basımevi.

Eren, N. (1996). Çağlar boyunca toplum, sağlık ve insan (ss. 336–337). Gelişim Dizgi & Yayıncılık.

Erk, N. (1978). Veteriner tarihi. Ankara Üniversitesi Veteriner Fakültesi Yayınları

Ergin, Ö. (1997). Işık mikroskobu. TÜBİTAK Bilim ve Teknik, ss. 54–60.

Copyright © 2025 by ISRES Publishing

Karasszon, D. (1988). A concise history of veterinary medicine (pp. 394–401). Akadémiai Kiadó.

Kirkpatrick, P. (1976). Mikroskop ve dünyası (ss. 3–5). Remzi Kitabevi.

Larsen, E. (1975). Gençler için teknik tarihi (ss. 331–334). May Yayınları

Long, E. (1965). History of pathology. Dover Publications.

Lyons, A. S., & Petrucelli, R. J. (1987). Medicine: An illustrated history (pp. 439–441). Harry N. Abrams.

Mettler, C. C. (1947). History of medicine. The Blakiston Company.

Merdivenci, A. (1975). Türkiye'de mikroskop ve tarihi. Hilal Matbaacılık.

Pearse, A. G. E. (1968). Histochemistry: Theoretical and applied (3rd ed., Vol. 1, pp. 1–3). Little, Brown.

Purtle, H. R. (1974). History of the microscope. Armed Forces Institute of Pathology

Reid, N. (1970). Ultramicrotomy (pp. 224–225). North-Holland Publishing.

Sarı, N. (1994). Tıp tarihi ders notları. İstanbul Üniversitesi Cerrahpaşa Tıp Fakültesi.

Sarton, G. (1950). Introduction to the history of science (Vol. 2, Parts 1–2). Williams & Wilkins

Sencer, M. (1998). Bilim tarihinde dönüm noktaları (ss. 269–270). Say Yayıncılık

Tekeli, S., Kahya, E., Dosay, M., Demir, R., Topdemir, H. G., Unat, Y., & Aydın, A. K. (1999). Bilim tarihine giriş (s. 299). Nobel Yayın Dağıtım.

Theodorides, J. (1993). Biyoloji tarihi. İletişim Yayınları.

Ural, Ş. (1998). Bilim tarihi (ss. 269–270). Kırkanbar-Aralık Yayıncılık.

Uzlun, F. N. (1959). Genel tıp tarihi I. Ankara Üniversitesi Tıp Fakültesi Yayınları.

Ünver, S. (1943). Tıp tarihi (I ve II. kısımlar) (ss. 120–121). İstanbul Üniversitesi Yayınları.

Westfall, R. S. (1987). Modern bilimin oluşumu (İ. H. Duru, Trans., ss. 91–116). Verso Yayınları.

Wolf, A. (1950). History of science, technology and philosophy in the 16th and 17th centuries. Allen & Unwin.

About the Authors

Altan Armutak is a Turkish veterinary historian and ethicist who has served as a faculty member at Istanbul University's Faculty of Veterinary Medicine. Born in Istanbul in 1961, he completed his doctoral studies in veterinary medicine before going on to specialise in the history of veterinary medicine and professional ethics. Throughout his academic career, he has taught courses on veterinary ethics, animal rights, and publication ethics, and has contributed significantly to the field through his research on the historical, religious, and moral dimensions of human–animal relationships. His scholarly work includes examinations of animal rights in Islamic, Christian, and Jewish sacred texts, as well as analyses of contemporary ethical issues such as veterinary responsibilities during the pandemic of the Coronavirus (SARS-CoV-2). Armutak's academic profile is distinctive in its integration of veterinary science, history, and ethical philosophy, thus providing significant insights into the cultural and moral foundations of animal welfare.

E-mail: armutak@iuc.edu.tr **ORCID:** 0000-0003-0643-7492

Ayca UVEZ, Assistant Professor of Histology and Embryology at the Faculty of Veterinary Medicine, Istanbul University- Cerrahpasa in Istanbul, Turkiye. She holds a doctorate in Histology and Embryology, with her dissertation focusing on the effects of mangiferin and paclitaxel combinations on cancer treatment using *in vitro* and *in vivo* methods. Her research focuses on cancer treatments, particularly mechanisms such as apoptosis, autophagy, and angiogenesis, with an emphasis on innovative strategies using natural compounds

E-mail: ayca.uvez@iuc.edu.tr **ORCID:** 0000-0002-3875-2465

Elif Ilkay ARMUTAK, Senior Professor of Histology and Embryology at the Faculty of Veterinary Medicine, Istanbul University- Cerrahpasa in Istanbul, Türkiye. She holds expertise in veterinary histology and embryology and has contributed significantly to both research and teaching in her field. Her educational background and professional experience include roles in research, academia, and project management. Prof. Armutak is actively involved in teaching at undergraduate and postgraduate levels. Her research focuses on cancer therapies, particularly mechanisms such as apoptosis, autophagy, and angiogenesis, with an emphasis on innovative strategies.
E-mail: elif@iuc.edu.tr **ORCID:** 0000-0002-7359-6568

Similarity Index
The similarity index obtained from the plagiarism software for this book chapter is 9%.

Copyright © 2025 by ISRES Publishing