

Lina Stern (1878-1968) and the blood-brain barrier. A life between Geneva and Moscow

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ABSTRACT

Lina Stern, an important neuroscientist and biochemist from the Soviet Union, dedicated more than 50 years of her life to research, beginning at the University of Geneva, and from 1925 directing the Institute of Physiology in Moscow. Although she was initially interested in oxidative metabolism, from 1918 Stern mainly researched neurophysiology; she pioneered the study of barrier mechanisms in the human body, especially the blood-brain barrier, which she named the “haematoencephalic barrier” in 1921. She gained recognition and distinctions in the Soviet scientific media, where she also studied such topics as longevity, the sleep-wake cycle, cancer, and the treatment of traumatic shock and tuberculous meningitis. In 1948, she was persecuted for being Jewish and a member of the Jewish Anti-Fascist Committee: Stern was imprisoned and exiled to Central Asia. She returned after Stalin’s death and resumed her research as if nothing had happened.

KEYWORDS

Anti-Semitism, blood-brain barrier, Lina Stern, oxidative metabolism, Stalinism, University of Geneva

Introduction

Lina Stern is a little-known figure in the fields of biochemistry and neurophysiology of the first half of the 20th century. Her early remarkable contributions were in the field of biochemistry, where she studied oxidative metabolism. She later came to focus on neurophysiology, studying barrier mechanisms in the human body, especially the blood-brain barrier (BBB), to which she assigned the name “haematoencephalic barrier” in 1921. In 1925, she exchanged the tranquillity of the University of Geneva for the adventure of a new life in Moscow, where she directed the Institute of Physiology and gained an important position in Soviet neuroscience. Based on the barrier concept, she used suboccipital puncture to treat several pathologies. Under Stalinism, she was imprisoned in 1948 and subsequently exiled to Central Asia. After Stalin’s death in 1953, she was able to return

and resumed her research work until her death at nearly 90 years of age.

The aim of this study is to present the life and work of this important neuroscientist, who is still little known in our days. To this end, we reviewed the literature on the subject.

Development

Between Liepāja and Geneva

Lina Stern was born on 26 August 1878 in Liepāja, in Curland, a province of the Russian Empire which now belongs to Latvia, in the region known as the Pale of Settlement, where Jews were permitted to live. She was the eldest of the seven children of a German-speaking Jewish merchant. For two years, she attempted to enter the School of Medicine at the University of Moscow,

but she was not accepted because she was Jewish and a woman. In 1898, Stern decided to travel abroad to start her studies at a more liberal University in Geneva; half of its students were foreigners, mainly Russian.¹

While she was a student, she started working in the department of physiology directed by Jean Louis Prévost (1838-1927), who introduced modern medical physiology in Geneva. In 1902, she published her first article on the internal secretion of the kidney, which received an award from the university.¹ In 1903, she earned her doctorate in medicine, with a dissertation on the motor function of the ureter.²

Given the lack of professional opportunities in Switzerland after she finished her studies, she went back to Liepāja and passed the Russian examinations for the title of Doctor of Medicine. As she prepared to start her professional career, Stern received a letter from Prévost inviting her to become his assistant at the department of physiology in Geneva¹; she returned to the Swiss city in 1905 and became an assistant in the physiology laboratory and “privat-docent.”³

At that time, she mainly researched cellular respiration and intermediary metabolism. She published several studies on the topic, collaborating with her superior, the Italian researcher Federico Battelli (1867-1941), who succeeded Prévost (his father-in-law) in 1913.³ They also investigated the effects of electric discharges on the heart and on the central and autonomic nervous systems, as well as the physiology of the blood.¹ In the laboratory, they studied oxidative fermentation and described several steps of the Krebs cycle; Hans Krebs acknowledged their contribution when he completed it 20 years later, in 1937. In 1913, Lina Stern gave a presentation on oxidation at the 9th Congress of Physiology in Groningen (the Netherlands). Furthermore, she worked intensely as a university lecturer from 1906.¹

In 1918, at the end of the First World War and at the request of Prévost, Stern was appointed associate professor and made responsible for a new department of medical biochemistry, called “physiological chemistry” at the time. Although her salary was not increased, she was at least able to choose her collaborators and to sign as the main author in the research papers she published.³ Stern was the first woman at the university, and one of the first in Europe, to become a professor.⁴ After becoming head of department, her scientific interests turned toward the physiology of the central nervous system



Figure 1. Lina Stern in Switzerland.

(CNS), inspired by her friendship with Constantin von Monakow (1853-1930), the Russian neurologist and anatomist, professor in Zurich, and founder of the Swiss Neurological Society, who conducted extensive work in the fields of neuroanatomy and neuropathology.¹ At that time, Stern also became interested in the physiology of the cerebellum and in extracting samples from organs to study their biological activity.^{1,3} She developed a method, which she later perfected in Moscow, of extracting metabolites from several organs and tissues, and obtaining hormonally active agents.⁵

She was a member of the German Academy of Sciences Leopoldina and received funds from the Rockefeller Foundation for research and teaching, which enabled her to train scientists from several countries in her



Figure 2. Lina Stern at the laboratory in Geneva.¹

laboratory.⁴ She also earned additional income as a consultant to pharmaceutical companies.⁵

Among the international scientists who worked in her laboratory, we can mention the Spanish pharmacist Leopoldo López, who was awarded a scholarship by the Council for the Extension of Studies and Scientific Research to study cellular oxidation during the 1916-1917 period.^{6,7}

The blood-brain barrier

Toward the end of her time in Geneva, she started studying the physiological mechanism which ensures the stability of the brain's internal environment and its protection against the threat of noxious external influences, mainly substances from the blood. She named

this mechanism the haematoencephalic barrier (today, the blood-brain barrier): a barrier between the blood and the tissue of the brain. She later applied the concept of barrier mechanisms, based on the permeability of blood capillaries, to all the organs of the body (histohaematological barrier).^{5,8-11}

This theory was based on the hypothesis that in order to function properly, every organ needs to be supplied by a specific fluid other than blood plasma. The composition of those fluids would be kept within more or less constant values by mechanisms, called the "milieu intérieur" by Claude Bernard or homeostasis by Walter Cannon, that determine the exchange between blood and the extracellular domain.¹² She used the designation "barrière hématoencéphalique" for the first time on 21 April 1921, during a session of the Medical Society of Geneva¹; the same year, the article describing the concept was published in a journal directed by von Monakow.^{2,8} In 1923, on the great Russian neuroanatomist's 70th birthday, Stern and her colleague Raymond Gautier (1885-1957) published all the results of their studies on the BBB, which were very well received.^{3,9-11} From this point, she always used the corresponding translation of the French term in her articles in English (haematoencephalic barrier), German, and Russian.¹

Until then, very few studies had been published on this topic, with those by Erlich, Lewandowsky, and Goldman being worthy of mention. Between 1918 and 1925, with the collaboration of Gautier, Stern injected various substances and stains into the subarachnoid space, cerebral ventricles, and blood. They demonstrated that the subarachnoid space is anatomically connected to the ventricles of the brain, and that the cerebrospinal fluid (CSF) in the ventricles and in the subarachnoid spaces is identical, and necessary for transporting chemical substances to the ventricles. Not all blood substances reach the brain, but all the brain substances do reach the blood. Immediately after injecting substances into the blood, they would perform a bilateral nephrectomy to avoid elimination by the kidneys. They subsequently took CSF samples to verify whether there was staining. Among the substances able to penetrate the BBB, they found bromide, thiocyanate, strychnine, morphine, and atropine, whereas iodide, ferrocyanide, salicylate, curare, epinephrine, eosin, and fluorescein were absent. Stern and Gautier established a correlation between the penetration of certain substances into the CSF and their effect on the CNS. They also showed the immaturity



Figure 3. Lina Stern at the 13th International Physiological Congress in New Haven (Connecticut), 1929.²
Figure 4. 14th International Physiological Congress, Rome, 1932. Lina Stern and Ivan Pavlov, third and fifth from left, respectively.¹

of the BBB in the developing brain and suggested that the BBB's functions included protecting the brain from toxic agents, supplying substances for metabolism, and maintaining the brain's internal environment.^{1,2,9-11}

Return to the USSR

Lina Stern's political ideas were influenced by the circle of Russian émigrés living in Switzerland. She was acquainted with the relatives of Plekhanov, the founder of Russian Marxism and Lenin's main mentor. She was also a friend of Aleksei Bach (1857-1946), founder of Russian biochemistry, and Boris Zbarsky (1885-1954), who was made responsible for the care of Lenin's mummified body. They had both lived in Switzerland and later returned to the USSR.^{1,5}

By the time she decided to return to the Soviet Union, Stern had already made a name for herself in science and enjoyed economic and academic success in peaceful, bourgeois Geneva. She unhesitatingly changed everything for a new life in a new environment, in a society which was building socialism, where peace was the last thing one could expect. Her friends in Geneva

and the West tried to dissuade her, predicting that she would be exiled to Siberia, but she did not yield and in 1924 immediately accepted the proposal by Aleksei Bach, who sent her an official letter offering her the vacant position of head of the Department of Physiology at the Second Moscow State University.^{2,5} Among her colleagues, only Prévost supported her decision.¹

During her last days in Geneva, her relationship with Battelli, which had never been easy, deteriorated, which made her return to the Soviet Union easier. Battelli even forbade her from taking documents related to her research in Geneva with her. Stern tried to recover them during her subsequent trips to the Swiss city, which she made almost annually at the beginning, and even during her final trip in 1947.³

She arrived in Moscow on 31 March 1925, aged 46, to start a new life totally dedicated to science. During her early years there, she taught a course on physiology and biochemistry, organised two scientific laboratories, and published 49 articles in Russian and several other languages. On 1 April 1929, with the help of the People's Commissariat of Public Health, she founded the

Institute of Physiology in Moscow and was appointed as its director. The Institute had a large staff and departments of physiology, biochemistry, morphology (pathological anatomy), and electrophysiology; and a metabolic laboratory. By 1930, her group presented 14 communications at the 4th Soviet Congress of Physiologists; these communications particularly addressed the BBB and cellular oxidation.¹

Lina Stern always maintained regular contact with her Western colleagues. Until 1935 she travelled abroad every year to attend international conferences and to maintain her friendships with colleagues.^{5,13} She attended international congresses of physiology in Boston (1929) and Rome (1932) with Pavlov and other Soviet scientists, although her personal relationship with the great neurophysiologist was not good due to mutually incompatible personalities. Stern actively participated in the organising committee of the 15th International Physiological Congress in August 1935, held in Moscow and Leningrad and presided over by Pavlov, who was opposed to the event. Some of the most important international scientists accepted Stern's invitation to visit the Institute of Physiology in Moscow, donating research equipment and collaborating in staff training.^{1,5}

By that time, Ivan Pavlov was the leading figure in Soviet physiology, and most of the physiologists and psychologists teaching or researching at higher education centres were students of his.⁵ According to Julián Fuster, a neurosurgeon at the Burdenko Institute in Moscow, Pavlov rejected studies on isolated cells, muscles, and nerves, since he considered them too abstract and despised the articles published on the topic: "If we work on this, we will never move forward." He preferred to experiment with living animals, with no narcotics, and created conditions in which he could study the function of the entire organ or the organism while it was in operation.¹⁴

In the prevailing environment of political and scientific uniformity in the USSR, an "alien" such as Lina Stern did not receive a warm welcome. Those meeting her for the first time were not attracted by this short, corpulent person with her short, grey hair. She was not fluent in Russian, which she spoke with a strong French accent, and could speak French, English, German, and Italian, but not Yiddish. Her personality and personal relationships were contradictory. She arbitrarily alternated between a tone of confidence and a mood of

distrust, and when interacting with her subordinates, she would use a mixture of democratic and despotic tones. She combined a diplomatic attitude with an aggressive frankness reflecting a total lack of tact, which earned her enemies in a short time.⁵

When she started organising her work at the Department of Physiology at the Second Moscow State University, she had to begin by selecting the research staff, prioritising equipment requirements, and organising courses with laboratory demonstrations and independent experiments. She needed inexhaustible energy and the support of her few but influential friends. Stern had to train her collaborators on the basic methods of physiological experimentation, starting with how to place animals on the table, followed by the administration of subcutaneous, intravenous, and intracerebral injections, and completing the training with more complex operations.⁵

She dedicated most of her time to research, especially studying the BBB, the blood-tissue barrier, and brain homeostasis. She conducted experiments in situations of physical exercise, hunger, emotional stress, and sleep deprivation, which demonstrated that the BBB works differently during the different functional states of the brain. Moreover, she discovered that the BBB plays a role in neuroendocrine signalling, neuroimmune and neuroinflammatory responses, drug metabolism, protection against neurotoxicity, and intracellular regulation in the brain.¹

Lina Stern was a pioneer in the study of sleep and wakefulness in the Soviet Union, publishing her first article on the subject in 1932. She was also interested in the question of longevity; based on experiments showing that maintaining cell metabolism extends cell life, Stern concluded that the blood-tissue barrier and intracellular homeostasis may play a crucial role in extending life. She published numerous articles and was interviewed by non-medical publications, so the general public was aware of her research.¹

In 1932, she was appointed a member of the Russian Academy of Sciences, becoming the first woman to achieve this distinction.⁴ In 1934, a book was published that paid homage to her 30-year career in science and teaching. Outstanding internationally-known figures participated in the book, including seven past or future winners of the Nobel Prize.^{3,15} That same year, she was named a "Distinguished Scientist of the USSR" and

received a car as a gift. In 1939, the Institute of Physiology became part of the structure of the Academy of Sciences; Stern was elected full member, the first female member in the USSR. A few years later, she became a member of the Academy of Medical Sciences. She enjoyed great scientific recognition and became editor-in-chief of the *Bulletin of Experimental Biology and Medicine*. Stern was included in the “eminent women of Europe” list and became the vice president of the Physiological Society of the USSR.¹ She was admitted to the Communist Party in 1939, and in 1943 received the Stalin Prize for her achievements in the study of the BBB.⁴ In an open letter to Stalin, published in *Pravda*, she donated the 100 000-rouble prize to the construction of a medical aeroplane, for which Stalin offered thanks in the same newspaper.¹

Personal life

With her distinctive sense of humour, Stern told Natalya, daughter of the anatomical pathologist Yakov Rapoport and his wife Sophia, one of Stern’s closest collaborators, why she became a scientist. She was the eldest of seven children and her father organised a *débutante* ball, during which her very pretty younger sister became the centre of attention of all the young guests, who invited her to dance and ignored young Lina. At that precise moment, she realised that she was destined to become a scientist.⁵

During her stay in Geneva, Stern had a relationship with B., a British teacher whom she almost married. Years later, she confessed Rapoport that B. had been her only real love, but due to his traditional English view of family and the place of a wife, he asked her to abandon her scientific career after the wedding. She ended the relationship and both remained single for the rest of their lives, loyal to their love. During her first years in the USSR, they would meet during her frequent trips abroad. Stern was frequently intolerant towards women working at her laboratory who were married or mothers, and got angry when they were distracted from scientific work by family demands, which she believed to be a betrayal of science.⁵

The Second World War

The year 1939 marked the start of a bad time for Lina Stern, with the Winter War and the German-Soviet Frontier Treaty, of which she disapproved. She believed

that the treaty would end in war, since no negotiation was possible with fascists. When a politician tried to explain it to her as a marriage of convenience, she answered by saying that even marriages of convenience have children, but that in that particular case, she could not imagine the offspring.⁵

In 1937, she had presented studies on the changes caused by traumatic shock in the CSF and the autonomic nervous system, with the subsequent increase in sympathetic activity.¹ During the Winter War, she developed a peculiar method for treating traumatic shock and performed the first experiments, even travelling to the front to monitor the technique. The method was based on the hypothesis that the BBB not only protects the nervous system against harmful substances but may also block the substances necessary to restore normal cerebral function. Her approach was to find formulations acting directly on the nerve centres, circumventing the BBB. She suggested injecting potassium phosphate directly into the cisterna magna by suboccipital puncture; in injured patients who did not respond to the treatment, she indicated direct injection into the brain.^{1,13} When Germany invaded the Soviet Union in 1941, efforts were made to raise awareness of the method, but it was not widely applied since it required sophisticated surgical techniques and yielded inconsistent results. Furthermore, it was not supported by the head of the Main Military Medical Directorate, Yefim Smirnov (who later became Minister of Health), or the head surgeon Nikolai Burdenko.⁵ In any case, the Soviet government had Stern’s techniques translated; they were published in prestigious English journals.^{13,16}

In his book on Soviet surgery, Julián Fuster lists Lina Stern among the great international researchers of traumatic shock and analyses the limited success of her suboccipital puncture method, which was used in several hundred injured Soviet soldiers in 1943 and 1944, with limited results.¹⁴

Lina Stern also recommended suboccipital injections for treatment of asthma, cardiac arrhythmias, tetanus, severe infections, hearing loss, alimentary dystrophy, peptic ulcers, arterial hypertension, eczema, and epilepsy. In most cases, this approach was inappropriate.^{1,4,13}

The Institute of Physiology was transferred to Alma Ata in 1941 and returned to Moscow in 1943.⁵ Stern was very active not only in the field of science, but also in public life. When the Second World War broke out,



Figure 5. The Jewish Anti-Fascist Committee. Lina Stern, fifth from left.

she published numerous antifascist articles, including an appeal to the International Federation of University Women in July 1941.¹

Tuberculous meningitis

She was more successful in her research into tuberculous meningitis. In the United States in 1943, the Ukrainian Selman Waksman synthesised the broad-spectrum antibiotic streptomycin, which was found to be very active against tuberculosis. In 1946, the parents of a 10-year-old girl with tuberculous meningitis asked Stern to help them. She managed to obtain the antibiotic in a short time despite its being included on the list of substances whose exportation required the special permission of the United States Congress. Streptomycin was injected directly into the cisterna magna and the girl recovered with hearing loss as the only sequela; this was the first case to be cured in the USSR. Bruno Stern, a brother of Lina's who lived in the United States, would buy the antibiotic with his own money and violate the law by mailing it to Lina. He was discovered, and lost his fortune before being forced to leave the country. Meanwhile, Stern, who for a time held a monopoly over the use of streptomycin in the USSR, prepared and delivered the drug to the medical centres on the condition that they use her suboccipital puncture method, and only for treating tuberculous meningitis.^{1,5,13} Her group treated 1452 patients with tuberculous meningitis, with 979 showing full recovery.¹

The Jewish Anti-Fascist Committee

Between 1941 and 1942, in order to obtain the support of Western countries, the Soviet government created 5 antifascist committees for women, scientists, young people, ethnic Slavs, and Jews. Lina Stern belonged to the committees for scientists, women, and Jews. In December 1941, Stalin appointed Solomon Mikhoels (1890-1948), director of the Moscow State Jewish Theatre, as head of the Jewish Anti-Fascist Committee (JAFC); members included the most distinguished scholars, physicians, scientists, and politicians of Jewish origin. The committee was successful, perhaps even too successful, in a country where the secret police suspected any citizen in contact with foreigners of espionage.¹

On January 1948, Mikhoels was murdered in Minsk by Stalin's secret agents and the JAFC was dissolved due to the distrust raised by the strong links established between the Soviet Jews and those from Western countries, something that Stalin himself had initially promoted.^{1,5}

Storm clouds

After the Second World War, Stalin triggered a wave of anti-Semitism, euphemistically called anti-cosmopolitanism.¹⁷ Black clouds gradually appeared over the head of Lina Stern and her arrest was preceded by several actions intended to discredit her as scientist, although it would be naïve to think that her arrest was caused by any scientific fault. During that time, such important scientists as the biologist Nikolai Vavilov saw their prestige destroyed, whereas other, more ignorant individuals such as Trofim Lysenko and Olga Lepeshinskaya, were acclaimed as geniuses. A determinant factor of Lina Stern's arrest was her membership to the JAFC, where she was a *rara avis*, with her Western manners and sharp tongue.⁵

The campaign against Stern started during the summer of 1947 with an article by Bernstein, who was head of the Biochemistry Department at the Ivanovo State Medical Institute, downplaying her research on BBB. In mid-1948, Bernstein published a pamphlet entitled "Against Simplification and Simplifiers." Bernstein was Jewish, making him more useful in an attack on Stern than as anti-Semite. On May 1948, a few months before the publication of the pamphlet denouncing Lina Stern's pseudo-teaching, she was suddenly summoned by the president of the Academy of Sciences, Sergei Vavilov, who informed her that the Institute was to be transferred

to Leningrad and that academy member Konstantin Bykov had been appointed director. Representatives of the new director came to pack the equipment, which was damaged beyond use, and the library, for transport to Leningrad. Her collaborators were disbanded and forced to find work with little promise, since many of them were also Jews.⁵

During the joint session of the Academy of Sciences and the Moscow Society of Physiology, Biochemistry, and Pharmacology, held on 5 October 1948,¹³ Stern was accused of anti-scientific practices, undervaluing Pavlov's ideas, disloyalty, and being in contact with the West. The speakers, all eminent scientists, were simple puppets in the hands of the Party leadership. Stern again showed her surprising personality, fearless but with dignity and self-respect, and answered the accusations with sharp, detailed replies.⁵ This session, which was only held to justify measurements that had been already taken, was the first of a series taking place in the 2 years previous to the notorious Pavlovian session (June-July 1950), the "Scientific session on the physiological teachings by the academy member I.P. Pavlov", where such top Soviet neurophysiologists as Orbeli, Anokhin, Bernstein, Beritashvili, and even Stern, who had been imprisoned for more than one year, were accused of anti-Pavlovian ideas, and were excluded from teaching and research.^{1,13,17}

No subtlety was needed in a debate organised from above and directed by Ivan Razenkov, president of the Society of Physiologists and member of the Academy of Medical Sciences. The show took place at the anatomy auditorium of the University of Moscow. All 6000 seats of the auditorium were occupied, and some people were seated on the stairs; the audience included many students. The audience's sympathies were with the victim, as they knew of her merits and were guided by the consideration that if the accused scientists were punished and vilified, then they must be right and deserve support; the audience rewarded Stern's supporters with deafening applause and yawned when her attackers spoke. The Society's directors were unable to achieve the necessary quorum for a conviction order, which was never issued.⁵

Imprisonment and exile to Central Asia

During the winter of 1948-1949, all Jewish public personalities related to the JAFK were arrested as American spies in times of war. Stern's arrest warrant

arrived on 27 January 1949.¹ Three avenging angels, two men and a woman, arrived at one a.m. at the apartment where she lived with her elderly maid Katya. The visitors informed her that Lavrentiy Beria had invited her for an interview. Stern innocently believed the invitation was to discuss some kind of business, and told them that it could wait until the next morning, as she was about to go to bed; the visitors insisted that it would be impolite to make the director of the NKVD (the People's Commissariat for Internal Affairs) wait. Stern then began dressing, with the help of Katya and the female agent, who carefully examined every piece of clothing before she put it on, and even accompanied Stern to the toilet.⁵

Lina Stern was arrested for belonging to the JAFK. She did not remember the specific charges against her or the misdeeds she was accused of. She knew little of the politics of that time; before her interrogators, she only admitted that she was never too interested in the Committee's affairs, that its activities were not her business, and that she had not been properly vigilant, although as a communist she probably should have been.⁵

During her interrogation, the interrogator set upon her with insults and obscenities; most of these words were unintelligible for Stern, who spoke little Russian and had never heard such vulgar language. This method was frequently used.⁵ In addition to the abuse and humiliation of the interrogations, the days spent at the Lubyanka prison must have been a great physical and mental pressure for Stern, an elderly woman who already had difficulty dealing with everyday problems without the help of her friends and maid. She was made to perform such tasks as cleaning the floor of the cell that she shared with three other women, or taking out the rubbish. During her 3 year, 8 month stay at the Lubyanka, she was frequently rebuked and ridiculed by her cellmates. The most terrifying episode was her transfer to the Lefortovo prison, in which she spent 20 days in a punishment cell, where she had to remain standing at all times. There, she became sick and suffered hallucinations. She later returned to the relative comfort of Lubyanka.⁵

The members of the JAFK were tortured, and all admitted their guilt. The judgement convicted them of being Jewish nationalists and American spies, and sentenced them to death, with the exception of Lina Stern, who was exiled to a remote area for a period of 5 years. On the night of 12 August 1952, the JAFK members were executed by direct order of Stalin; 13 of the 15 convicts

were shot, since one had previously died in prison. That night was known as the “Night of the Murdered Poets.” All their families, including small children, were deported to remote places in Siberia and Kazakhstan. We can speculate on the reasons why Lina Stern escaped execution. The most plausible hypothesis is that Stalin’s paranoia about his health played a crucial role in his decision. Some of her research dealt with longevity, and the Soviet leader was aware of this fact. This may have been one of the reasons for the exception.¹ She was sentenced to 5 years of exile in Central Asia, which she started in Dzhambul (now Taraz), in Kazakhstan. She was returned the money and jewels that were confiscated from her during her arrest, and permitted to use her bank account. Stern was not a very practical woman and found herself in a strange city, where she was fooled and her jewels were stolen. The prophecies of her friends in Geneva had nearly come true: while they had warned that she would be exiled to Siberia, she was finally sent to Central Asia.⁵

By the end of 1952, Rapoport got the first news from Lina Stern in the form of a letter sent from Dzhambul, where she gave him details of her whereabouts and asked for somebody to visit her. This was a call for help from an elderly woman in despair, who had never been able to manage everyday domestic tasks. It was also proof of her egocentric nature and her inability to understand the realities of other people’s lives and circumstances. Finally, her dutiful secretary Olga Skvortsova ventured to travel to Dzhambul, in spite of the potential consequences.⁵

After several requests, she was given paper and pencils at Lubyanka, and she systematically wrote a series of scientific articles for the general public, including her concept of barrier functions in the treatment of cancer.¹ Stern took these notes with her to Dzhambul, and by the time she returned to Moscow, they formed a thick package of hand-written pages dedicated to her favourite topic, the BBB. Yakov Rapoport read these texts later and was convinced of their lack of scientific value.⁵

In 1952, the anti-cosmopolitan campaign entered its fifth year of fanatic anti-Semitism with the launch of a new operation: “the doctors’ plot” or “murderers in white coats,” in which Yakov Rapoport, together with other eminent physicians, most of them Jews, was charged and arrested in January 1953 for conspiracy to murder the main Soviet leaders. During an interrogation after his arrest, Rapoport acknowledged his fight against

neurological despotism and his support to Lina Stern. Researchers accused him of contradicting Pavlov’s teachings, of being fervently opposed to the advanced science of the USSR, and of supporting Virchow and Stern’s reactionary teachings. After the death of Stalin, the new government acknowledged that the cases against the JAFM members and the “doctors’ plot” were setups. All the JAFM members were granted amnesty in 1953, and rehabilitated in 1958, but only Lina Stern survived.^{1,5}

Back to Moscow

After ten months’ exile in Dzhambul, Stern returned to Moscow in June 1953 and spent the first days at the home of Rapoport, whose wife Sophia had been her first collaborator. She was very depressed, as though recovering from psychic shock.⁵ In the mid-1950s, she was asked about how she was feeling and she innocently replied: “Well, of course, it is getting better: the epidemic has ended, but the quarantine continues.” To the question “why were you arrested, what were the charges?” she answered:

They charged me with espionage, nationalism and other serious issues; they made their judgement based on three articles. Each article carried a sentence of capital punishment, but on the basis of all three, logically, they condemned me to only 5 years of exile.¹

In Moscow, Stern returned to her two rooms in the communal apartment house on Starokonyushenny Lane, which had been sealed up during the intervening years. She also recovered her dacha, and her daily life gradually returned to normality. She had not been expelled from the Academy of Sciences, so she received the salary corresponding to her period of absence (500 roubles per month as academic member); this returned her to a prosperous economic position. The recovery of her political status was slower; she was re-admitted to the party in 1958, after her professional and scientific rehabilitation.⁵

After the interrogations, prison, and exile, nobody would have expected this 76-year-old woman to continue with her scientific work, but Stern always acted contrary to expectations. She never ceased to amaze, and returned to science with her well-known energy, with as sharp a mind as ever.¹

A special decision of the Presidium of the Academy of Sciences permitted her to return to the laboratory; she

was afforded the necessary assistance, with the return of her former team. She became head of the Physiology Laboratory of the Institute of Biophysics of the Academy of Sciences of the USSR, where she worked until her death.^{2,5} In 1958, she authored a review of the problems related to the BBB, which included a subtle statement in the introduction: "Our scientific research was interrupted in 1948." The review was a detailed analysis of the history of the research on this subject, particularly of what had been published over the past ten years in the Western literature.¹⁸ She resumed contact with her foreign colleagues and organised several conferences on barrier mechanisms in the human body, with the participation of the most prestigious international physiologists and neurologists. Her personal files at the Academy of Science include more than 1000 letters. Among them, there is regular correspondence with Maurice Battelli, son of Federico and grandson of Prévost, whom Stern considered to be family. In 1960, she was awarded the degree of *doctor honoris causa* by the University of Geneva.¹

Stern died on 7 March 1968, several months before her 90th birthday, and was buried at the Novodevichy cemetery in Moscow, with a ceremony that gathered many attendees on a cold and windy day. Among the farewell words, full of love, admiration, and gratitude, was a speech from one of her collaborators, G.I. Kositsky:

"Lina Solomonovna Stern has passed away; out went the bright star, which for so long has lit up the horizon of Soviet and world physiology. Gone is the great toiler, whose motto in life was: "Work, work, work!"¹

In autumn 1978, a special conference was held on the centenary of her birth.^{2,5}

Conclusions

Lina Stern occupies a special position among the great European neuroscientists of the first half of the 20th century. With a secure career as a professor at the University of Geneva, in 1925 she took the decision to leave for the Soviet Union to lead the Institute of Physiology in Moscow, where her work was fruitful until she was persecuted for being Jewish in the late 1940s. After being granted rehabilitation following Stalin's death, she continued her scientific work until she died at 89 years of age. She dedicated her life almost exclusively to science and had no personal life.

Initially interested in biochemistry, as an expert in the study of oxidative metabolism, she described several steps of what later came to be known as the Krebs cycle. From 1918, she essentially dedicated her time to neurophysiology, researching the body's barrier mechanisms, especially the BBB, to which she assigned the name "haematoencephalic barrier" in 1921. Her subsequent research addressed matters related to the application of these mechanisms to the study of such subjects as longevity, sleep-wake periods, or cancer. She also researched the injection of substances by suboccipital puncture to treat such pathologies as tuberculous meningitis, with which she achieved success, or traumatic shock, with which she obtained more debatable results.

It is highly regrettable that such a relevant scientific figure as Lina Stern should be forgotten. It is time that Lina Stern took her rightful place in the history of international neuroscience and biochemistry in the first half of the 20th century.

Conflict of interests

This is an original study that has not been presented at the SEN's Annual Meeting or at any other meeting or congress or submitted to any journals. This study has not received and financing of any kind.

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