



Medical instruments in Imperial Russia: from a blacksmith to a factory for medical instruments, headed by a leading surgeon N.L. Bidloo

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The two Grand Embassies to Europe and his view on the world helped Peter the Great to start reforms. Already as a child, he had a broad interest in medicine. Peter often followed a two-track policy. One for immediate application in the current practice and one for the development of specialists in collaboration with science. Peter established a medico-surgical hospital school in Moscow to prepare the students to become doctor medicinae and learn to make their own medical instruments along the line of the Leiden medical school. In Saint Petersburg, he opened a navy and an army hospital, intended to train students as a barber-surgeon for the army and navy. Also in Saint Petersburg Peter built the first factory for "mass" production to provide the military with medical instruments.

His successors followed his two-track policy. Catherine the Great started to merge the two tracks. During the reign of Tsar Aleksander I and his brother Nicholas I, the merger came together and was further developed. They understood that strong cooperation between a physician and a designer is essential to create and produce useful medical instruments. If correctly designed, medical instruments and devices increase safety for the patient. We will shed light on the development and manufacture of medical instruments and appliances in Imperial Russia, an underdeveloped subject in the world medical history.

Key words: Netherlands, Russia (pre-1917), history, medicine, medical instruments.

Медицинские инструменты в Императорской России: от кустарного изготовления до промышленного производства, возглавляемого ведущим хирургом Н.Л. Бидлоо

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Два «великих посольства» в Европу изменили взгляд Петра Великого на мир и помогли ему начать реформы в России. Еще в детстве он проявлял особый интерес к медицине. В период проведения реформ Петр рассматривал медицину в двух направлениях, с одной стороны стремился использовать ее для немедленного применения в текущей практике, с другой – для подготовки специалистов в области фундаментальной науки. Он основал в Москве первый постоянный сухопутный госпиталь, и при нем – школу для подготовки студентов, чтобы они стали докторами медицины и научились делать свои собственные медицинские инструменты, в том числе, по образцу Лейденской медицинской школы. В Санкт-Петербурге по повелению Петра также были открыты Адмиралтейский и Сухопутный госпитали, предназначенные для подготовки лекарей для армии и флота. В Санкт-Петербурге по указу Петра I была построена Мастерская изба – первый завод массового производства медицинских инструментов.

Преемники Петра Великого следовали его политике в области медицины. Екатерина Великая сделала попытку объединить оба направления – развитие практической медицины и науки. Во время правления царя Александра I и его брата Николая I произошло слияние этих направлений и получило дальнейшее развитие. Правители осознавали, что тесное сотрудничество врача и мастера необходимо для создания и производства необходимых медицинских инструментов. Они считали, что при правильной конструкции медицинские инструменты и устройства повышают безопасность проводимых оперативных вмешательств.

В данной работе уделено внимание исследованию вопросов разработки и производства медицинских инструментов в Российской империи. Указанный вопрос в современной историографии является малоизученным.

Ключевые слова: Нидерланды, Россия (до 1917 г.), история, медицина, медицинские инструменты.

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Introduction

Research on the history of medical instrument making has been limited. John Kirkup extensively studied instrument makers and instruments that contributed so much to patients' health and safety. Since then, his work has not been followed much by others for regions beyond the United Kingdom. He called for more research on this part of medical history [18, 19]. We took his invitation by studying the development of medical instruments in Imperial Russia. We detected that the training for instrument-making in Russia was influenced by the Dutch practices, particularly at Leiden University. Therefore, we dedicated some attention to surgeons' education in the Netherlands in the sixteenth century.

Since ancient civilization, artisans achieved a high degree of skill in producing beautiful and very functional instruments [17, 28, 36]. Many instruments were undoubtedly made by armourers, blacksmiths but also by barber-surgeons and surgeons. These labourers developed continuously medical instruments exclusively for surgery, and new instruments emerged. However, military requirements dominated healthcare treatments. Thus the army had its own trained cutlers, armourers, and blacksmiths.

Likewise, people in ancient Russia searched for means to alleviate pain and illnesses [28, 34]. The Slavic people were exposed to various climates and heavy physical labour on the field. They lived a simple life and were unfamiliar with luxury. Since 822 Kiev was the capital of Kievan Rus' and later part of the Russian Empire. The country converted to the Byzantine Christian faith in Greece in 988. Yet there were no Greek doctors at the court. Traditionally, it was the clerics, no doctors, who advised, supported, and nursed the sick. When the people founded settlements and villages, infectious diseases developed. Loyalty to a leader led to hostility, to war and thus injuries.

A gap between the court and nobility, on the one hand, and the ordinary people, on the other hand, affected not only to wealth but also to medicine [20, 28]. The family heads, the fathers in the settlements exercised "home medicine" in a practical, rough and arbitrary way, passing it on from father to son. They knew how to treat sores and burns proficiently with ointments. An overlap between instruments used for domestic, cosmetic, and funerary purposes and those for surgery existed.

Complicated medicine requires a different approach

The nobility asked for scientific expertise because of their sophisticated living standard with excessive eating habits and ensuing diseases. But the ordinary man remained his own physician [20, 28]. The effect of home remedies was recorded in handwritten medical books, and pharmacists occurred earlier than fully trained scientific doctors. Despite a close relationship with Greece, ties became more established with other European countries like England, Germany and the Netherlands [20, 27, 28]. Observation in Medicine became more accurate. Among others, Vesalius (1514–1564) described anatomy, Harvey (1578–1657) discovered the blood circulation in Physiology, and Sydenham (1624–1689) introduced the empirical system. In the 17th century, also in Russia, healthcare started to change [28, 34]. The tsars competed with each other to employ suitable doctors and surgeons. However, the establishment of schools for physicians' training, the construction of major hospitals and a factory for medical instruments were reserved for Tsar Peter the Great and his successors.

Tsar Peter the Great (reign 1682–1725) visited Europe two times during his Grand Embassies in 1697–98 and in 1717 [2, 4, 9–12]. A particular concern for Peter was purchasing medicines and medical instruments, which were to be done by the doctors accompanying the embassy [4]. In March 1698, the Amsterdam merchant Wouter Falden (Valden) received a substantial sum for medical instruments specially made for the Tsar. These instruments were transported to Moscow by the physician Alfer Penders. Admiral Cornelis Cruys, together with Johan Termont, were responsible for the purchase of medicines and medical instruments for the army. Cruys transported them to Russia with 4 Arkhangelsk ships. The Dutch merchant Christopher Brandt was also responsible for major medical purchases and personally responsible for delivering to Moscow. In May 1698, the Tsar bought in Amsterdam a small travel pharmacy for 15 gold ducats and medicines from the pharmacy het Gouden Doel ("the Golden Goal"). At Peter's request, his travel pharmacy was delivered to him at the Dutch East India Company's shipyard. Especially for his court physicians Johann Termont and Zacharias van der Hulst and others he purchased medical instruments, not only in the Netherlands but also in Great Britain (Fig. 1) [4, 10, 26].

In Great Britain, he paid a physician named Baldwin Anders for crats and transportation of his medical instruments purchases. He wanted to hide them from the medical trade during the transport from Detfort to London [4]. Therefore, possibly several old instruments in the Hermitage are descended from these two doctors as well. Several of his medical purchases were collected in the large Amsterdam Pharmacy



Fig. 1. Medical instruments of Tsar Peter the Great's court physicians? The State Hermitage Museum St. Petersburg, Russian Federation. Photograph © Leiden University Medical Center, Leiden, The Netherlands. Photo by Inge F. Hendriks. Reproduced with permission.



Fig. 2. The building of the Aptekarskiy Prikaz in the Moscow Kremlin, pen and ink drawing, artist Margarita V. Apraksina, Saint Petersburg, 2016. Private collection, reproduced with permission.

Gouden Doel, from where they were transported to the Aptekarsky Prikaz¹ in Moscow (Fig. 2) [4].

During his two Grand Embassies, Tsar Peter the Great visited the Leiden University three times, in 1697, 1698 and 1717 [8, 9, 12]. During both visits, he was very interested in the establishment and bylaws of Leiden University. He was twice presented with the university statutes.

He needed a new court physician and invited Nicolas Bidloo, an alumnus of Leiden University, as his court physician and later his "architect" for medicine and "developer" of professional medical education [7, 26, 27].

In 1707 Peter the Great and Nicolas Bidloo opened in Moscow, the Medico-surgical school with a hospital and an anatomical theatre de-

signed by Bidloo [1]. The school worked along the lines of Leiden University both theoretically and practically. Furthermore, Nicolas Bidloo introduced the Leiden method of exam for surgeons [6]. This school laid the foundation for a systematic higher medical education in Russia. In 1710 Bidloo finished a handwritten Instruction to study surgery [3] for his students. It is not only a scientific publication, but it is also the first and original textbook for higher medical education in Russia. The manuscript habitually contains terms, names, and the use of surgical instruments in French, German and even Dutch.

During his second Grand Embassy, Peter went in 1717 to all Leiden factories and had interesting, detailed talks with manufacturers and masters of instruments and devices [8]. With its physician-scientists, Leiden University was located at the Rapenburg like most of the medical instrument makers [30]. This area could be considered as the nowadays Leiden Bioscience Park.

¹ Historical meaning for "Приказ" is "Ministry" according to the dictionaries of S.I. Ozhegov – N.Yu. Chvedova and of V. Dal'. The meaning here is "Ministry of Healthcare".

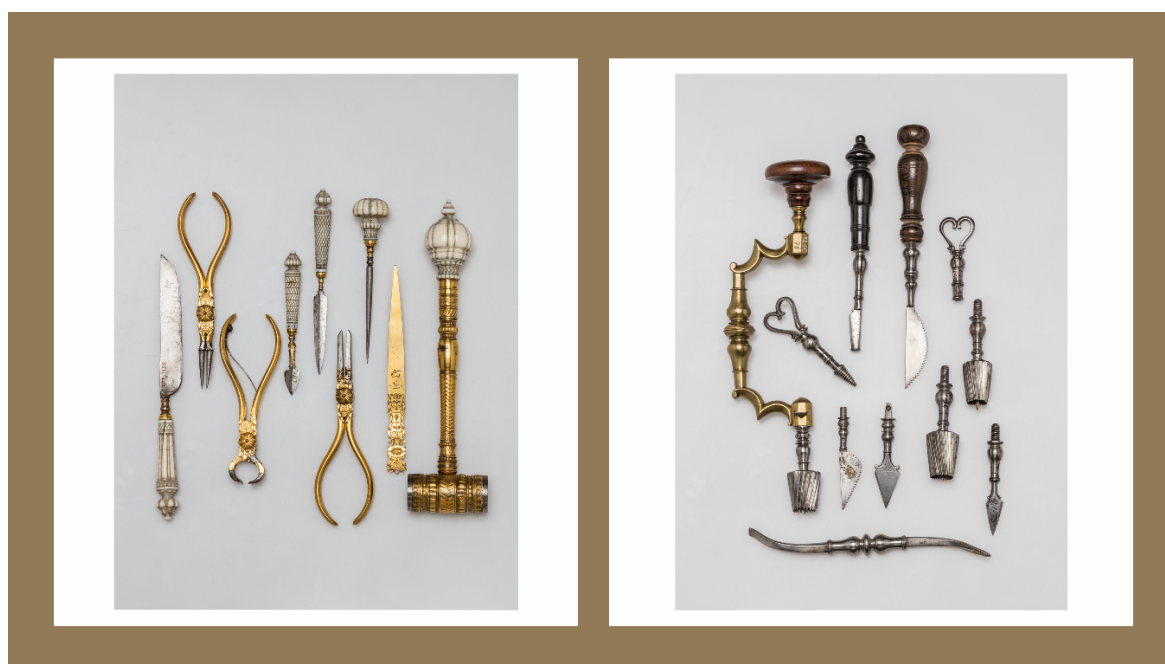


Fig. 3. Surgical instruments Inv.no. ERTh-1132-1140 and Trepanation instruments Inv.no. ERTh-957, 960, 961, 963, 1069a-b, 1068, 1075, 1978, 1089, 1755 from the Petrine era, The State Hermitage Museum, St. Petersburg, Russian Federation. Photograph © The State Hermitage Museum. Photo by Pavel Demidov. Reproduced with permission.

Because the Dutch played an essential role in medical education and in the development of Russian instrument making, we will first discuss the historical development of the Leiden surgery and instrument making. Tsar Peter owned a beautiful collection of surgical instruments decorated with ivory and gold (Fig. 3).

Development of surgery and medical instruments at the Leiden University

In the 16th and 17th centuries, only one country in Europe, namely Germany, and especially the city Nuremberg, owned a factory with flourishing mass production of professional medical instruments specialized among others in many forms of forceps and saws [13, 17].

In the Netherlands, France and other countries, the local craftsmen, blacksmiths, and cutlers produced instruments on a local surgeon's request. These craftsmen were organized in a guild, protecting its members against unfair competition and safeguarding the products' quality. The blacksmith or the cutler stamped their mark/symbol into the object. This punch mark was the symbol of the guild/manufacturer. From the middle of the 15th century on barber-surgeons and surgeons likewise started to organize guilds [17].

In the 16th century in the Northern Netherlands, the guilds detailed the requirements, qualifications, exams, and exam judgment for becoming a member. The exam was a combination of a theoretical and practical part. The theoretical part consisted of knowledge of anatomy, unusual

growths, wounds, ulcers, fractures, dislocations, and the textbook *Antidotarium Nicolai*² [17, 13]. The guild of Leiden followed the Northern Netherlands policy. However, the Leiden surgeons' guild differed much from those in other major cities in Holland, such as Amsterdam and Delft [17]. The Leiden surgeons were essential assistants to the professors of the medical faculty of the Leiden University when they taught anatomy and demonstrated dissections on post mortems to the students. The surgeons were spectators and also assisted the Leiden professor during public dissections in the *Theatrum Aatomicum*. In other cities, the 'praelector anatomiae', a doctor medicinae, and supervisor of the guild appointed by the city carried out these demonstrations. In Leiden, the assigned Professor for teaching anatomy acted as the supervisor and 'praeses' of the guild. Moreover, he was responsible for the theses on which the aspiring surgeon was questioned. In Leiden, anatomy was considered a basic science for the profession of surgery. Therefore the Professor carried out the theoretical instruction and examine of the surgeons.

A part of the surgeon's practical examination included the correct diagnosis of a few medical cases, successful phlebotomy, one surgical operation, and the manufacture of two or three lancets from a piece of raw iron. The assignment of manufacturing lancets by surgeons was introduced in December 1612.

² A late 11th or early 12th-century Latin book also known as the *Antidotarium parvum* or small antidotarium, about 150 recipes to create medicines from plants and minerals

In the 17th century, "modern" textbooks were used among others from Wilhelm Fabricius von Hilden, *Aanmerkingen rakende de genees ende heelkonst*, translated from German to Dutch (1646, 1656), Johannes Scultetus, *Magazyn ofte wapenhuys*, translated from German to Dutch (1657, 1741 and 1748), Cornelis Solingen, *Manuale Operatien* (1684), Pierre Dionis, *Cours d'Opérations de Chirurgie démontrées au Jardin-du-roi* (1708). Another book that appeared was from Lorenz Heister, *A general system of surgery* in three parts, translated from Latin to English (1750) [13].

Cornelius Solingen was a doctor/surgeon and former student of the Leiden University with a practice in The Hague. He divided for his description of instruments the human body into four areas: the head and shoulder, the thorax, the abdomen, and the limbs. He did not only describe and illustrate his own manufactured instruments, but also those of others. More importantly, Solingen described the effect of dirt on the healing process. Consequently, he made smooth instruments.

Members of the Leiden surgeons' guild were surgeons and barbers, although the latter were of lower prestige. Their knowledge of the veins, arteries, and nerves was put to the test. Practically, they had to refine two or more rough lancets and to polish up its shape and its functioning within 14 days, which were tested with a sheet of leather sturdy held between fingers. A close relationship developed between the Leiden surgeons' guild and the University. In the late 17th century teaching of surgery integrated more and more in the Leiden University's educational program [17]. In the 18th century there were even professors of surgery appointed, like Johannes Jacobus Rau (1668–1719) and Fredericus Bernhardus Albinus (1715–1778). Even the specialization in medical instrument-making became an education, concurring with surgery education, especially at the Leiden University.

A two-track policy of instrument making and medical education

From the time of Kievan Rus' on, skilful blacksmiths, gunsmiths and locksmiths worked in artisan settlements and later also in cities as Moscow, Novgorod, Tula and Nizhny Novgorod. They supplied medical instruments, among others to army regiments [7]. Two physicians of an army regiment were provided with a set of surgical instruments consisting among others of a double-bladed saw for amputation; a screw with a cone-shaped rod to taken out bullets, a bullet pincer/forceps, pincers to clean the mouth; a curved knife; 2 lancets, a wooden tube with a pewter spray tube in it; a tool for cauterization of wounds; long spoons with copper pins; and others.

In Moscow in the seventeenth century existed only two pharmacies, one in the Kremlin

and a second one in the city centre [21, 26, 27]. These pharmacies had to produce and repair the surgical instruments, but due to the lack of skilled artisans, new tools seldom appeared. But the handicraftsmen and artisans could quickly satisfy the minimal need for surgical instruments [7, 20]. The pharmacies were the suppliers, but only on prescription.

During the reign of Tsar Peter the Great, who inherited these two pharmacies, eight private pharmacies in Moscow were opened [7, 26]. The production and repair of surgical instruments was private business, consisting of single individual artisans, usually, foreigners, who worked on a contract [21, 22]. The assortment and quality of the instruments were various. From 1700 to 1721 Russia was at war with Sweden to obtain access to the Baltic Sea. In 1703 Russian troops made their way to the Finnish Gulf and in the same year, Peter the Great built his new capital, Saint Petersburg, at the mouth of the Neva. The Russian army multiplied, shipyards built new warships, and the number of hospitals increased. During the continuous long-distance marches, medical instruments were lost, damaged, and rusted. The instruments of the regimental chests had to be cleaned, repaired and replaced, and chests to be refilled. Making surgical instruments was not easy. It required high skills from the craftsman. A complete regimental set with various surgical instruments had to be handmade. In one year, one master, together with his student, produced no more than six boxes (sets) of instruments, although working from dawn to dusk, and not less than 16 hours per day [7].

Tsar Peter understood the great need for an excellent military healthcare service with suitable physicians and medical instruments. To meet the enormous demand for qualified physicians and good quality medical instruments, he set up an educational two-track policy, with one track for the army for educated barber-surgeons and one track for educated doctors *medicinae*. His two-track approach also resulted in two ways of manufacturing instruments, one by the *Ap-terkarsky Prikaz* and the other by the factory for medical instruments, only to change around 1800 with other healthcare reforms.

The development of the manufacturing of medical instruments

Since the year 1733, according to the rulings, the *Meditsinskaya Kantselyariya* registered instrument makers, apprentices, and others, who worked in the pharmacies (Fig. 4). The *Kantselyariya* made extremely stringent demands for the quality of the instruments [26, 27]. Many instruments, like catheters, were made of silver and the handles of instruments of ivory, tortoiseshell, and ebony [7, 21, 22].

These instrument-makers repaired, cleaned, and made new instruments, with newly

Name	Founder or Renamer	Founding or renaming year	In charge
Aptekarskiy Prikaz	Mikhail Fyodorovich	1620	Apothecary
Aptekarskaya Kantselaryariya	Peter the Great	1707	Doctor medicinae (Arkhiyater)
Meditsinskaya Kantselaryariya	Peter the Great	1707	Doctor medicinae (Arkhiyater)
Meditsinskaya Kollegiya	Catherine the Great	1763	board of three directors (Collegium) inclusive doctor medicinae
Meditsinskaya Kollegiya	Aleksandre I	1802	Ministry of Internal Affairs with a Medical Department
			Ministry of Education with department Medical education

Fig. 4. Overview of the development of the "Ministry of Health", with the names that were used, the founder of the governmental structure, the founding year and the individual or collective that was in charge. Produced by the authors.

purchased instruments from Paris, Danzig, Leipzig, and Stockholm as examples. The most common tools enlisted in the pharmacy register were the trepan with accessories, dental forceps, pincers, saws, various scissors, chisels, trocars, bullet forceps, cauterization instruments, small and large, straight and curved surgical needles, bellows for irrigation of wounds, and other instruments. In every pharmacy also students worked, recruited mainly from Russia, to become a graduate instrument-maker.

The catalogues of the surgical instruments were periodically reviewed. Outdated instruments were taken out of production, new ones corresponding to the level of medical science were added. For example, during the Russian-Turkish war of 1735–1739, field doctor Nitsch proposed to add to the regimental chest a turnstile, which was accepted and every chest got one.

In 1715 the Tsar built in St. Petersburg in the Vyborg district a Landforce and an Admiralty hospital. The Aptekarskaya Kantselaryariya, earlier named the Aptekarsky Prikaz, supplied the hospitals with drugs and dressings, and large numbers of surgical instruments imported from Europe.

In 1717 during his second Embassy Peter visited among other countries France, where he in Paris signed a contract with the instrument-maker Etienne Stephen Lubote. In 1718 Lubote arrived in St. Petersburg, which as a Parisian he did not enjoy. He obtained permission to move to Moscow, where he joined the staff of Aptekarskaya Kantselaryariya and created a surgical instrumental case. We assume that in the Hermitage state museum still can be found instruments of Lubote, some made by him in Paris and some made by him in Russia (Fig. 4).

After Peter's return from abroad, he built a wooden factory for medical instruments on the

Apothecary Island in his new capital, Saint Petersburg, which was finished in 1722. The factory had a length of 10 yards and a width of 5 yards [22]. Dinghy boats started to bring simple equipment like anvils, hammers, pincers, and bellows for the forge. The instrument-maker received a vice, a sharpener/grinder, a saw, a workbench with a wheel and a wooden log and surgical instruments imported from Europe. Vasily Shershavin was appointed as the skillful master. Before the altar of the church, he took the oath to the Tsar. He was assigned for official tool-cases. Ivan Noskov became his journeyman, Nestor Stepanov, a minor student "for the blast bellows" and a disabled soldier was assigned to "the spinning wheel". The Russian masters started without instructions or help from foreigners. The first surgical instruments received a good reputation, and surgeons appreciated them.

The subtle art of making surgical instruments required long-term training [7]. In 1736 tsarina Anna Ivanovna approved regulations for orphans and children of soldiers and employees of Meditsinskaya Kantselaryariya, the new name for Aptekarskaya Kantselaryariya. They had to learn to read and write and afterwards became students for medical instrument-making. The same fate awaited their sons. As a result in the village on the Apothecary Island arose not a guild but a dynasty of instrument makers, who passed their craftsmanship from generation to generation. Their career was long and not comfortable. After a study as a journeyman, another 12 years passed before becoming a high-qualified instrument maker. Vasily Shershavin led for almost 20 years the factory for surgical instruments on the Apothecary Islands and generated outstanding instrument makers like Ivan Noskov, Nestor Stepanov, and Samoil Novogorodov. In their turn,

they did likewise. In 1738 Shershavin was transferred to the Meditsinskaya Kantselyariya in Moscow.

The instrument makers of the early eighteenth century

Ivan Noskov led the workshop till 1743 and produced hundreds of sets of surgical instruments for the army and navy regiments doctors for the treatment of the soldiers [7]. The demand was high, and the number of instrument makers increased. Therefore Noskov, still a journeyman, should have been granted the title of master. But instead of giving Noskov the position, Johann Fischer, Arkhyater and president of the Meditsinskaya Kantselyariya, appointed journeyman Andreas Ketsher in January 1738 as the master. Ivan Noskov never received the title of master. It would be his son Peter, who in 1757 was promoted to apprentice and only after another ten years (1765) master instrument maker of surgical instrument cases.

Similarly, Samoilo Novgorodov befell a life full of hardship, deprivation, and abuse. Being already an excellent instrument maker, in 1728 he was transferred from St. Petersburg to the Moscow main pharmacy workshop, headed by the Frenchman Etienne Stephen Lubote. He appreciated the skills and abilities of the young Novgorodov, who soon became his right hand and, in fact, ran the whole workshop. However, the French master kept him in the rank and provided him with a journeyman's salary. In 1737, a fire in the Moscow and St. Petersburg workshops changed the serene life of master Lubote [7]. The fire damaged almost all stocks of surgical instruments of the Moscow and St. Petersburg hospitals and pharmacies. Likewise, the work of Lubote went up in smoke. Meanwhile, the war with Turkey demanded the replenishment of surgical instruments in the regimental cases. The Meditsinskaya Kantselyariya put their hope on Lubote, but he could not fulfill the demands and experienced much trouble and even fell ill. He tried to convince the Meditsinskaya Kantselyariya that it was impossible to produce 15 boxes with surgical instruments in six months, certainly not in a month. More so if his best student Samoilov Novgorodov would be sent to Petersburg. In return, he asked for one more student to fulfill the task. When the difficulties had passed, Lubote decided to get rid of his useful, authoritative, and popular assistant. Then he suddenly changed his tactics and fully extolled Novgorodov. Lubote recommended him to the factory in St. Petersburg and petitioned him for a salary raise.

After a decade of absence, Novgorodov returned in March 1738 to his hometown Petersburg with his sparse belongings on a passing cart, which carried materials and supplies for the Central and Admiralty Pharmacy. He was not appointed as the master instrument maker but as an apprentice. He refused this position and

started to wander and set up field pharmacies for the army in Voronezh and Lubny. After four years he returned to Petersburg. In 1743 he was finally appointed as a journeyman after the death of Ivan Noskov. He held this post for 16 years. With his transfer to Moscow in 1754, he became the successor of the deceased Lubote and was awarded the title of master and received a salary of 160 rubles. Novgorodov survived seven tsars and tsarinas, and he died in 1767 in poverty during the early reign of Empress Catherine II. The fate of Ivan Noskov and Samoilo Novgorodov was similar to that of many talented Russian instrument makers and under-awarded compared to foreigners.

The expansion of the factories

In 1769 the Petersburg factory for medical instruments moved to a stone building [7]. Simultaneously in Moscow, Tobolsk, and later in 1799 in Kherson other factories opened. Around 1800, four factories existed. In the factory in Moscow worked one master, six apprentices, 13 students, and eight employees; in St. Petersburg two masters, eight apprentices, 23 students, and 14 employees; in Tobolsk one apprentice, three students and three employees.

Looking at these numbers, it is noticeable that in the smaller cities Tobolsk and Kherson no single master instrument maker worked, there was only one master instrument maker even in Moscow.

In 1792 a two-level stone building was constructed and became in 1796 the factory for medical instruments in Saint Petersburg [7]. Most of the labour had to be done still by hand and by the light of tallow candles, which required tremendously high skilled artisans. The instrument makers' core was still the inhabitants of the Aptekarsky settlements: the children and grandchildren of the founders of the production of Russian surgical instruments. The circumstances at the working place hardly changed; they still worked from dawn till dusk and under other excruciating conditions. Yet, it did not worsen the abilities and talents of these craftsmen. However, their hands created the most beautiful surgical instruments, made of silver and steel, fulfilling the domestic surgeons' wishes and needs.

Foreign masters and Russian craftsmen

In the case of Meditsinskaya Kantselyariya, the records of orders continued with the individual craftsmen's name (instrument maker), like Novgorodov [21]. Other masters were Van Dengivel, Stepanov, and Novgorodov, who worked in the eighteenth century's fifties and sixties in Moscow. The delivery of orders was usually on a decree of "His Imperial Majesty".

The range of instruments was different, but the sets mostly were made for military purposes. In 1755 master Van Dengivel made an anatomical

set consisting of 1 straight incisional scissor, 2 incisional knives, 1 large and 1 small scalpel.

During the later reign of Tsarina Catherine the Great (ruling period 1762–1796), Russian born scientists were increasingly appointed in important positions instead of foreign doctors *medicinae*. Among others I.V. Protasov, K.I. Shchepin, D.S. Samoilovich, who obtained their PhD-degree at the Leiden University in the Netherlands. Catherine made significant changes in the management of medical affairs in Russia [6, 26]. In 1763, the *Meditsinskaya Kantselyariya* was transformed into the *Meditsinskaya Kollegiya* (Medical Collegium) with extended powers among others the right to confer the degree of doctor of medicine.

Pavel Condoidi, a born Russian with Greek roots, an alumnus of the Leiden University and head of the *Meditsinskaya Kollegiya*, appointed Samoilo Novogorodov as the master instrument maker of the *Meditsinskaya Kollegiya* in Moscow [6, 7]. Since then, the factory and workshops in Saint Petersburg expanded. In 1756 in the factory worked in addition to the Dutch master Van Denguin already seven artisans, like the journeyman/apprentice Semyon Kobelev, the students Stepan Semenov, Peter Noskov, Vasily Stepanov, and Artemy Pleshkov. New buildings for the workers and forges arose, and new equipment, made in six English factories, were purchased. The cases of surgical instruments expanded with new ones and the old ones were repaired. In 1760 A.I. Cherkasov, not being a doctor, became the successor of Condoidi. He was very dedicated to the development of medical instruments and surgery in Russia. The production of surgical instruments steadily grew together with the demand for military medicine.

Machine technology and Russian steel

In the 18th century, Russian steel was used for making surgical instruments, but at the beginning of the 19th century, it was replaced by the cheaper British steel [7]. Napoleon imposed on Russia a continental blockade of England over the Tilsit peace in 1807, and Russia was urgently forced to seek a replacement for the English steel. The growing domestic market necessitated a local industry. Factories and workshops superseded the unproductive employees and machine technology was upcoming, also in the instrument factory on Apothecary Island. Peter Murinov, a senior master and a talented technician and organizer, put an end to the technical backwardness. He enlarged the factory's equipment with turning, polishing, drilling, drill rigging, ploughing, drawing, and other machines. But the low productivity of equipment, driven by the hands of disabled soldiers, increased production costs but did not increase surgical instruments' production. The machine technology required a mechanical engine, and so a steam engine with a capacity of 15 horsepower was purchased in the

twenties of the nineteenth century. It was one of the first steam engines in an industrial enterprise in Saint Petersburg.

The factory became a laboratory for the development of high-quality steel [7]. Even before the Napoleonic Wars in 1812, the factory expanded with a building containing eight forges where experiments were conducted, and high-grade steel was formed into medical instruments. Semyon Badaev, a talented self-taught steel-maker, but a serf, volunteered to melt steel for instruments with a quality higher than English. He had the support of Murinov. However, the smithy equipment of the factory was not very suitable for this purpose. The first smelting, produced in 1809 on a simple blacksmith's forge, did not yield the desired results. Badaev continued his experiments and succeeded to make the looked-for quality steel and solved the problem. Badaev's steel had remarkable qualities: the hardness and strength combined with high viscosity and welding ability. During polishing the surface became a mirror and an anticorrosion surgical instrument, which was very valuable. At that time the nickel plating technology was not yet invented.

The best masters of the factory Peter Murinov, Peter Akinin, and Andrei Tugarinov made 2 amputation knives, 2 scalpels, 2 lancets, 2 razors, and other tools from Badaev's steel. The director of the factory, Sapolovich, endorsed the possibilities of steel production. Similarly, the Mint (now still existing) made from this steel punches, cutters, drills, chisels, springs, rakes, and other tools. In 1810 Badaev, being still a serf, wrote a petition to Tsar Alexander I, who decided that the Ministry of Finance had to pay 1800 rubles for the release of Badaev from his serfdom. Badaev was awarded a golden order of Vladimir. He was paid a lump sum of 500 rubles and was sent to the Ural. Badaev tirelessly improved the steel and samples, which were sent to the factory in St. Petersburg. He died at the age of 69 in 1847.

The merger of instrument making and teaching

In 1786, both medico-surgical hospital schools were separated and converted into independent medico-surgical schools (the Bidloo school in Moscow and the navy and land force hospital school in Saint Petersburg). In 1798, 12 years later, Moscow and St. Petersburg's medico-surgical schools had been renamed to Imperial Medico-Surgical Academies.

Tsar Aleksander the First (reign 1801–1825) instituted further far-reaching reforms for healthcare management and abolished the *Meditsinskaya Kollegiya* in 1802 [26, 31, 34]. The governance of civil medicine became the responsibility of the Ministry of Internal Affairs. Military medicine became the Ministry of Defense's commitment, and medical education manage-

ment was transferred to the Ministry of National Education. The Moscow Medico-Surgical Academy existed until 1804 [31, 34]. Not only were its 45 students assigned to the Imperial Medico-Surgical Academy in Saint Petersburg, but also all the medical instruments and the library.

The Petersburg Academy played a significant role in training doctors. In 1808, it consisted of 260 students, 12 departments, 3 own clinics. The Imperial Medico-Surgical Academy was also closely connected with the development of medical instruments produced in the factory on Apothecary Island [21]. The president of the Academy, the Scotsman Baronet James Thomas Willie, was actively involved in the factory.

Expansion of the Saint Petersburg factory

After 1807, the Petersburg factory again began to expand its production [7, 21, 22]. The form of the chest altered, and the variety of the surgical sets changed. Willie created in 1808–1810 for the army the following sets:

A regimental chest with surgical instruments of modern design

- a small box with one removable board; on the board and the bottom were placed 19 surgical instruments, exclusive a copper turnstile, flexible catheters, probes, bougies, silk, Gomborg ointment, and as an example some pierced splints, all placed in individual compartments, and with whalebone with a cord under the lid. Every instrument had a number.

A tiny battalion case/kit with a strap and worn over the shoulder:

- it contained 10 surgical instruments also numbered. The set also included flexible catheters, bougies, etc. These instruments were reproduced by private Russian instrument makers according to new models made by and bought from the Englishman Vrun. The sets had to be controlled by Sapolovich, the director of the factory [21, 22].

In 1811, along with the medical pocket kits, the factory produced new instruments and applications for the city hospitals. New devices were developed for bloodletting; cataract; pulling teeth; perforation of the respiratory throat; extraction of foreign bodies from the throat; the release of accumulated water in patients; the celiac joints; the release of urine; retain abdominal hernias; amputation of extremities; reviving the drowned. Simultaneously, the factory produced, by special order, needles to perforate the eardrum of the deaf.

In the same year, the factory made more than 300 kits for regiments, battalions, paramedics, and many different instruments. Including bloodletting equipment, lancets, scalpels, scissors, tweezers, dental wrenches, tongs and forceps, probes, nose pliers, knives, silver catheters, trocars, saws, tourniquets, chisels, bandages,

splints were made. The medical instrument factory earned with only 30 instrument makers the considerable amount of almost 37.000 thousand rubles. In 1828, for example, on the value of the production of 51.136 rubles, the profit was 11.799 rubles. On average of about 20% profit was gained on the cost of the output.

As chief medical inspector of the army, James Willie was involved in the war against Napoleon and saw a great need for surgical instruments [7]. During the Napoleonic War George Brown, owner of a private factory for medical instruments, and Willie received the lion's share of the orders to produce surgical instruments for the army. They were generously paid for the orders. Remarkable was that the quality measure for acceptance was made by Brown and approved by Willie. Consequently, despite the urgent need for these instruments, they were, due to uselessness, not used and written off. Willie protected his countryman Brown. Hence, his reputation at the Ministry of Internal Affairs was not affected. Willie was still the director of the instrumental factory and only interested in commercial operations. But in the end, this resulted in a complete collapse of the factory. The dynasty of instrument makers turned against Willie and started an impeachment. The Minister of Internal Affairs fired him and consequently ended the career of George Brown in Russia unexpectedly.

Among the masters of the factory were prominent specialists like Peter Murinov, Peter Akinin, Andrey Tuganov, Peter Trifonov, Alexey Evstratov, Yakob Harin, and many others. The instruments, trimmed with gold, silver, tortoiseshell, ivory, mother of pearl, black, and palm wood, were amazingly done with technical perfection and beauty. Rumours of the unique art of the instrument makers reached the royal court. On request of Alexander I the factory also produced razors decorated with gold and silver with cuttings made of tortoise and ivory; scissors for cutting paper, nails, and hair; knives for table and pen and various artistic trinkets. The Tsar gave them away as relation presents to foreign monarchs, who loved these gifts.

The hardships of the past were unchanged. Labour was hard in unhealthy circumstances and with a low salary. The working day lasted from six o'clock in the morning until eight o'clock in the evening. In general, the people were weakened by the exposure of sudden changes in temperature with frequent transitions from heat to cold and back again, inhalation of fine dust consisting of different metal particles, that caused breast, lung, and larynx diseases. The mortality of the workers was quite high, which began to threaten the production.

The Imperial Medico-surgical Academy in Saint Petersburg (now the S.M. Kirov Military Medical Academy) and the instrument factory were placed in 1838 under the Ministry of Defence's roof [7, 21, 34].

The new rule for the factory

The Ministry restored the weakened connection between the factory for medical instruments with the Imperial Medico-surgical Academy [7, 21, 34]. Again, the leading surgeon was appointed as the director of the factory. The factory's close relationship with the Petersburg Medico-Surgical Academy surgeons culminated officially in the rule that the leading surgeon of the Academy also became the head of the factory [7]. The first appointed head of the Academy was the leading surgeon Y.O. Sapolovich. He played a decisive role in the further development of the factory, also during the French-Russian War of 1812. Napoleon's invasion in Russia demanded even more hard work. When the French approached Moscow the total production of instruments came entirely down on the factory's shoulders in St. Petersburg. To ensure a trouble-free supply of medical and paramedical instruments, armourers from the city of Tula and freelance instrument makers were attracted. After the Napoleonic War, while being in Paris during 1814–1815, Russian doctors carried out complex operations in hospitals with their own Russian made medical instruments.

The management of Buyalsky

In January 1829 Ilya Vasilyevich Buyalsky, an anatomist, surgeon, and clinician, who was technically skilled at the operating table, was appointed head of the factory for medical instruments [7]. Despite the fact that the factory (or rather, the individual masters of the factory) produced first-class, artistically decorated instruments, the factory's state was unfortunately far from brilliant. As a good manager, Buyalsky was concerned about the improvement of the products and sought to keep the costs low. He introduced the specialization of artisans, which allowed for the growth of the art and work and increased productivity. Since 1829 the income increased from 12,330 rubles to 97,713 rubles in 1835. The Petersburg factory could fully meet the demand of the Army, the Navy, and the civilian medical faculties. Therefore the Moscow factory was closed, and the best masters moved to Saint Petersburg.

Buyalsky immediately proceeded to recover the factory and renewed the appointments of the talented junior craftsmen Peter Potapov and Alexey Zavyalov. He concluded that 35 of the 67 craftsmen were useful. He set up a drawing class similar to Nicolas Bidloo did a century earlier. Possibly he simply duplicated Nicolas Bidloo because he had access to his heritage [1, 6]. At the factory, the young students learned how to draw, especially surgical instruments [7]. He acquainted the students with how to use a ruler, a triangle and compass, and taught them the names of lines and angles. Thus, Buyalsky was able to select the best capable students for this excep-

tional artwork. Classes took place twice a week. Because the Ministry had refused to release money for drawing, Buyalsky purchased materials at his own expense. Within two years, 40 skilled instrument makers were trained, thanks to these classes. He also took care of training artisans for wood processing, case-holders, bandages, silver, and gold. To this end, seven young students of the factory received three years of training to become free masters. He also established free education at the Aptekarsky Island school for the children of, among others, craftsman Karpov, Afanasyev, Trofimov, and Zavyalov. The latter was an excellent, skilled master of making the most delicate and complex surgical instruments.

The production significantly increased in quantity and quality. Potapov and Zavyalov worked as master instrument makers on sets for, among others, eye operations, trepanation, and pocket sets for surgeons. The subtle eye instruments were furnished with pearl handles. A master studio for pewter was established to produce pewter bores, throat syringes, large enema syringes, and others. Also, it widely began to make silver and gold instruments by using Dutch ducats.

Buyalsky created a spatula for pushing the entrails when sewing the abdominal wound, which still bears his name [7, 33, 35]. He proposed a silver turnstile to stop bleeding, a syringe for blood transfusion, an aneurysm needle, a screw rocker, and a special spoon for scraping the uterus. He perfected the lithotome with a particular head's attachment to preclude the risk of a wound accident. He bought a detached house next to the Botanical Garden and lined up lathes in it. Here, the tinwork was produced for pharmacy and helminthes, other eye-care cups, and various syringes, used for nursery, applications for the uterus, throat, and with blunt ends for wounds. He also paid particular attention to the improvement of surgical sets. He was directly involved in improving the old and creating new ones which were presented at the First Russian Exhibition of Manufactured Works, organized by the Ministry of Finance in May 1829 in St. Petersburg to promote the Russian manufactory industry [7]. The surgical sets were highly appreciated. After the exhibition, they returned to the factory and laid the foundation for the factory's museum. Buyalsky gathered an extensive collection of instruments, using them as examples for mass production. He ordered instruments in Britain, Austria, Germany and from in that time famous instrument maker Joseph-Frédéric-Benoît Charrière in Paris. In his collection of half a century, he sampled about 1400 different anatomical and surgical instruments.

In June 1835, the Second Russian Exhibition of Manufactured Works was organized in Moscow. Here the factory demonstrated its newest sets of instruments, including sets for blood



Fig. 5. Surgical pocket set that belonged to Nikolay Ivanovich Pirogov image 0022928, Museum of the Ministry of Defense of the Russian Federation, Saint Petersburg, Russian Federation. Reproduced with permission.

transfusion, and anatomy. The factory's contribution also included a special siphon for drawing poisons from the stomach and a set for lithotripsy (fragmentation of stones in the bladder). This set consisted of 20 different instruments of an original, sophisticated design for which Nikolay Tyabin had been appointed master instrument maker.

Nikolay Ivanovich Pirogov

Nikolay Pirogov (1810–1881) defended his doctoral thesis in 1831 and was appointed in April 1836 full Professor of theoretical, operational and clinical surgery at Dorpat University (now Tartu in Estonia) [7, 15, 25]. The Ministry and the Imperial Medico-surgical Academy (now the S.M. Kirov Military Medical Academy) in Saint Petersburg were searching for a new Professor. After a five years' service in Dorpat, Nikolay Pirogov was appointed on 3 March 1841 as Professor of Hospital Surgery and Applied Anatomy at the Medical-Surgical Academy and chief surgeon of the Second Military Landforce hospital (with 1000 beds) in Saint Petersburg. He also worked as a consultant-surgeon in three other hospitals in the city and ran a busy private practice.

His appointment as Professor at the Medical-Surgical Academy went along with that of director of the instrument factory. Under Pirogov, a process started through functional redesign of existing instruments and development of new instruments, resulting in a targeted instrument evolution.

With his characteristic curiosity and energy, Pirogov proposed changing the first-aid instruments and pocket kits for the surgeons radically within two months [7, 15, 25]. Before he

started to describe each instrument, he outlined the principles for a good functional medical pocket set, which should at the first place include instruments for bloodletting, opening abscesses, carrying out coverings, sewing up wounds and extracting foreign bodies; and secondly, instruments necessary for such procedures are strangulated hernia, ligation of arteries, tracheotomy, catheterization, etc.(Fig. 5).

Albert Kleinhans from Würzburg, a German, was the master instrument maker when Pirogov was appointed [21]. Unfortunately, he died of pneumonia in 1843. Pirogov and the successor of Kleinhans, Henry Mersch, introduced new instruments with new shapes, controlled the existing instruments, and prepared chests and cases. Together they dramatically improved the mass production of the factory. Pirogov was for 15 years (from 1841 to 1856) the technical director of the factory [32]. It was a period of flowering of the factory.

Pirogov insisted on the accuracy and purity of the instrument. However, it also had to have an elegant shape and had to be easy handled. He also wanted this for the accompanying accessories [7, 23]. He regarded these basic principles and critical conditions necessary for any surgical instrument, as well as for the accessories. Pirogov highly valued the talent and art of the instrumental craftsmen. He encouraged and advanced them. When in 1842 the Ministry of Internal Affairs requested for an instrument master, Pirogov recommended the senior pupil Vasily Kochergin and gave an excellent evaluation of his instruments [7]. This review, of course, played a decisive role.

Pirogov was very critical and paid much attention to each instrument based on his own experience and emphasized the design of instru-

ments should be for the surgeon's convenience. For example, tweezers, used for twisting arteries during ligation, should be light so the hand could hold it for longer without becoming tired. A surgeon should also be able to handle the tweezer without the help of an assistant. He designed and (re)developed samples of many other surgical kits for various applications, including anatomy, maternity, veterinary, and instruments for anesthesia [14, 16]. He was not satisfied with the kits for surgeons or paramedics. He went to the factory and urged the workers that every delay in treatment implied danger to a patient's life. He concluded that the pocket sets for a feldsher should be twofold. First, it must include instruments for surgical proceedings, done by paramedics in hospitals. And, secondly, tools for small operations performed by doctors during their visits to hospitals. Under his leadership, Pirogov developed the factory and mastered several important medical sets for the military medical service and private practice [7, 14, 25, 32]. Since late 1841 till 1844 Pirogov already revised all instruments. He also developed new surgical sets like a paramedic pocket set, a surgeon pocket set, a resident pocket set, battalion set, regiment set, an anatomical regimental set, a hospital set, and an anatomical hospital set. Pirogov stood at the basis of medical devices' production, among others the Weiss's devices for pumping poisons from the stomach, large and small lancets, large and small bloodletting bowls.

In March 1846 Pirogov went for six months abroad. He used his sabbatical to purchase different devices, instruments and to visit anatomical institutes. When he returned to St. Petersburg, he started to investigate the use of ether and chloroform in surgical practice. These experiments were crowned with complete success. Pirogov created his own instruments for anesthesia and strongly modified the inhaling apparatus for anesthesia by Joseph Frédéric Benoît Charrière [14, 24].

His efforts to improve surgical instruments were not limited to the design of instruments. As a technical director, he participated in examining each surgical set, considered to be accepted merely if there was an act signed by him.

Pirogov created his famous "pack set" especially for his work in the field, which he used during his journey to the Caucasus in 1847. This set functioned well until antiseptic and aseptic agents emerged in surgery, but then it was just necessary to make small adaptations to the set. These chests produced by the factory since 1850 were not only for the military but also for civil purposes. However, the number of sets for civilian uses was tiny. All these sets were reviewed and approved by the authorization commission with members as Arendt, Schlegel, Florio, Salomon, Naranovich, and Dubovitskij. The work of this commission lasted until 1891.

In 1852 Pirogov made some small changes to the regimental chests. These chests again un-

derwent again some changes in 1874–1878 and became corps chests. For many decades the army, navy, and civil medicine of Russia were supplied with sets of Pirogov's instruments. Only the introduction of asepsis required a change in the stacking of the sets, and the development of abdominal surgery asked for newly designed instruments.

As Pirogov was the creator of the osteoplastic operation, the forefoot amputation, which carries his name [14]. Therefore, he was interested in a lightweight prosthesis and established an orthopedic department for manufacturing prostheses and bandages produced following his instructions.

In 1854 the War Office commissioned Pirogov to consider and evaluate a set of surgical instruments made by one of the most famous German companies [7]. He carefully studied them but was not satisfied. He considered them rough and carelessly made, outdated, not applying the latest improvements and requirements of operative surgery and not modern.

The instrument factory coped with new instruments, since the demand for production was already very high, especially considering that in 1861 the Tobolsk factory was closed and the supply of the Siberian region was also entrusted to the St. Petersburg factory. In 1868 resection sets were introduced, set for operation on the army corpses, consisting of 126 instruments. Later, in 1875 sets for field hospitals were created.

Pirogov, during his 14 years as director, had put the factory on the right track for 50 years. After the resignation of Pirogov, Professor Naranovich took his position until 1865, and his successor was Karpinsky, an associate professor of the Medico-Surgical Academy, who was succeeded in 1869 by Shcheglov. Until 1890 nothing changed.

The instrument factory was known not only in Russia, but also abroad [7]. Daily the factory received many different kinds of surgical instruments for correction, and for replacing. Daily, essential and significant shortcomings of the instruments were detected. Following the instrument's actual need and purpose, the external form, the decoration, and styling of the instruments improved to a high degree of perfection.

When Pirogov joined the Crimean War he left the Instrument factory, although formally still listed until 1856 as a professor at the Academy and as the technical director of the plant. When the Crimea War was over, Pirogov returned to Saint Petersburg, but he was deeply shocked by the experiences in Sevastopol. He could no longer put up with the deadening situation of the bureaucratic world. He decided to give up his professorship at the Medical-Surgical Academy and his other posts, including his position at the instrument factory in 1860.

The factory under the leadership of Pirogov participated in Russian exhibitions in Moscow

(1843) and in Petersburg (1849), where they received excellent rates. Among the factory exhibits were new tools developed under Pirogov, including tonsil instrument for cutting almond-shaped glands. The instrument factory still exists and was later named Krasnogvardeets (Red Guard). The factory is inseparable from the history of medicine development in Russia, and many Russian surgeons were factory managers [7, 15]. It is also very well recognized that the close collaboration between physicians, instrument makers, and factories was crucial, not only for physicians' comfort but also for the quality of healthcare in total.

Conclusion

Peter the Great did not only pursue a policy of improvement of medicine but also of the manufacture of medical instruments. The medical students of the Bidloo School had drawing and design lessons, for, among others, the production of instruments. They also had to manufacture their own instruments. Even during their further studies at the University of Leiden in the Netherlands, they would make instruments as part of their exam. Unlike Holland, in Russia, barber-surgeons received their instruments by the Apterkarskiy Prikaz from the factory or by order. The Apterkarskiy Prikaz often changed its name in the 18th century.

The development policy for instrument making and medical doctors over 100 years gradually merged as the development of medicine in Russia matured. By 1800 there were three renowned medical training institutes, including the Imperial Medico-surgical Academy that was the continuation of the Bidloo School in Saint Petersburg. Likewise, a well-trained dynasty of instrument makers had emerged in Saint Petersburg that produced functional and beautiful instruments.

Technological developments often go hand in hand with innovation in medicine [29]. In 1808 James B. Willie, a Scotsman was appointed head of the Medico-surgical academy and head of the instrument factory. During the Napoleonic War together with his countryman George Brown, an instrument maker, Willie became even more involved in instrument manufacturing. Both than had only personal gain in mind and unfortunately the quality of the instruments became of secondary importance. Their behavior almost led to the factory's demise.

After the Napoleonic war, Tsar Alexander I decided to appoint the Medical-Surgical Academy leading surgeon as director of the factory. The first person to hold the position as such was Ilya Buyalski, a well-trained physician. He reintroduced the drawing and design lessons of Nicolas Bidloo to recognize talented instrument makers. He initiated the innovation of instrument making and gradually, the factory flourished again. Niko-

lay Pirogov, the successor to Buyalskiy, was a great innovator in surgery and anatomy, and after the introduction of anesthesia on a large scale in Russia in 1847 of anesthesia apparatus. Pirogov as an innovator, was in great need of precise instruments. Together with his instrument makers and factory workers, he designed suitable lancets, saws for both amputations, and created deep-frozen sections of the human body for his three-dimensional atlases and an inhaler for anesthesia with the possibility of controlling aeration during anesthesia. Many of these revamped instrument versions were exhibited at special fairs, which led to Russia even exporting abroad.

From an international perspective, French instrument makers pioneered surgery by designing instruments to enable surgical improvements. An example is the introduction of the screw action lithotrite, a suitable instrument designed by Joseph Charrière from Paris (1806–1876), later modified by Weiss in London [5]. British surgical instrument manufacturers were generally not very innovative in the design of their products. The typical surgical instrument was very conservative and fully exposed to the whims of their clients. In the second half of the 19th century, it was no longer necessary in Great Britain for surgeons to have their personal instruments [36]. In the mid-17th century surgeons, hairdressers, and students could already borrow medical instruments from Leiden University [13]. In Russia, the surgeon told the instrument maker what he wanted to make his medical instruments even better. We also encounter a 100-year influence from Leiden University when making instruments. Russia has undoubtedly not lagged behind Germany and the Netherlands in instrument making.

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