Nikolay Ivanovich Pirogov and his contribution to medicine in 19th Century Imperial Russia

Hendriks, I.F.

Chapter 8

The Dutchman Herman Boerhaave and the Russian Nikolay Ivanovich Pirogov are brilliant medical scientists, whose remembrance will be eternal

I.F. Hendriks, I.A. Goriacheva, J.G. Bovill, F. Boer, I.V. Gaivoronskii, P.C.W. Hogendoorn

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Abstract

The Dutchman Herman Boerhaave (1668–1738) and the Russian Nikolay Ivanovich Pirogov (1810–1881) were brilliant physicians who made significant contributions to the practice of medicine. Herman Boerhaave graduated as a doctor in 1693 and eventually became professor of medicine, botany and chemistry at the University of the city Leiden. He is perhaps best known as a teacher and for introducing bedside teaching to the medical curriculum. Nikolay Ivanovich Pirogov qualified as a physician in 1828 at the Moscow University, was awarded with his PhD at the German-Baltic University of Dorpat in 1832. In 1836 he was appointed as a professor in Dorpat and in 1841 as professor of surgery and applied anatomy at the Imperial Medico-Surgical Academy in St. Petersburg. Scientific achievements of N. I. Pirogov in medicine are multifaceted: he is the originator of unique technologies for studying the structure of a human being and developed anatomical atlases on these technologies. He was a virtuoso surgeon, an early adopter of ether anaesthesia, and innovator of medical triage and evacuation of the wounded. Why in one article a comparison the scientific achievements of these two briljant personalities, who have entered the world history of medicine, are investigated, becomes clear from the words of N.I. Pirogov, who greatly appreciated Herman Boerhaave. Pirogov wrote that "…he did not consider himself an equal to Herman Boerhaave…" Was Pirogov right or were it modest words, this is up to the reader to decide. The influence of Anglo-Saxon literature and scientific schools, the role of Herman Boerhaave in the professional development of N.I. Pirogov, and the innovations created by them in medicine were analysed on basis of archival documents.

Introduction

In the 16th century the most influential medical schools in Europe were those of Padua in Italy, and Montpellier and Paris in France.[1] The Netherlands during the 16th and 17th centuries suffered under eighty years of brutal Spanish occupation which ended in 1574 under the leadership of William Prince of Orange, also known as William the Silent, when the months-long siege of the city of Leiden by the Spanish was broken with the help of the citizens of Leiden and the Spanish eventually expelled. In gratitude Prince William granted the city of Leiden its own university (Fig.1), the first in the country, with a medical faculty.

Because of a Papal edict that excluded all non-Catholics from Italian Universities, the centre of medical studies moved from Italy to northern Europe, and especially to the protestant University of Leiden.[2-4] The university was open to all students irrespective of race, nationality or religion and this is reflected in the motto of the university "*Preasidium Libertatis*", in English "*A bastion of liberty".* There were two opposing concepts of medical education among medical schools in Europe; one accepted and introduced the new method of independent scientific research to study the structure and functions of the human body, the other choose to keep to the older, classical ideas.[5] Leiden embraced the new, scientific, approach to medicine based on undogmatic research.

In 1589 at the request of Pieter Pauw (1564 -1617) an anatomical theatre was established in Leiden, where Pauw regularly gave anatomical demonstrations using the Vesalius methods and recommended his textbooks to the students. Then in 1636

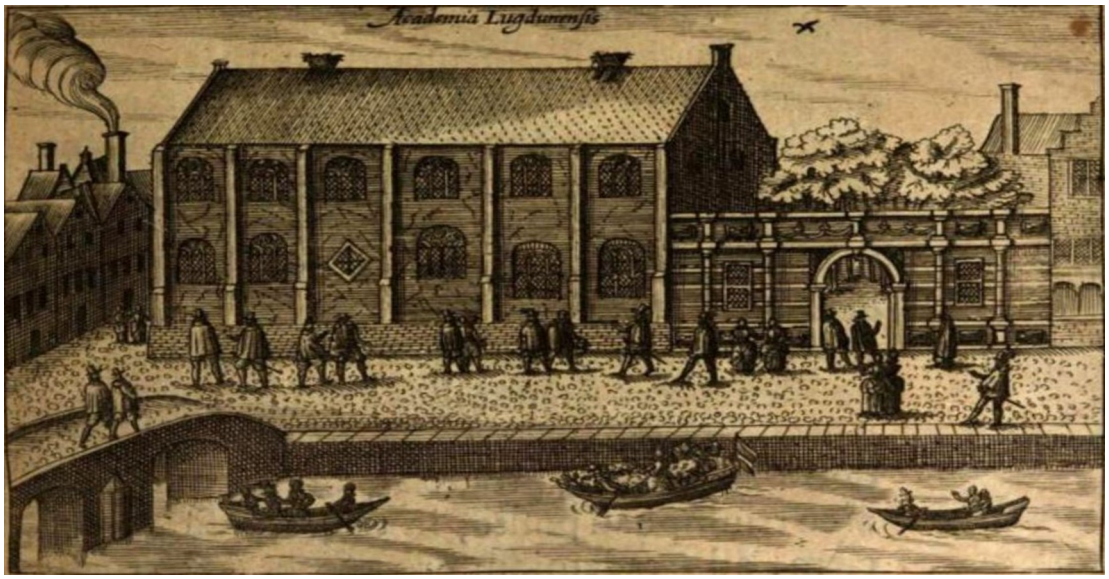

Fig. 1. The Academy building of Leiden University in 1614, a pen-and-ink drawing by Jacob Marci and Justum à Colster, 1 January 1614, Academia Leidensis. In: Marci,J., à Colster J., Illustrium Hollandiae Westfrisiae ordinum alma academia Leidensis, Lugduni Batavorum (Leiden), 1614. In public domain.

Leiden University introduced clinical bedside teaching in the Caecilia hospital in the city, based on the system used by Padua University. The Leiden medical faculty was to play an important role in educating medical students from around the world, as it still does to this day.

In Russia for much of its history the majority of the population had little or no access to qualified healthcare, but relied on folk healers and traditional folk remedies, although monks in the monasteries provided a basic health care. In contrast, from the beginning of the 17th century the ruling classes had access to qualified foreign physicians, including graduates of Leiden University.

Tsar Peter the Great instigated several radical changes to Russian society, including to healthcare and medicine, based on his observations during his first tour of Europe (commonly known as the Grand Embassy) in 1696-97.[6-8] Together with his Dutch court physician Nicolaas Bidloo he built the first hospital and medical school in Moscow, which was officially opened by the Tsar in 1707. The most talented Russian-born medical students were sent abroad after graduation on state scholarships to medical centres of excellence in Europe including Leiden. During the 18th century these Leiden trained physicians and other foreign medical graduates made significant contributions to Moscow University, established by the daughter of Peter the Great, Elisabeth Petrovna, in 1755. Despite these changes, Russia still lagged considerably behind the Netherlands and the rest of Europe in the field of Medicine.

Herman Boerhaave, professor of Medicine, Botany and Chemistry

Herman Boerhaave (1668-1738) was born in Voorhout on 31 December 1668, the son of the minister of the local Dutch Reformed church.[1,9] (Fig. 2) He was educated at home by his father who taught him the classic languages as preparation of him entering grammar school. In 1684 he finished grammar school and entered Leiden University to study philosophy and theology with the intention of following in his father's footsteps as a minister of religion.[10,11] He graduated in 1690 in philosophy but continued his study of theology, and also started to study mathematics and medicine.

From 1690 until 1693 Boerhaave studied anatomy and clinical medicine under Carolus Drelincourt; clinical medicine under Lucas Schacht; anatomical demonstrations under Govert Bidloo, Jan Rau and Antonius Nuck. However his attendance at lectures was fragmentary and he taught himself by studying the works of Hippocrates, Vesalius and Tomas Sydenham, at that time considered the entire body of classical medicine. When he felt that he had sufficient knowledge of medicine, he defended his thesis *De Utilitate explorandorum in aegris excrementorum ut signorum* [*About the importance of investigation into excretions and signals in a patient*] not in Leiden but in Harderwijk on 14 July 1693.[1,10,12] He then returned to Leiden and opened a medical practice at home.[5] He also began to study chemistry and carried out experiments in his home, which he continued even after he had been appointed a lecturer at the faculty of Medicine.

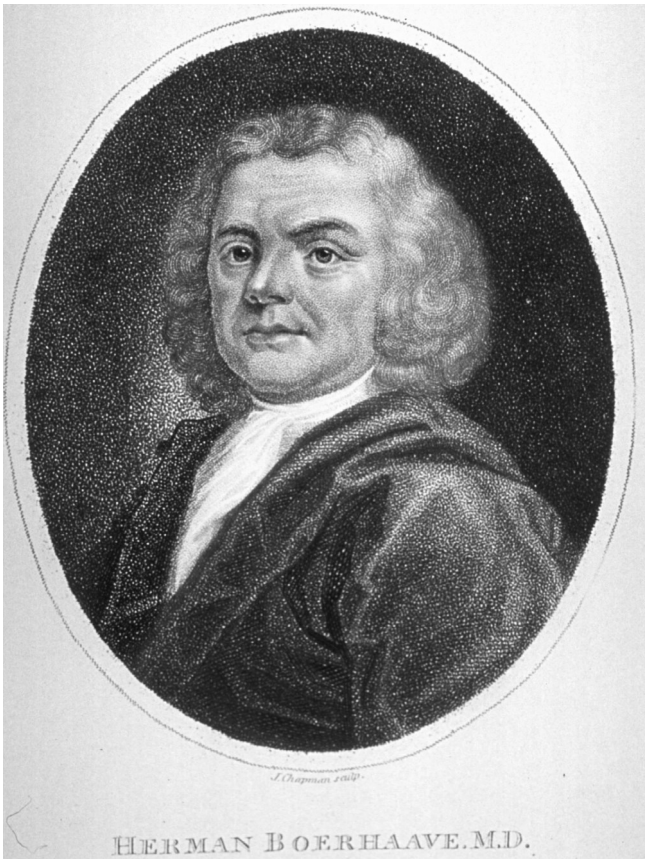

Fig. 2. Portrait of Herman Boerhaave, Dutch physician, botanist and chemist. Painted by J. Chapman, 8 December 1798, Image http://resource.nlm.nih.gov/101408907. In public domain.

In 1701 Boerhaave was appointed as lecturer in theoretical medicine at Leiden University to replace Carolus Drelincourt, who died in 1697.[13,14] He also had to cover for Govert Bidloo, professor of anatomy and medicine, during his absence as personal physician to King-Stadtholder William III.[5]

Boerhaave gave his first lecture in clinical medicine on 23 June 1701. He chose as the title of his lectures *Institutiones Medicae* [*Lessons of Medicine*]*;* they were divided over five themes: physiology, pathology, semeiotica, hygiene and therapeutics.[12] He also gave clinical lessons at the bedside of the patients in the Caecilia hospital in the centre of Leiden.[5] The hospital had twelve beds reserved for teaching purpose. He published two textbooks covering his theoretical and clinical lectures; the first *Institutiones Medicae* published about 1708 and the second *Aphorismi* in 1709.

Herman Boerhaave was more of an educator than a scientist. He was a follower of Hippocrates and Sydenham, and he used the history of medicine as an instrument of learning.[5] He introduced the pocket lens and the thermometer into clinical medicine as tools that aided the diagnosis of diseases.

In 1709 Boerhaave was appointed professor of Medicine and Botany and in 1714 appointed as professor of Clinical Medicine. Although the introduction of bedside teaching has often been attributed to Boerhaave, it had been introduced much earlier by Johannes van Heurnius (1543-1601) [15], and Franciscus de le Boe Sylvius (1614-1672) [16] but it was Boerhaave who re-introduced it.[5] Indeed it appears that Boerhaave did not put much emphasis on bedside teaching.[11] Between 1697 and 1710 only 40 patients per year were used for this purpose, from 1710 to 1720 per year 20 patients, from 1720 to 1730 per year 3 patients, between 1732 and 1736 no patients and from 1737 to 1742 only 20 patients each year.

Boerhaave was not only interested in theology, philosophy and medicine but also in botany, chemistry and physics. He made every effort to keep abreast of progress in these fields.[5,11] He wanted to apply these natural sciences in clinical medicine because, as he wrote:

> *the human body is a machine, some of whose intrinsic parts consist of vessels suited to contain, transport, reconstitute, divide, collect, and secrete the fluids; others consist of mechanical instruments, which by reason of their shape, their hardness, and the firmness of their connection are able both to serve as supports for other parts and to execute certain movements.*[5]

Boerhaave introduced a new three-part curriculum for medical students, a preparatory study consisting of lectures on the natural sciences, followed by an advanced study of anatomy and physiology. In the third part students were taught at the bedside, with emphasis on the importance of careful observation of the patient, and the principles of treatment. Autopsies were conducted at the Caecilia Hospital. In 1715 Boerhaave was appointed Rector Magnificus of the Leiden University and again in 1731.[17]

Rudolf Virchow (1821-1902) wrote that physiology and pathology were still not separated and that the *Institutiones Medicae* was made in one piece.[18] According to Rudolf Virchow (1821-1902) Boerhaave's lectures would have confused his students by using the terms physiology and pathology since during the time of Boerhaave the two were not considered as separate disciplines. It was a pupil of Boerhaave's, Hieronymus D. Gaubius (1705-1780), who made known his master's definition of physiology: The illness that develops in a human body, and which the human body itself cannot heal itself using the rules of nature, is called disease. [18]

Herman Boerhaave had been giving private chemistry lessons to foreign students since 1702. Then a year after his appointment as lecturer in clinical medicine he was given permission from the university to teach chemistry. He was subsequently appointed as professor of chemistry in 1718 after the death of the previous incumbent of the chair, Professor Jacobus le Mort (1650-1718).[12,13]

Peter the Great, Tsar of all Russia, twice visited the Netherlands with his Great Embassy in 1696-97 and in 1717. In October 1697 he visited the university in Leiden, where he was received by the Rector Magnificus (President), Govert

Bidloo, and his fellow professors.[19] They showed him around the university and the anatomical theatre, which he examined with great interest. Govert Bidloo then presented the Tsar with a document in Latin describing the institution and the laws of the university.[6,20] On 28 April 1698, on his way back from Britain to Amsterdam, Peter the Great first visited Delft to view to the crypt of Prince William of Orange, the founding father of the University. Afterward he again visited Leiden university, viewing the anatomical theatre and the botanical garden.[6,21] During his second Great Embassy tour Peter the Great visited Leiden University for the third time in March 1717 and met with Herman Boerhaave in his capacity of Rector Magnificus.[22]

But was Boerhaave really as important for medicine as is often assumed? As Lindeboom, in the introduction to his first volume of *Boerhaave's Correspondence* wrote: '…*What is done in Holland to keep alive and illuminate the figure of Boerhaave*…'[13] Even in the city of Leiden, where he spent all of his working life, it was not until 1870, 122 years after his death, that a statue of Boerhaave was erected in his honour. In Great Britain in 1739 two accounts of the life of Herman Boerhaave were published the year after his death, one by Samuel Johnson [23], the other by William Burton [24]. Burton's book was republished in 1746 and since than no book on Boerhaave has been published in Great Britain.[10,17] As Sassen wrote in his paper for the International Symposium in commemoration of the three hundredth birthday of Boerhaave, held in Leiden in November 1968, '...*In Great Britain Herman Boerhaave is now familiar only to students of the history of medicine and science*…'[10]

Nikolay Ivanovich Pirogov, an innovator who transformed surgery from a craft to science.

Nikolay Pirogov was born 13 (25) November 1810 in Moscow.[25,26] (Fig. 3) Until the age of 9 years he was taught at home initially by his mother and sisters, then by private tutors who taught him Latin and French.

The family had friends from diverse backgrounds who influenced the young Pirogov, including the retired A.M. Klaus, who's profession was vaccinating. He showed the young Nikolay how to use a microscope. But the one who had the greatest influence was the surgeon, anatomist and physiologist, Efrem Osipovich Mukhin, Professor and Dean of the Medical Faculty of Moscow University. It was Mukhin who successfully treated Nikolay's older brother, when he was bedridden with rheumatic fever, after several other physicians had failed. This made a great impression on Pirogov and fostered in him an interest in medicine.

In 1821 Pirogov entered a private boarding school, but within two years financial difficulties befell the family and he had to leave the school. Efrem Mukhin arranged for him to be admitted as a student in the Medical Faculty of Moscow University even though he was then only thirteen years old. He graduated as a physician in 1828 [25] after which he won a scholarship to the German-Baltic University of Dorpat (now Tartu in Estonia), where he studied anatomy and surgery. After graduating he remained for a further two years in Dorpat to carry out a research

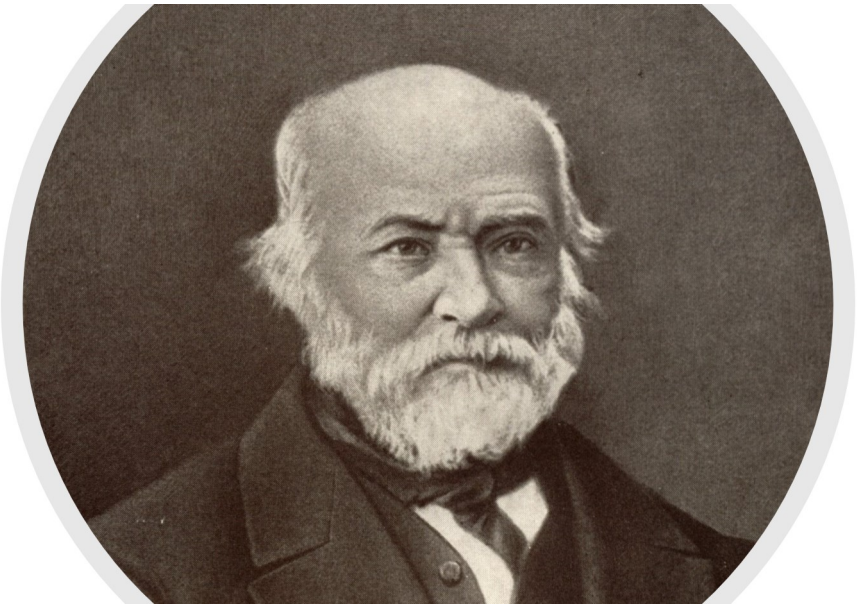

Fig. 3. Photograph N.I. Pirogov in the 1870's. In: N.I. Pirogov, Collected work in 8 Volumes. Volume VII: Moscow, Gosudarstvennoe Izdatelstvo Meditsinskoy Literatury, 1960, p. 7. Military Medical Museum of Defence Ministry of Russian Federation, Saint Petersburg. Reproduced with their permission.

project for his doctorate. He successfully defended his thesis '*Is ligation of the abdominal aorta with an aneurysm of the groin a readily feasible and safe intervention?'* in August 1832.[27] Pirogov then spent two years at the Charité Hospital in Berlin and during summer holidays also studied in Göttingen before returning to Dorpat in 1835. In February 1836 he was appointed professor of theoretical, operative and clinical surgery at Dorpat University. Between 1837 and 1846 Pirogov travelled to Paris on paid nine months leave and in the same period he published three manuscripts: *Surgical anatomy of arterial system and fasciae, 1837* in Latin and German [28], *Clinical records in two volumes, 1839* in German [29], and *The cutting of the Achilles tendon as an operative orthopaedic remedy, 1840* in German.[30]

In 1841 he was appointed professor of hospital surgery and applied anatomy at the Imperial Medico-Surgical Academy (now the Military Medical Academy named S.M. Kirov) (Fig. 4) in St. Petersburg and Chief Surgeon of the Second Military Land Force Hospital.[31]He also worked as a consultant-surgeon in three other hospitals and had a private practise at home. Pirogov instituted the teaching of microscopy and histology to the medical curriculum. His objective was: "*To assist in raising the medical skills in Russia to a level equal of that of the advanced countries of Europe*".[25,32] He became the secretary of the Academy of Science and one of the four members of the Medical Council of the Ministry for Internal Affairs.[25,32]

In 1846 he established the Institute for Applied Anatomy within the academy, where in addition to teaching medical students future teachers of anatomy in Russia were

trained. Pirogov published extensively on anatomy, including several anatomical atlases, the most notable his three-dimensional atlas of topographical anatomy published in four volumes between 1852 and 1859. The topographical atlas was Pirogov's last work on medicine before he took part in the Crimean War during 1854-1856. It laid a firm foundation for the field of topographical anatomy, with great practical significance for surgery and enhanced his reputation as a distinguished surgeon and anatomist. Several anatomical structures are named after him, including the Pirogov angle (the junction of the internal jugular and subclavian veins), the Pirogov aponeurosis and the Pirogov triangle, an area located between the mylohyoid muscle, the intermediate tendon of the digastric muscle and the hypoglossal nerve. He also invented a number of surgical operations, the best known, the osteoplastic foot amputation, is named after him. Pirogov was a dedicated teacher who encouraged students to excel clinically, guided them in scientific endeavours and equipped doctors with scientifically based techniques of surgical intervention. From his work during the Caucasian and Crimean wars he can be considered the founder of military field surgery.

Nikolay Pirogov was a key figure in the development of anaesthesia in Russia.[33] He experimented with alternative techniques for administering ether and investigated the use of chloroform in animals and humans. He was the first to perform systematic research into anaesthesia-related morbidity and mortality. Pirogov was one of the first to administer ether anaesthesia during surgery on the battlefield. His textbook on the principles of military medicine remained virtually unchanged until the outbreak of the Second World War. He was that rare combination of a scientist, a skilled surgeon and an excellent teacher.

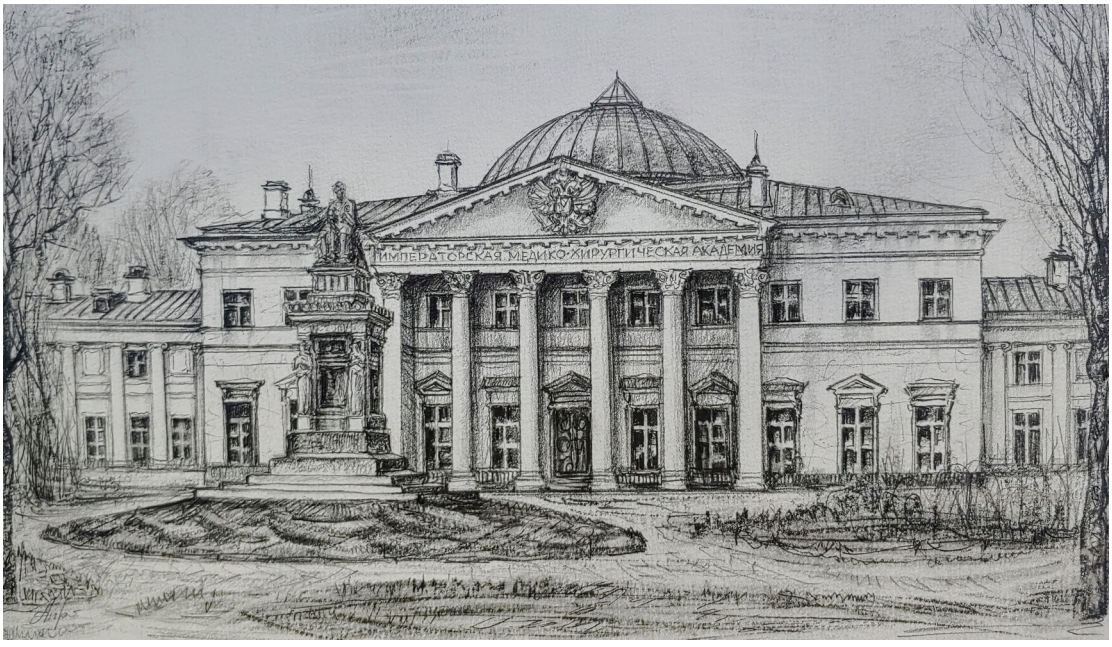

Image 4. The main building of the Imperial Medico-Surgical Academy around 1800, pen-and-ink drawing, artist Margarita V. Apraksina, St. Petersburg, 2019. Private collection, with permission.

The 19th century Crimean war was a major stimulus for the participation of women in healthcare in Russia, largely due to the initiatives of Nikolay Ivanovich Pirogov and the Grand Duchess Elena Pavlovna, sister-in-law of Tsar Nicholas I. Together they organized and trained nurses to care for the wounded on the battlefront during the war. Indeed Russia was the first country to send well-trained female nurses to the battlefront, and their work under such extreme situations was invaluable. Seventeen Russian nurses died, and those who survived continued their nursing careers and became the foundation for what later became the Russian Red Cross, established in 1867. After the Crimean War Nikolay Pirogov resigned his position at the Imperial Medico-Surgical Academy and focused more on education and supervising students during their foreign internship in Germany.

Pirogov was a forerunner of the International Red Cross, co-founder of the Russian Red Cross and acted as its Inspector-General. During the Crimean war he had pleaded for the establishment of an international treaty that would oversee the provision of international help, including the use of volunteers, to both civilian and military victims of war, regardless of rank or nationality. On 17 February 1867 he was appointed as Privy Councillor to the Russian Red Cross.[34] His managerial skills, which proved invaluable during the Caucasian and Crimean wars, were also of great value for his work for the International Red Cross. In April 1869 the Russian Red Cross sent Nikolay Pirogov as its authorized representative to the Franco-German War in Alsace and Lorraine.[34] In a period of five weeks he visited up to seventy military hospitals in France and Germany and met many foreign physicians. He recorded his findings and conclusions in a Russian report to the Russian Red Cross.[35] After his return from the war zone the Committee of the Russian Red Cross unanimously awarded him honorary membership of the Russian Red Cross as a token of their deep gratitude for his work on behalf of the Committee.[34]

During the Russo-Turkish War of 1877-1878, also known as the Balkan War, a conflict between the Ottoman Empire and a coalition of Russia, Bulgaria, Serbia and Montenegro Nikolay Pirogov, now 67-years-old, was again asked to report on this armed conflict by the International Red Cross.[36-38] He visited dressing stations and hospitals in Romania and Bulgaria, investigating their procedures for organizing care for the wounded and for evacuating patients. Pirogov's report to the Red Cross on the Balkan War was published in Russian and in German.[39]

Nikolay Ivanovich Pirogov died on 5th December 1881 in the village of Vishnya (now Vinnytsia, Ukraine). His body is preserved using embalming techniques he himself developed shortly before his death and rests in the village church in Vishnya.

The international network

Herman Boerhaave

Herman Boerhaave never studied abroad nor accepted a position abroad. Indeed he seldom travelled further than between his home in Leiden and later Oegtsgeest, a distance of about five kilometres. He did receive several offers, including an

invitation to become a court physician of Tsarina Anna Ivanovna[40] and to become a member of the Imperial Russian Academy of Science, both of which he declined. He was, however, elected as a member of the French Academy of Sciences in 1728, and two years later of the Royal Society of London. He did, however, maintain an extensive correspondence with colleagues worldwide.[13] The personal archives of Herman Boerhaave have been kept since 1798 in the fundamental library of the Military Medical Academy named S.M. Kirov in Saint Petersburg. Two authors (IFH and FB) searched the catalogue of the library for entries about Herman Boerhaave, including his (international) correspondence.[41] The volume of this correspondence they found was considerably less than suggested by Lindeboom. [13]

Nikolay I. Pirogov

In 1837 Pirogov visited several hospitals in Paris, where he met a number of senior surgeons, among them Alfred-Armand-Louis-Marie Velpeau, renowned for his knowledge of surgical anatomy, and Astley Cooper, a surgeon and anatomist, who was professor of comparative anatomy at the Royal College of Surgeons in London. [25] In 1844 Pirogov travelled on a grant to visit anatomical departments in Italy, France, Switzerland and Austria.

Pirogov's heritage was valued by others, but the posthumous recognition by his colleagues for his contribution to medicine would have been the most gratifying to him. On the eve of the meeting of the XII International Congress of Medicine held in Moscow 16 years after his death in August 1897, a memorial statue of Pirogov was unveiled in front of the entrance to the medical faculty of the University of Moscow in the presence of thousands of his medical colleagues from across the world.[42] During this Congress several speeches were delivered by fellow colleagues illustrating not only Pirogov's enormous contribution to medicine and in particular to surgery and medical education. Some compared him to past illustrious physicians such as Harvey, Jenner, Helmholtz, Pasteur, Virchow and Lister. One speech in particular is worth recording:

> *For a long time two main directions existed in surgery: empiricism and theory. For centuries the practice of our art was in the hands of artisans, who in the barber shop climbed from apprentice to companion. There was no more theory here than with other crafts. The predominantly technical nature of surgery could not derive general concepts and scientific guidelines from its operations. This only took shape when lessons were learned from science, which so far had no connection with surgery, and this science organically learned to connect with. The first scientific principle that appeared in surgery after the development of the medical sciences was anatomy. Ambroise Pare, "the first barber of kings", as he called himself, who had also worked as a dissector on the anatomical floor, symbolizes the merger of barber-surgeon with anatomy. Jean Louis Petit, Desault and Bichat are then the other formidable landmarks in the scientific development of surgery. When we go outside to the Djevichje field here in Moscow, we are vividly reminded of this combination of surgery and anatomy. We can see from the beautiful and historical true monument of Pirogov that,*

among his many other accomplishments, he also had the great merit of contributing to the introduction of anatomy into surgery.[43]

Their scientific heritage

Method of the Bibliographic search

We undertook a bibliographic search for Nikolay Pirogov and Herman Boerhaave using for books the online NLM catalogue, IndexCat and Worldcat, and for journal articles Pubmed, Medline, Embase, Web of Science and PubMed Central from their first published material up to and including any articles referring to them up to 2018. We included any publications by themselves, manuscripts, books and journal articles, also re-publications of their published works. For comparison we added a bibliographic search for Rudolph Virchow (1821-1902), who lived approximately in the same time period as Pirogov and who was internationally well-known as the founder of cellular pathology.

The terms for our search were Pirogov, Boerhaave or Virchow in the title or keywords. Articles that contained the terms "Boerhaave syndrome" or "Boerhaave's syndrome" were excluded as they did not refer to Boerhaave as a person. Similarly we excluded articles that did not refer to Virchow as a person, such as Virchow-Robin space or Salmonella Virchow. All publications were individually checked by one of the authors (FB) for eligibility to be included in the dataset.

All references were sorted according to title, author, language of the publication, type of publication (book or journal article) and publication year and added to separate files for Pirogov, Boerhaave and Virchow; these were then combined in one master file. The name variations in English or Russian as a result of the difference in transcriptions were homogenised. Duplicate publications were removed. The resulting files were used for further analysis using Microsoft Excel.

Our search in the online sources yielded 678 unique publications about Pirogov and 630 for Boerhaave. The earliest publication in the Pirogov set was his thesis published in 1832.[44] The earliest publication in the collection of Boerhaave was a book published by him in 1687 (*Disputatio de cohaesione corporum*) [Disputation on the cohesion of bodies] when he was studying theology and philosophy.

What we can learn from the search

Pirogov published on medical themes or themes related to medicine. In contrast, Boerhaave published on a variety of themes not always related to medicine. Publication by or about Pirogov are largely in his native language, Russian (82%) but also some in German, while Boerhaave is mentioned only in a minority of articles written in Dutch (25%) or in the scientific language of the time, Latin (15%). While publications about Boerhaave are largely in other (modern) languages (60%), the number of non-Russian articles on Pirogov (18%) are significantly less (Chi-square test; $p<0.001$)). In comparison, Virchow is closer to Pirogov than to Boerhaave in terms of the percentage of publications in a non-native language. We can therefore conclude that Pirogov is much less well-known outside Russia while Boerhaave was better recognised outside the Netherlands.

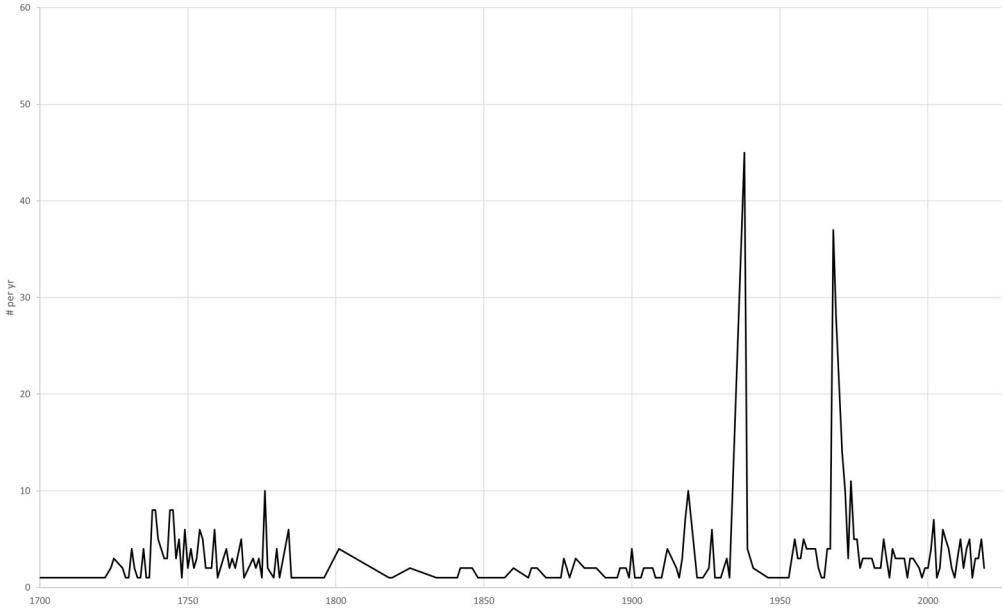

Fig. 5. Number of annual publications for Herman Boerhaave.

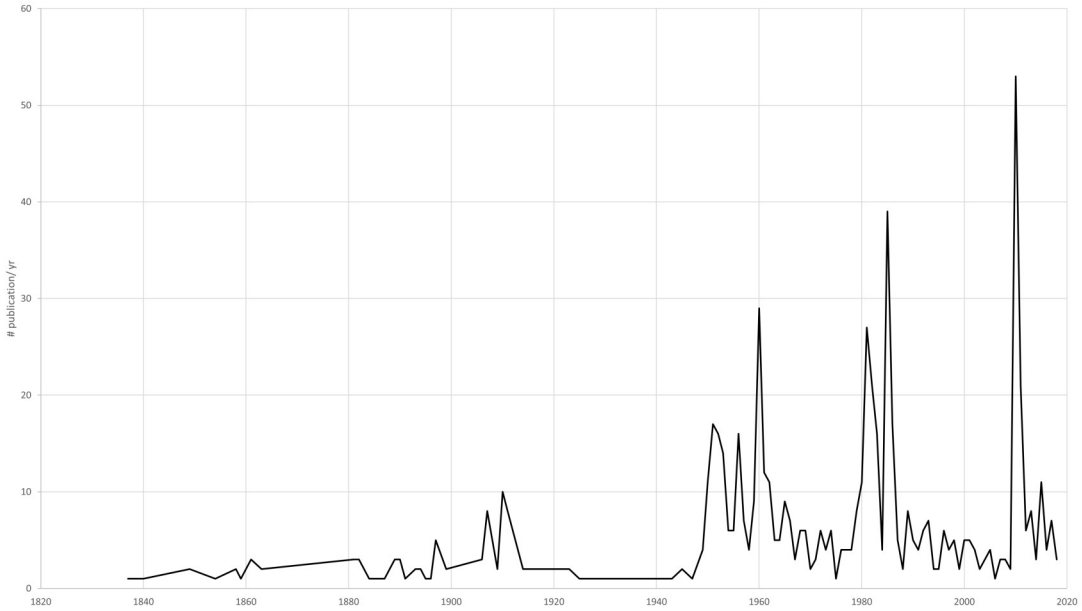

Fig. 6. Number of annual publications for Nikolay Pirogov.

The number of publications each year for Pirogov, Boerhaave and Virchow are shown in the figures 5 to 7. All the three graphics show a non-homogeneous pattern over time for the three authors. For Pirogov the number of publications peak around 1910 (100 years after his birth), and again around 1960 and 1981 (100 years after his death), but there were also larger peaks in 1985 and in 2010.(Fig. 6.) During his life and shortly after the death of Boerhaave there was an increase in publications largely attributable to re-publication of his works and to publications of the notes of

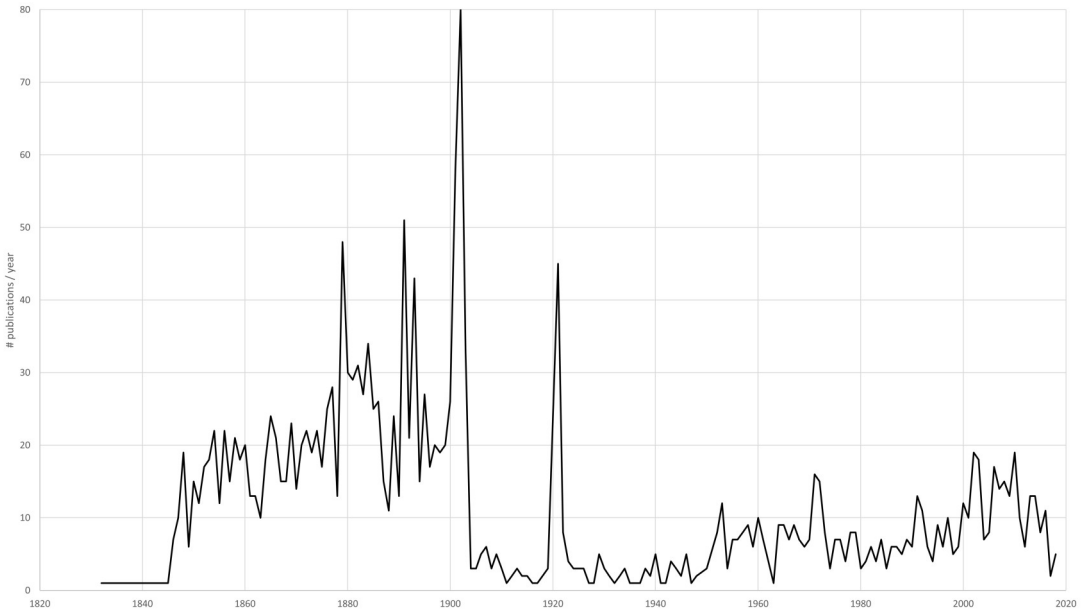

Fig. 7. Number of annual publications for Rudolf Virchow.

his students.(Fig. 5.) For a long period thereafter only 1-2 publication appeared annually. A first peak of 10 publications occurs in 1919 and a second peak in 1938, 200 years after his death. A third peak occurs in 1968, followed by a somewhat increased baseline publication activity. The data for Virchow is somewhat different, as he was a very prolific author and during his life the number of publications (840) was significantly higher than in the years after his death in 1902.(Fig. 7) After his death there is a gradual increase of publications about him, but his graphic does not show the marked spikes seen with Pirogov and Boerhaave.

Table 1 shows details of all the authors of books and articles on both scientists. For Boerhaave there were 334 authors, many of whom only published one article. Table 2 shows authors who produced at least six publications. Apart from Boerhaave himself, the most prolific authors about him were Lindeboom, van Swieten and Swammerdam. For Pirogov there were 351 authors. The most prolific author about him is Geselevich. For both Boerhaave and Pirogov their work was reprinted in later years and were counted as separate publication. Especially for Boerhaave there is a small group of prolific authors had a significant number of publications. Lindeboom, for example, attracted at least 300 citations, from his publications on Boerhaave. Twenty of his 39 publications were in English, enabling a broader scientific public to become aware of Boerhaave. For Pirogov only Geselevich can be considered a prolific author and he published only in Russian.

Our search for publications about Pirogov and Boerhaave has some limitations. The catalogues we used were predominantly in digital format, and the accuracy of this conversion is very dependent on the extent to which especially older literature has been entered into the catalogues we used. Many of our original sources, both in Leiden and Saint Petersburg, were handwritten and, in some cases, very difficult to

Table 1: Number of publications including their own publications. Produced by the authors

	Pirogov	Boerhaave	Virchow
Total items in biography	678	625	2013
Language			
Russian	552	1	22
Dutch	1	159	14
German	18	53	1521
Latin	4	93	2
Other languages	98	318	445
n.a.	5	1	9
Publication form			
Book	175	334	809
Journal	502	291	1221

Table 2: Authors of the books and articles on both scientists

Publication for Boerhaave		Publications for Pirogov		Publications for Virchow	
Author	number	Author	number	Author	number
Boerhaave (Own publications (6) and posthumous reprints)	39	Pirogov (Own publications)	51	Virchow (Own publications)	866
Lindeboom	41	Geselevich	22	Andree	70
van Swieten	32	Makovoz	8	Diepgen	9
Swammerdam	13	Mirskii	8	Orth	9
Alpinus	8	Budko	7	Pagel	9
Belloni	8	Bukin	7	Schmidt	8
van Leersum	8	Zabludovskii	7	Ackerknecht	7
Schoute	7	Lubotskii	6	Aschoff	7
Kaiser	6	Oborin	6	Beneke	7
Luyendijk-Elshout	6	Rudenko	6		
Schultens	6	Shabunin	6		
		Sorokina	6		

decipher. It is therefore possible that this, together with transcription errors arising during the conversion to digital format, could have resulted in a less than 100 % success rate. We limited our search to Boerhaave or Pirogov in the title or the keywords. Our method could not detect references to them in general articles dealing with, for example, the development of medicine in a particular period or on

the history of a particular medical treatment. Thus, our dataset is much smaller than if we had broadened the scope of our search.

Supervision of Doctorate students
Between his appointment as professor of medicine in 1709 and his death in 1738 Herman Boerhaave supervised 178 doctorate students, of whom 102 were foreigners. They included 48 from German-speaking areas and 43 from English-speaking areas.[45] However, not all of the 178 students would have been studying medical subjects since Boerhaave also held the chairs of botany and chemistry. Nikolay Pirogov supervised 12 doctorate students during his time as professor in Dorpat and a further 38 students after his appointment to Saint Petersburg in 1841. [46]

Conclusion
Herman Boerhaave and Nikolay Pirogov shared a common interest in furthering the practice of medicine and in medical education, despite their different backgrounds. They both excelled in their scientific and practical work during their life and were highly appreciated by their contemporaries. Both had an extensive international network around them. Pirogov travelled widely in Europe making many connections with colleague physicians. In contrast Herman Boerhaave is thought never to have travelled further than from Leiden and his home.

The main difference between Boerhaave and Pirogv is that Boerhaave held more chairs than just medicine, such as botany and chemistry, and was interested in physics.

Boerhaave was more theoretical than a practical physician, and can’t be considered a medical scientist. Nowadays you can describe Boerhaave as a specialist in internal medicine.

Pirogov was not at all satisfied with his basic medical education which was rather theoretical along the way of the Dutch Leiden medical school. He promised himself if possible to change this form of education. Pirogov, therefore, did not hesitate to criticise his colleagues through substantiated scientific research, which he published internationally and by giving demonstrations not only in his own country but also abroad. He wanted medicine to become not a handcraft but a science to the benefit of his colleagues and the patient. Even in wartime, he taught "hostile colleagues" and treated "hostile patients" because he was primarily a physician and not a military physician. Because the injured and sick were high in his standard, his humane side also drifted upwards. After the Crimean War various negative publications appeared concerning Russian medical treatment. He responded by publishing his findings of war management, not only in the Crimean War but also in the Caucasian war. This publication became the guide in times of epidemic and war situations worldwide. This led to Pirogov being considered the forerunner and co-founder of the Red Cross and shows that he lifted medicine beyond political conflicts.

After their death both scientists were gradually forgotten as the number of publications diminished, but both periodically attracted attention from other authors. Publications about Boerhaave were often in languages other than Dutch, particularly in English, whereas those about Pirogov were largely restricted to Russian. Despite that Boerhaave comes from a very small language area (Dutch) he is more often mentioned in international literature. His most important biographer wrote the majority of his publications in English, and we assume this aided to a larger stream of international publications. However, in the past decade many of the publications about Pirogov have been in languages other than Russian (25%), which could help to make him better known internationally.

Pirogov's oblivion both in Russia and abroad has several causes. He was married to a noble lady, and the family had close and warm connections with the Imperial family. In 1917, the revolution took place in Imperial Russia. Especially for the nobility and faithful to the Imperial family it was a hard and disastrous period.[47] During communism, Pirogov's archives were put under lock and key and Pirogov was banned in Russia.[26] It was only during the Second World War that he was "rediscovered" and in particular his work on war management was studied. And in the fifties and sixties of the 20th century during the de-Stalinization led by Khrushchev, extensive research was started into the archives and works of Nikolay Pirogov.[26,47] This has led to a Russian instruction manual, in which can be found information on his scientific career, and in which all his publications, textbooks, etc are mapped.[46] In the same period all his works were republished in Russian in 8 volumes.
Because many of Pirogov's original works have been published in Russian, Latin, and German, many researchers encounter barriers.
We conclude that not only internal but also external environmental factors have led to Pirogov's unfamiliarity. Even though the Netherlands is a very open country, researchers encounter a similar language barrier for Herman Boerhaave. But a second barrier is that since the 1740's the archives of Boerhaave are located in the Military Medical Academy named SM Kirov in Saint Petersburg, Russian Federation. Access to these files has been very limited during the last 300 years. Still, both scientists are not forgotten and publications in a common scientific language (first Latin, later English) keep the memory of the achievements Boerhaave and Pirogov alive.

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