EMANUEL EDWARD KLEIN'S ANATOMICAL RESEARCHES

Atalić, Bruno

Original Scientific paper

UDC: 61:929 Клајн Е.
61(091)"18/19"
DOI: 10.5281/zenodo.4589502

Bruno Atalic, MD, MSc (Oxon), PhD, MPhil (Cantab)
Clinical Departement for Diagnostic Radiology
Clinical-Hospital Centre Rijeka
Kresimirova 42, 51000 Rijeka, Croatia
00 385 99 6 734 736
E-mail: bruno.atalic@cantab.net

EMANUEL EDWARD KLEIN'S ANATOMICAL RESEARCHES

Abstract: Emanuel Edward Klein (1844–1925), anatomist, embryologist, physiologist, histologist, and microbiologist, has finished medicine in Vienna and developed his professional career in London. Due to the fact that his greatest contributions were in microbiology, his researches in the other fields of medicine such as anatomy were generally neglected. In this respect this paper tries to systematically present his anatomical researches. Special notion is given to the highlighting of the connection between his earlier Viennese and his later London years in order to establish his role in the transmission of the knowledge between the Continent, precisely the Viennese Medical School, and the United Kingdom. With this goal the archival sources comprised of the original documents on Klein's life, the library sources composed of the primary and the secondary sources about Klein's career, and finally Klein's published works were analysed. Descriptive, comparative and analytical methods were used with the aim of their evaluation. Emanuel Edward Klein's anatomical researches were thus interpreted in the general context of the development of medicine at the end of the 19th and the beginning of the 20th century and with the regard to the contemporary medical achievements.

MeSH key words: History of Medicine

Non-MeSH: Emanuel Edward Klein, Experimentalism, Viennese Medical School, Anatomy, 19th century, 20th century

Introduction

Emanuel Edward Klein (figure 1) was born on the 31st October 1844 in Osijek, as a centre of the Virovitica County and a capital of the Kingdom of Slavonia, which was then part of the Austrian Empire and today is in the Republic of Croatia, to a German speaking, non-observant Jewish family. Although his family was poor, Klein received a good education in German, Hungarian, French, and Classics. He finished the grammar school in his hometown in 1863, and with the help of a scholarship studied medicine at the famous Viennese Medical School, which has put a great impact on the teaching and research of anatomy [1, 2, 3, 4, 5, 6]While the First Viennese Medical School was founded in the 18th century by Dutch Physician Gerhard van Swieten (1700–1772), a personal physician of the Empress Mary Therese and an organiser of the health system in the Habsburg Monarchy with his sanitary low entitled *Normativum Sanitatis* and published in 1770, who perceived medicine as a part of the natural philosophy, the Second one was established by Czech Physician Baron Carl von Rokytansky (1804–1878), humoral pathologist, humanist philosopher and liberal politician, who has directed medicine towards science and experimentation. [7 , 8, 9] The important role was played by his two colleagues: the university professors Ferdinand Hebra (1816–1880), who founded a modern dermatology as a separate specialisation, and Josef Škoda (1805–1881), who started a new concept of physical diagnostics through the improvements of the terminology and the interpretation of percussion and auscultation phenomena [10, 11] Their contemporary Ernst Wilhelm von Bruecke (1819–1892) has founded Viennese experimental physiology and researched physiology of eye, phonology, chemistry of proteins, nerves, muscles, digestive system, blood cells and electrophysiology through the introduction of the physical and chemical methods into physiology based on the animal vivisections, while his colleague Salomon Stricker (1834–1898) has started Viennese experimental pathology and demonstrated contractility of the capillaries ad occulos, diapedeses of the erythrocytes, splitting of cells in vivo, described a structure of the chorea and clarified a relationship between the cells and the extracellular matryx. [12, 13] Both of them were Klein's menthors, who after obtaining his MD in 1869 continued to work at the Viennese Medical School and in 1871 became a *Privat Dozent*. [14] They had thought him experimental methods and microscopical techniques in anatomy and pathology, inspired his experimental work in science and medicine, and directed his professional interests and research directions. [15]

Stricker's most important work was a histological textbook published in two parts under the title *Handbuch der Lehre von den Geweben des Menschen und der Thiere* in 1869 in Leipzig. Beside him its contributors were Max Schultze, Wilhelm Kuehne, Joseph von Gerlach, Sigmund Mayer, Heinrich Wilhelm Waldeyer, Theodor Meynert, Ewald Hering and Emanuel Klein who contributed two chapters, one on the endings of the peripheral nerves in the tadpole's tail and the other on the development of the blood vessels in the chicken embrio. [2] In that same year Klein was sent to London to determine terms for the translation of the mentioned textbook with Henry Power who acted as a translator for the New Sydenham Society. [3] During his visit [16]

he had made an excellent impression on experimental physiologist John Scott Burdon Sanderson (1828–1905) [17], medical reformer John Simon (1816–1904) [18] and comparative anatomist Thomas Henry Huxley (1825–1895). [19] This was the main reason why in 1871 he was invited by Sanderson, who was in a need of a histologist, to work under his supervision on the investigation of the tubercles in his private laboratory in Howland Street. One of the reasons for the Klein's move from Vienna, which was then a leading European and world centre of medical research, to London, which was still gaining its medical status, lay in the fact that although he was schooled under the influence of Austrian humoral pathologist Karl von Rokitansky, in his researches he was more inclined towards his rival, German cellular pathologist Rudolf Virchow (1821–1902). It was precisely his experience in the medical researches that made him interesting to both Sanderson and Simon who wanted to give a further impetus to the then still nascent medical researches in the United Kingdom. On the other hand, it was precisely this possibility to direct a development of medical researches according to his interests, which was another reason for the Klein's movement from strictly hierarchically academically organised Vienna, where he was already an Assistant Professor, to still in medical sense developing London, where he had to build his career from the begining. Despite this already in 1873 he was appointed by Simon as an Assistant Professor of Comparative Pathology at the Brown Sanitary Institution in order to conduct anatomical, pathological and microbiological investigations under his supervision. In that same year after an invitation from Sir William Savory, an Ordinary Professor of General Anatomy and Physiology, he also began his collaboration with the Saint Bartholomew's Hospital, where he was appointed as a Joint Professor of General Anatomy and Physiology (Saint Batholomew's Hospital London: Minutes Signed of the Board of Studies of Anatomy 1905–68). Klein's main contribution was the rigorous implementation of the continental achievements, especially his Viennese experimental anatomical and pathological experience, into his work which he has spread among his associates and has passed onto his pupils and because of which on the 3rd June 1875 he was elected as a Fellow of the Royal Society of London together with Ray Lancaster after a nomination based on the general acquaintance with John Tyndall and a personal one with William Sharpey, Michael Foster, John Simon, William Kitchen Parker, Thomas Spencer Cobbold, Thomas Lauder Brunton, Arthur Gamgee and Charles Darwin (figure 2). [20] Emanuel Klein became a naturalized Briton in 1877, and on this occasion, he adopted his middle name Edward. On the 25th July 1877 he married a widow, Mrs Sophia Amelia Mawley (1843–1919), a daughter of William Metcalfe, in an Anglican church. They had two daughters, and a son, Doctor Bernard Klein, who was also a physician at the Saint Bartholomew's Hospital. Suffering from chronic bronchitis, he retired first to Earls Court in 1911, then to Chislehurst in 1914, and finally to 13 Wilbury Villas, Hove, Sussex, where he died from the complication of influenza by pneumonia on the 9th February 1925 at the age of 80. He is buried at the Hove Cemetery. [21]

Matherials and Methods

Matherials of this paper are comprosed of the Klein's eleven anatomical papers which have dealt with the oesophageal and mouth muscles, peripheral nerves' endings, peripheral distributions of neural cords, nerves of cornea, plexus Aurebachi, organ of Jacobson, and lymphatic system of lungs and serous membranes (Table 1). They were based on anatomical autopsies, animal vivisections and their combinations, and were conducted in the areas of general, comparative and pathological anatomy at the beginning of his career, precisely in the period between the years 1868 and 1880, and thus as such could be divided into two periods, the Viennese and the London one. In order to establish Klein's role in the transmission of the knowledge from his Viennese menthors onto his London students, researched themes and used methods will be highlighted from his papers and put in the general context of the development of medicine at the end of the 19th and the beginning of the 20th century, with the regard to the contemporary medical achievements. [22] With this goal the archival sources comprised of the original documents on Klein's life, the library sources composed of the primary and the secondary sources about Klein's career, and finally Klein's published works will be analysed. Descriptive, comparative and analytical methods will be used with the aim of their evaluation.

Klein's Anatomical Researches

Vienesse Period

Klein's early papers were written in German during 1868 while he worked as a *Privat Dozent* at the Viennese Medical Faculty. They have dealt with the oesophageal muscles of man and dog and the composition of mouth muscles. [23, 24] Both of them were illustrated with three microanathomical drawings done by Austrian pathologist Carl Heitzmann (1836–1896).

a)'Ueber die Vertheilung der Muskeln des Oesophagus'

This paper presents comparative anatomy of oesophageal muscles between man and dog. Klein describes two muscular layers, mucosal – *muscularis mucosae* and superficial – *tunica muscularis*. While in a man *muscularis mucosae* is composed of the inner longitudinal and the outer circular layer of smooth muscles, in a dog they are clearly divided only in the middle third of oesophagus. According to him neural cells in the muscularis layer correspond to the intestinal plexus Auerbachi, while the ones in submucosa correspond to the intestinal plexus Meissneri. [23] His observations are in accordance with the current understandings . [25]

b) ‚Zur Kenntniss des Baues der Mundlippen des Neugerbornen Kindes'

This paper describes the three layers of lips: skin, the transitional one and mucosa. It presents various kinds of taste papilla. Klein then explaines his discovery of the skeletal muscle fibres which due to their origin, course and ending deserve to be designated as a separate muscle which he calls 'musculus compressor labii'. He concludes that its function is to support the *musculus sfincter oris* and cause squeezing of lips

from back towards front. [24] The mentioned muscle represent Klein's original discovery which he achieved simultaneously with and independently from Christoph Theodor Aeby, Renald Bover and Karl Friedrich Theodor Krause. [26] He correctly recognized that the skeletal muscle fibres which he observed in the child's mouth due to their origin, course and ending deserve to be designated as a separate muscle. He also rightly concluded from its structure that its function was sucking which was in accordance with the then predominant positivist epistemiology Today it is known as the *musculus depressor labii inferioris* or the *musculus rectus labii proprius*. [27]

c) Peripheral nerves' endings

The above presented papers were followed by the ones on the peripheral nerves' endings Klein, 1869 [28, 29]. The first one from 1870 was on the nerves' structure in the tadpole's tail. It was followed by the two papers on the peripheral distribution of the non-myelinated nerve fibres with the first one on the human corneal nerves and the second one on the peripheral nerves in the rabbit's tongue and the ciliary duct in the toad's tail.

B) London Period

As mentioned above, in 1871 Klein was invited by Sanderson to cooperate with him in his work on tubercles at his private laboratory in Howland Street, and then in 1873 he was appointed as an Assistant Professor of Comparative Pathology at the Brown Sanitary Institution in order to conduct pathological, clinical and epidemiological researches under the supervision of Simon, among which the ones on the anatomy of the lymphatic system and the serous membranes of the lungs with regard towards tuberculosis should be highlighted. He was in charge of the laboratory and was paid from Mr Lowe's Grant by the combination of a fixed salary and a contract work on the behalf of the Medical Department of the Local Government Board. It was during this period that his most important anatomical researches were conducted.

a) 'Transactions of the Some Remarks on the Finer Nerves of the Cornea'

This study was read in front of the Royal Microscopical Society on the 6th March 1872. Illustrated with eight drawings done by Klein himself it promotes then a new method of the chlorides of gold usage in the preparation of the delicate nerve fibres (Figure 3). [30] Klein describes a deep and a superficial intraepithelial network of nerve fibres. He criticizes some of his predecessors who had due to the usage of the unsuitable methods mistaken nerve fibres for connective tissue.

b) 'Contributions to the Anatomy of Auerbach's Plexus in the Intestine of the Frog and Toad'

In this paper Klein compares the anatomy of the Auerbach plexus between the intestines of a frog and a toad. [31] He describes a net of the ganglion cells which is

positioned between the circular and the longitudinal layers of the colon and which he divides into the independent fibres and the grouped ones. His paper is in accordance with the earlier researches of Jakob Henle (1809–1885) who had described the colon epithel. [25, 26]

c) 'A Contribution to the Minute Anatomy of the Organ of Jacobson'

Klein's interest for the Organ of Jacobson [32] was on the same track with the then contemporary investigations of sensory organs like for example the Italian anatomist Alfonso Corti's description of the hearing organ in 1851 which was later named after him. Klein positions the Organ of Jacobson in the lower or bony part of the nasal septum and describes it as a tubular flattened structure. Its lateral wall is made of superficial epithelial and muscular cells which is in contrast to its medial wall made of sensory cells and olphactorial nerves. Based on this he concludes that it is a rudimentary organ for scent sensations. On the one hand, his determination of the organ function from its anatomical structure was on the same way of thinking with his contemporary German anatomist and physiologist Johannes Mueller (1801–1858) who had established the analytical physiology .[33] On the other hand, his explanation of the rudimentary function of the Organ of Jacobson was on the same track with German anatomist Wilhelm Roux (1850–1924) who introduced the developmental mechanics in order to explain the development of organisms with the causal-analytical method which had emphasized the importance of the functional adaptation in the genesis of the particular body parts . [25, 26]

d) 'Contributions to the Normal and Pathological Anatomy of the Lymphatic System of the Lungs'

The most important Klein's anatomical paper deals with normal and pathological anatomy of the lymphatic system of the lungs. [34] It represents an end view on his researches done in the collaboration with Sanderson and Simon for the Medical Department Privy Council. They were based on the vivisections conducted on the Guinea pigs, rabbits, rats, dogs and cats. According to them the lymphatic system of the lungs can be divided into the three subsystems: subpleural, perivascular and peribronchial. Subpleural is then further divided into intermuscular or pleural and subpleural. In accordance with their names, while the perivascular follows the blood vessels, the peribronchial spreads around bronchi. All three subsystems anastomose through the perivascular one. The mentioned findings are in accordance with the contemporary understandings . [25, 26]

e) *The Anatomy of the Lymphatic System*

Klein's most important anatomical work is a book entitled *The Anatomy of the Lymphatic System*. It was the most comprehensive work written on the mentioned topic until then. The first book, published in 1873, describes serous membranes, while

the second book, published in 1875, presents the structure of the lungs. The first book is further divided into two parts with four chapters on a normal anatomy and three chapters on the pathological conditions . [31] First chapter describes the endothelial surface of the serous membranes which was investigated on the fenestrated omentum of frogs, Guinea pigs, cats, dogs and monkeys. Klein in his researches combines comparative anatomy and experimental physiology, which as then the new disciplines had parallelly developed, and were based on the theory of evolution and the experimentalism, as a theory and practice of scientific investigation based on the creation and the conduct of the experiments, with the aim of testing validity of various hypothesis. [35]

Second chapter describes the cells of the matrix. Klein suggests that the omentum of the rabbit is the best for the research. He differentiates between lymphatic nodules built primarily from the lymphoid cells and the lymphatic tracts built primarily from the reticular fibres with a various number of the lymphoid cells. He further makes a difference between in situ formed lymphoid cells and the migratory ones and suggests division of nodules into endolymphangial and perilymphangial ones. According to him the white cells of the mesentery and the pleura are grouped around the blood vessels. Third chapter deals with the lymph vessels of the serous membranes which in their spread follow the blood vessels. Fourth chapter describes the blood vessels of the serous membranes which are composed from the afferent arterioles, the capillary network and the efferent veins. [31]

Klein begins the second part with a discussion on the formation of the germinative epithel of the serous membranes in the pathological conditions. First chapter describes the changes of the superficial endothel in the acute and chronic peritonitis. Acute peritonitis is characterised with the hyperaemia of the serous membranes, while the chronic one causes endothelial proliferation. Second chapter deals with the changes of the cells of the matrix in the acute and chronic peritonitis. While the acute peritonitis causes a formation of the acute oedema filled with the lymphoid cells, chronic one is characterised with the occurrence of the lymphoid cells on the peritoneal serosa, centrum tendineum, parietal pleura and mesentery. Third chapter discusses the relations between the blood vessels and the lymphatic vessels. Book is illustrated with ten cardboards with the hand-made illustrations of the different preparations. [31] Klein's investigations of the lymphatic system predate Bartels's investigations who in 1909 managed to show the lymphatic system of the entire body through the usage of the Gerott's injection technique, then perceived the role of the regional lymph nodules in the spread of the carcinomas and the infections, and finally divided the lymph nodes into various groups and described their variations in accordance with their number, location and age. [25, 26]

Second book on the composition of the lungs is also divided into two parts with five chapters on a normal anatomy and three chapters on the pathological conditions . [36] Klein starts with the presentation of his investigations of the connection between pulmonary and miliary tuberculosis in Guinea pigs, dogs, cats, rabbits and men. Tuberculosis represented an ideal example of the *seed and soil* disease. While the German pathological school claimed that the tuberculosis caused only inflammatory changes and not neoplasms, the French pathological school insisted on presence of both. On

the ground of the experiments conducted by Klein which had combined the anatomical research and the clinical experience, the British pathological school has suggested a compromise of inflammatory neoplasms. [37] First chapter describes the endothel of the pulmonary pleura and the second its matrix. Third chapter discusses the lymphatic system of the pulmonary pleura. Klein claims that the lymph vessels of the pulmonary pleura are in a free communication with the pleural cavity. [36]

Fourth chapter describes the lymphatic system of the bronchus. Based on his microscopical examinations Klein makes a distinction between the peribronchial lymph vessels situated in the adventitia and the perivascular lymph vessels which follow the main blood vessels. According to him there are two kinds of the lymph systems in the serous membranes: one composed of the lacunas connected with the channels and the other composed of the directly connected lacunas. Fifth chapter talks about the perivascular lymph vessels of the proper pulmonary tissue. They do not possess valves and their walls are made of the serous endothel similar to the one in the capillaries. Alveolar cavities are coated with the epithel, and not the endothel, which means that they represent a continuation of the bronchial epithel, and not the subepithelial endothel. Branches of the lymph system of the lungs could be grouped into three different networks: the superficial subpleural lymph vessels, the peribronchial lymph vessels and the deep perivascular lymph vessels. Subpleural lymph vessels are directly connected with the pleural cavity through the stomates, while the peribronchial and perivascular ones are indirectly connected with the alveolar cavities and the bronchial surfaces through the pseudostomates. [36]

First chapter of the second part describes changes of the pulmonary pleura in the acute and the chronic inflammation. They are both characterised with the spreading of the germinative epithel over the endothel of the serous membranes and the endothel of the pulmonary pleura. Second chapter presents changes of the pulmonary tissue in the artificial tuberculosis of the Guinea pigs where Klein differentiates between the conical nodules which are a seat of the caseous necrosis, and the spherical nodules which are the healthy ones. Third chapter discusses the acute miliary tuberculosis in men. According to Klein the big giant Langerhans cells are important, but are not pathognomonic, because they developed in the different diseases in the different organs, which is in accordance with the current understandings. This book is as well illustrated with nine cardboards with the hand-made illustrations of the different preparations. [36]

Discussion

This paper has presented Klein's eleven anatomical studies published between 1868 and 1880 which have comprised his anatomical, comparative anatomical and pathological anatomical researches. They were based on his above mentioned combining of the anatomical autopsies and the animal vivisections, as the naturalistic methods of the scientific investigations, which he has learnt from his menthors Bruecke and Stricker during his years at the Viennese Medical Faculty. On the one hand, his early papers on the comparison between the oesophageal muscles of dog and men and the com-

position of oral muscles were obviously influenced with the theory of evolution as the then still avant-garde theory. [23, 24] They were also the expression of the then current occurrence of the microscopical anatomy as a new field of the anatomical researches. [26] On the other hand, his papers on the peripheral nerves' endings with the above mentioned combination of autopsies and vivisections clearly show his experimentalist approach towards medical researches. [28, 29] In the broader context of the development of neuroanatomy during the 19th century they represent a continuation of the earlier researches conducted by Czech anatomist Jan Evangelista Purkine (1787–1869) and German anatomist Wilhelm His Senior (1831–1904) who had determinated the difference between the grey matter composed of the neural cells and the white matter composed of the myelinated axons. But on the contrary to the majority of his contemporary neuroanatomists, like French anthropologist Paul Broca (1824–1880), German psychiatrist Carl Wernicke (1848–1920) and German neuroanatomist Korbinian Brodmann (1868–1918) who had researched the central nervous system, Klein was primarily interested in the peripheral one . [26] It could be concluded that while he was in the same line with the then contemporary neuroanatomical researches, he has also conducted his original researches under the influence of positivism, naturalism and the theory of evolution.

In his study 'Transactions of the Some Remarks on the Finer Nerves of the Cornea' Klein promotes then a new method of the chlorides of gold usage in the preparation of the delicate nerve fibres. [30] His interest in the retina was in accordance with the then contemporary interest towards the investigations of the eye, precisely with the investigations of the retina by Italian anatomist Filippo Paccini (1812–1883), German anatomist Rudolf Albert Koelliker (1817–1925) who had collaborated with Klein's mentor Stricker, and Italian anatomist Alfonso Corti (1822-–876). One should highlight that his method presented in this paper of the maceration of the retina in the chlorides of gold, then in a dilution of distillate water and glycerine, and finally its rubbing with a fine camel whisker in order to show nerves' endings was completely original and fully avantgarde example of a naturalistic method of the scientific investigation, especially if one takes into an account that a later generally used method for the impregnation of the nerve cells with gold and silver was independantly developed by Italian anatomist and Pavian professor Camilo Golgi (1843–1926) and Spanish anatomist Santiago Ramono y Cajal (1852–1934) only between 1874 and 1880, and for which they both have received a Nobel Prize in 1906. [26] In his paper 'Contributions to the Anatomy of Auerbach's Plexus in the Intestine of the Frog and Toad' Klein in accordance with the theory of evolution compares the anatomy of the Auerbach plexus between the intestines of a frog and a toad which could be perceived as a continuation of the earlier researches of Jakob Henle (1809–1885) who had described the colon epithel [31, 26] As above presented his interest in the Organ of Jacobson as a rudimentary organ for scent sensations was parallel with the then contemporary investigations of the sensory organs like for example Alfonso Corti's description of the hearing organ in 1851; his methods and technics were on the same way with the experimental investigations of the sensory organs conducted by the German anatomist and physiologist Johannes Muller (1801–1858); while his explanation of its function with the help of

the positivist epistemology were in accordance with the German anatomist Wilhelm Roux's (1850–1924) developmental mechanics which explained the development of organisms with the causal-analytical method through the emphasis of the importance of the functional adaptation in the genesis of the particular body parts. [26]

As above mentioned, Klein's most important anatomical researches were dedicated to the investigations of the normal and the pathological anatomy of the lymphatic system of the lungs and their results were published as a paper entitled 'Contributions to the Normal and Pathological Anatomy of the Lymphatic System of the Lungs' and a book in two parts under the title The Anatomy of the Lymphatic System [31, 34, 36]. They were again conducted as a combination of the anatomical autopsies as naturalistic methods and the animal vivisections as experimental methods which together with the regular usage of microscope represent his main contribution towards a development of anatomy and pathological anatomy. They had enabled him to suggest a compromise solution of inflammatory neoplasms as the original explanation for the occurrence of the tubercles, and thus make the British pathological school independent from the extremes of the German pathological school, which claimed that the tuberculosis caused only inflammatory changes and not neoplasms, and the French pathological school, which insisted on the presence of both. [37] From this example it is obvious that although he followed and implemented the Continental achievements in his researches, he was enough self-confident to make his own conclusions and hypothesis. And precisely this way of thinking Klein had passed onto his students during his years at the Saint Bartholomew's Hospital where he was a Joint Lecturer in General Anatomy and Physiology (1873–1902), a Lecturer in Histology (1873–82), a Lecturer in Microscopic Anatomy (1874–92), a Lecturer in General Anatomy and Physiology (1882–1903), a Lecturer in Bacteriology (1903–12), and a Lecturer in Advanced Bacteriology (1910–11) until he retired in 1911 with the title of Emeritus Professor. [38, 39, 40, 41]

The most famous among them was British pathologist and bacteriologist Sir Frederick Andrewes (1859–1932) who studied geology, biology and medicine at Oxford, defended his doctoral thesis at Cambridge, and in 1924 obtained an honorary doctorate from the University of Durham. He started his work at the Saint Bartholomew's Hospital after an examination conducted by Klein himself and from whom he has later learned the basics of the laboratory work and whose example he has followed in the openness of his laboratory to students and in the organisation of various courses for physicians, students and nurses. In 1897 he became a practitioner and a lecturer of Pathology in the mentioned hospital and introduced a microscope in the regular examination of the pathological tissues which was on the same track with the Klein's introduction of a microscope in the regular examination of the clinical specimens on the presence of microorganisms in 1881. His researches of the lymphadenitis and the degeneration of the arteries represented a continuation of Klein's researches of the lymph and blood systems. In the beginning of the 20th century also under Klein's influence he oriented himself toward public health topics like the researches of microbes in canalisation, milk and air. [42, 43, 44] Another one was British anatomist and surgeon Charles Barrett Lockwood (1856–1914) who also worked in the Saint Bartholo-

mew's Hospital. Klein's influence on him is obvious from his papers 'The Lymphatics of the Vermiform Appendix' and 'Aseptic Surgery'. While in the first one he broadens Klein's researches of the thoracic lymph nodes on the abdominal ones through the usage of his combination of anatomical autopsies and animal vivisections, in the second one he is guided by the Klein's principles of the testing of the antiseptics based on the repeated series of the growing doses applied on the chosen microbs [45]. The last one one was British bacteriologist Mervyn Henry Gordon (1872–1953). He finished medicine at Oxford and afterwards worked as a bacteriologist in the Saint Bartholomew's Hospital. According to Garrod, he and Klein became family friends during his studies, which have enabled him to volunteer in the Klein's laboratory and subsequently choose a career in bacteriology in the same hospital as Klein. Together they have published three papers based on their researches of the causative agents of the mouth diseases. He continued Klein's anatomical researches of the lymph nodes and through a combination of his observations and the experiments conducted on the rabbits formulated his thesis of viral causes of lymphoid neoplasms such as the Hodgkin lymphoma [46, 47, 48 , 49, 50, 51, 52, 53, 54].

Conclusion

This paper tried to reapprais Klein's anatomical researches in order to highlight influences of his menthors Bruecke and Stricker from the Viennese Medical Faculty, which he has implemented into his work, and later passed onto his students Andrewes, Lockwood and Gordon at the Saint Bartholomew's Hospital. They are most obvious from their common interests in anatomy, comparative anatomy and pathological anatomy, their combining of the anatomical autopsies and the animal vivisections, and above all in their researches of the lymphatic system. In the wider context Klein's anatomical researches could be perceived as an example of the influence of the Viennese Medical Faculty on the development of the British medical research at the turn of the 19th and the 20th century.

Conflict of Interests

The author declares that there are no conflicts of interests.

References:

1. State Archive Osijek, Jewish Birth Records 1780-1899; number 344, page 27.
2. Andrewes FW. 1925. In Memoriam – Edward Emanuel Klein, MD, FRS. St Bart's Hosp R 58: 1-6.
3. Bulloch W. 1925. In Memoriam: Emanuel Klein: 1844-1925. J Pathol Bacteriol 28: 684-697.
4. Martincic J. 2001. Ravnatelji, profesori i maturanti 1729 – 2000 gimnazije u Osijeku. Zagreb – Osijek: Hrvatska akademija znanosti i umjetnosti - Zavod za znanstveni i umjetnički rad u Osijeku - Biblioteka Slavonije i Baranje - Knjiga 5.

5. Cravetto E. 2008. Povijest 15 – Kolonijalna carstva i imperijalizam (1871-1914). Piotello: Rotolito Lombarda.
6. Goldstein I. 2008. Povijest 21 – Hrvatska povijest. Zagreb: Europapress Holding.
7. Lesky E. 1976. The Vienna Medical School of the Nineteenth-Century. Baltimore and London: JHU Press; 1976.
8. Rumpler H. 2006. Carl Freiherr von Rokytansky. Vienna: Boehlau Verlag.
9. Dinjar K; Toth J; Atalić B; Radanović D; Marić S. 2011. Evaluation of Influences of the Viennese Anatomical School on the Work of the Croatian Anatomist Jelena Krmpotic-Nemanic. Wien Klin Wochenschr 123: 1–8.
10. Belicza B. 1992. Hebra, Ferdinand. In Padovan I. Medicinski Leksikon. Zagreb: Leksikografski Zavod Miroslav Krleža.
11. Belicza B. 1992. Škoda, Jozef. In Padovan I. Medicinski Leksikon. Zagreb: Leksikografski Zavod Miroslav Krleža.
12. Holubar K. 1987. Salomon Stricker (1834-1898). Pioneer Experimental Pathologist. Am J Dermatopathol 9(2): 149-50.
13. Lesky E. 1978. Bruecke EW. Neue Oesterreichische Biographie 5: 66–73.
14. Buklijaš T. 2008. Cultures of Death and Politics of Corpse Supply Anatomy in Vienna, 1848-1914. Bull. Hist. Med. 82: 570–607.
15. Atalić B. 2011. Emanuel Edward Klein's Role in the Establishment of Food Preservation Standards. Public Health 125: 476-480.
16. Atalić B; Fatović-Ferenčić S. 2009. Emanuel Edward Klein - The Father of British Microbiology and the Case of the Animal Vivisection Controversy of 1875. Toxicologic Pathology 37: 708-713.
17. Sharpey-Schafer E. 1927. History of the Physiological Society 1876–1926. Journal of Physiology 64/Supplement: 1-76.
18. Lambert R. 1963. Sir John Simone 1816-1904: and English Social Administration. London: MacGibbon and Kee.
19. Richards RJ. 2004. The Romantic Conception of Life – Science and Philosophy in the Age of Goethe. Chicago and London: The University of Chicago Press.
20. NA. 1875. The Proceedings of the Council of the Royal Society. London: NP.
21. Bulloch W. 1938. The History of Bacteriology. Oxford: Oxford University Press.
22. Atalić B; Drenjančević-Perić I; Fatović-Ferenčić S. 2010. Emanuel Edward Klein, a Diligent and Industrious Plodder or the Father of British Microbiology. Med Glas Ljek komore Zeničko-dobojskoga kantona 7/2: 111-115.
23. Klein EE. 1868a. Ueber die Vertheilungen der Muskeln des Oesophagus beim Menschen und Hunde. Aus der k. und k. Hof- und Staatsdruckerei NI: NP.
24. Klein EE. 1868b. Zur Kenntnis des Baues der Mundlippen des Neugeboren Kindes. Aus der k. und k. Hof- und Staatsdruckerei NI: NP.
25. Krmpotić-Nemanić J. 1993. Anatomija čovjeka. Zagreb: Medicinska naklada.
26. Škrobonja A; Muzur A; Rotschild V. 2003. Povijest medicine za praktičare. Rijeka: Adamić.
27. Who Named It. 2018. http://www.whonamedit.com/doctor.cfm/2826.html [accessed December 2018]
28. Klein EE. 1870. Beiträge zur Kenntniss der Nerven des Froschlarvenschwanzes. Aus der k. und k. Hof- und Staatsdruckerei. NI: NP.

29. Klein EE. 1871. On the Peripheral Distribution of Non-Modulated Nerve-Fibres – part I. London: J. E. Adlard.
30. Klein EE. 1872. On the Peripheral Distribution of Non-Modulated Nerve-Fibres – part II. London: J. E. Adlard; Klein EE. 1872. Some Remarks on the Finer Nerves of the Cornea. London: William Clowes.
31. Klein EE. 1873. Contributions to the Anatomy of Auerbach's Plexus in the Intestine of the Frog and Toad. London: NP; Klein EE. 1873. The Anatomy of the Lymphatic System - Part I: Serosal Membranes. London: Smith-Elder, and Co.
32. Klein EE. 1880. A Contribution to the Minute Anatomy of the Organ of Jacobson. St Bart's Hosp R 21: 1-7.
33. Ackerknecht EH. 1955. A Short History of Medicine. New York: The Ronald Press Company.
34. Klein EE. 1874. Contributions to the Normal Pathological Anatomy of the Lymphatic System of the Lungs. London: NP.
35. Agnes ME. 2001. Webster's New World College Dictionary. Foster City: IDG Books Worldwide.
36. Klein EE. 1875. The Anatomy of the Lymphatic System - Part II: The Lung. London: Smith-Elder, & Co.
37. Worboys M. 2000. Spreading germs: disease theories and medical practice in Britain, 1865-1900. Cambridge: Cambridge University Press.
38. Saint Bartholomew's Hospital London. 1843-1896. Medical Committees and Medical Staffing; MC1; Minutes of the Medical Council.
39. Saint Batholomew's Hospital London. 1867- 1892. Medical Council Reports for 1867; MC4/1; Reports of the Medical Council.
40. Saint Bartholomew's Hospital London. 1898. Handbooks to Bacteriology; MS 20; Medical College Handbooks.
41. Saint Batholomew's Hospital London. 1905-68. Board of Studies in Anatomy; Medical School/College; MS 100/1; Minutes Signed of the Board of Studies of Anatomy
42. NA. 1932a. Obituary Sir Frederick Andrewes, O.B.E., F.R.S. Nat Med 129: 390-391.
43. NA. 1932b. Obituary Sir Frederick Andrewes, F.R.S., M.D., D.C.L., F.R.C.P. Br Med J NI: 451-452.
44. NA. 1932c. Sir Frederick Andrewes. 1859-1932 M. H. G. and E. B. P. Obituary Notices of Fellows of the Royal Society 1(1): 37-44.
45. NA. 1934. Sir Alexander Cruikshank Houston. Obituary Notices of Fellows of the Royal Society 1(3): 335-344.
46. Klein EE; Gordon MH. 1902-1903a. Preliminary Report on the Bacterioscopic Examination of Materials from the Lincoln Outbreak of Throat Illness. Rep. Med. Offr. Loc. Govt. Bd. NI; 599-604.
47. Klein EE; Gordon MH. 1902-1903b. Further Report on the Lincoln Yeast Fungus Saccharomyces Hominis. Rep. Med. Offr. Loc. Govt. Bd. NI: 605-621.
48. Klein EE; Gordon MH. 1903. Ueber die Herkunft einer Rosahefe. Zbl. Bakt. Abt. 35(1): 138.
49. Gordon MH. 1914. On an Experimental Investigation in Relation to Mumps or Epidemic Parotitis. Rep. Loc. Govt. Bd. NI: 96.
50. Gordon MH. 1920. The Spirit of Research. St Bart's Hosp J 27: 128-129.

51. Gordon MH. 1945. The Spirit of Research: A Plea for Independence. Lancet NI: 807.
52. Gordon MH. 1953. Pathogenesis of Hodgkin's Disease. Br Med J NI: 860-861.
53. Garrod LP. 1954. Mervyn Henry Gordon. Obituary Notices of Fellows of the Royal Society 9(1): 153-163.
54. NA. 1952. Mervyn Henry Gordon. Br Med J. 4772(1): 1350.

Acknowledgement:
Author would like to thank his Oxford friend Marina Lipovšćak for her English language skills.

Received: 27/11/2020
Reviewed: 06/12/2020
Accepted: 13/12/2020

Table 1 – Emanuel Edward Klein's anatomical works

YEAR	TITLE	AREA	CADAVER	METHOD	PAGES
1868	'Ueber die Vertheilungen der Muskeln des Oesophagus beim Menschen und Hunde'	esophageal muscles	men, dogs	autopsy, vivisection	11
1868	'Zur Kenntnis des Baues der Mundlippen des Neugeboren Kindes'	mouth muscles	men	autopsy	10
1870	'Beiträge zur Kenntniss der Nerven des Froschlarvenschwanzes'	peripheral nerves endings	toad poles	vivisection	8
1871	'On the Peripheral Distribution of Non-Modulated Nerve-Fibres – part I'	peripheral distribution of nerve fibers	human corneal nerves	autopsy	6
1872	'On the Peripheral Distribution of Non-Modulated Nerve-Fibres – part II'	peripheral distribution of nerve fibers	toads' tongues, rabbits' tails	vivisection	6
1872	'Some Remarks on the Finer Nerves of the Cornea'	corneal nerves	rabbits, frogs, Guinea pigs	vivisection	8
1873	'Contributions to the anatomy of Auerbach's plexus in the intestine of the frog and toad'	Auerbach's intestinal plexus	toads, frogs	vivisection	3
1873	*The Anatomy of the Lymphatic System - Part I: Serosal Membranes*	serous membranes	cats, dogs, frogs, monkeys, Guinea pigs	vivisection	83
1874	'Contributions to the normal and pathological anatomy of the lymphatic system of the lungs'	lymphatic system of the lungs	rabbits, rats, dogs, cats, Guinea pigs	vivisection	13
1875	*The Anatomy of the Lymphatic System - Part II: The Lung*	lungs	cats, dogs, rabbits, men, Guinea pigs	autopsy, vivisection	78
1880	'A Contribution to the Minute Anatomy of the Organ of Jacobson'	nasal septum	men	autopsy	6

Figure 1. – Emanuel Edward Klein – with the courtesy of the archival staff of the Saint Bartholomew's Hospital