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On the occasion of the 120th anniversary of S I Vavilov's birth

About people with the same life attitude: 100th anniversary of Lebedev's lecture on the pressure of light

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Abstract. New findings and archival materials on P N Lebedev, V I Vernadskii, P P Lazarev, S I Vavilov, L I Mandelshtam, I E Tamm, M A Leontovich, A A Andronov and other scientists in their circle, as well as on the science philanthropists Kh S Ledentsov and A L Shanyavskii, are presented, allowing a better insight into the history of science.

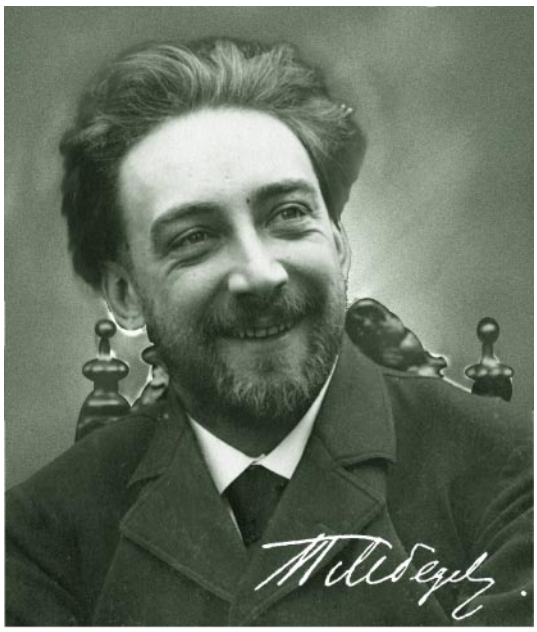
If Pushkin were alive
in our days,
he would be a physicist...
I E Tamm [1, p. 213]

The people presented in this paper shared a common attitude toward the natural sciences, their students, and life in general. It is precisely this that will be dealt with.

A sculpture of a quite serious P N Lebedev (1866–1912) dominates the entrance to the present building of the Physics Department of the Lomonosov Moscow State University (MSU). It was Lebedev who created the first physical school in our country [2, p. 3] and [3]. His name was given to the Moscow Physical Society and, more recently, to the Physical Institute of the Academy of Sciences, a street near the MSU main building, and the Gold Medal of the Academy of Sciences awarded for outstanding work in physics. Many generations have taken this sculpture as a monument of little interest and the generalized symbol of an armchair scientist rather than the image of a real person.

An insightful and creative scientist, Lebedev was a buoyant, cheerful, and passionate man. He flew in a balloon; went in for mountaineering and hiking; appreciated good books and good music; and could laugh contagiously and work contagiously, carrying his collaborators and students with him. His sparkling wit produced a strong impression on his listeners. Lebedev's photograph published here fully corresponds to his character.

In the late December 1909, the XIIth Congress of Naturalists and Physicians opened in Moscow. The future president of the USSR Academy of Sciences, at that time a student, S I Vavilov (1891–1951), was appointed one of the managers. This is how he later remembered Lebedev's report "On the pressure of light on gases" made at the meeting of the physical section (6 January 1910): "Never have I seen a more strained an audience, which listened to every word of the report about experiment of unheard-of complexity; never after have I heard an applause after a cold special report like the applause I heard that evening. That was truly a well-earned triumph of a great experimentalist physicist, who had implemented an experiment which was hardly within the powers of anybody else in the world" [4]. "*Lebedev is just a miracle-worker and a wizard*," said a participant of that congress [5, p. 63].



Leader: Petr Nikolaevich Lebedev

Lebedev's experiments were performed in the basement of the physics room of Moscow University. "How serious the impediments were... can be judged by the fact that up to twenty instruments were made, to mention only the final ones employed in the experiments" [6]. For his investigations, Lebedev was awarded a prize from the Imperial Academy of Sciences.

He was supported by a charitable organization, which was later named the Ledentsov Society for the Promotion of Experimental Sciences and Their Practical Applications [80].

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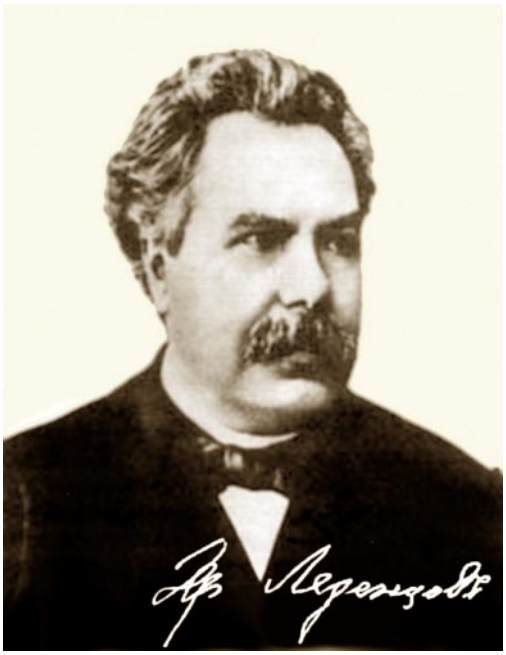


Philanthropist: Khristofor Semenovich Ledentsov

The organization was established under the Imperial Moscow University and Technical School in 1909 under the will of merchant Khristofor Semenovich Ledentsov [7, p. 84]. Lebedev was one of the scientific supervisors of the Society. The Society capital was greater than that of the nobel Foundation, and it allocated more resources for the development of science in Russia than the tsarist government. Even nowadays, given the requisite resources, the Ledentsov Society could have performed these functions set out by its founder; but after the 1917 Revolution it was disbanded and its property was nationalized, although the authorities had no right to confiscate public property (the confiscation was unlawful according to the Soviet laws existing at that time) [81].

Vavilov noted that a talented experimenter has the capacity of making simple instruments and nevertheless obtains results of fundamental significance. In particular, Lebedev made devices for discovering the pressure of light with his own hands [8; 9, p. 216]. He "ranked highly the association of science with technology" [10]. The following thoughts are encountered in Lebedev's letters: "I had never thought one might become so attached to science.... Day by day I come to love physics more and more.... I no longer understand how it is possible to live without physics" [11].

Vavilov also reminisced about the first lecture by professor Lebedev he had heard. It was quite unlike other university lectures. The lecturer addressed the audience as possible future scientists and spoke of how to become a good researcher. This proved to be a difficult task. The listeners remembered his image and his lecture for the rest of their lives.

"Great was the charisma of this brilliant personality — not only a brilliant scientist who combined an exceptional scientific insights with the extraordinary skill of an experimenter but also a leader of a scientific school who loved his students" [10]. He would say: "Exile me to Kamchatka but leave my students with me, and I will set up a new laboratory."

Owing to his keenness of observation and depth of thinking, he was able to accurately estimate the potentialities of his subordinates. And he treated them accordingly. In particular, he expelled those who were found to falsify data [12].

And here is an entirely different situation. Lebedev wrote about one of his collaborators, Petr Petrovich Lazarev (1878–1942): "[Lazarev] developed before my eyes, and in my laboratory... it became clear to me that in front of me is... a man of great talent, a huge stock of knowledge and an inexhaustible scientific imagination.... In my opinion, Lazarev is a huge power: he is both a talented scientist... and an excellent teacher...; in addition, he is a clever and good person.... Should he be compared to other physicists, let me compare him with myself: I can say with a clear conscience that Lazarev ranks substantially higher in scientific talent as well as in the capacity to organize a school of scientific workers" [13]. A photograph of Lebedev together with young Lazarev is given in Ref. [14].

Precious few supervisors can officially admit the superiority of a collaborator over themselves! It was Lazarev, about whom more is to be said below, who subsequently became the head of Lebedev's laboratory.

Lebedev was equally unerring in his judgment concerning the promise offered by different lines of investigation. In particular, in 1895, one of scientific journals reported the discovery made by the German scientist Roentgen. Only a month later Lebedev held a public lecture in the physics lecture room of the university [15] dedicated to this event (see Supplement 1). In the lecture, more specifically, we read: "This emphasizes with remarkable lucidity the frequently forgotten verity that any progress in applied science or technology is underlain exclusively by advances in the area of basic sciences, in the area of pure knowledge."

Soon after the congress mentioned in the foregoing, Moscow University lost its best lecturers, who resigned in protest against the lawlessness of the tsarist government. About one third of the corps of academic professors left the university, including Lebedev and Lazarev. These best lecturers gained support from nongovernmental organizations — the Ledentsov Society and the Shanyavskii Moscow City People's University. That university promoted scientific investigations and was supposedly the only institute of higher education which anyone could join, irrespective of origin, education, gender, age, nationality, or religious beliefs.

The story of Alfons Leonovich Shanyavskii, a general of Polish origin in the Russian army and later the owner of goldmines, of his efforts to set up and fund this educational and scientific center, is told in Refs [7, Ch. 4, 16]. Here is a citation from Shanyavskii's letter to the minister of public education, which dates to 1905: "... there is nothing to be done with hands and feet alone; clever brains are also required..." [16].

When Lebedev found asylum at the Shanyavskii University, it took several months to equip his workrooms with the necessary facilities. There, he executed experiments in an endeavor to elucidate the nature of terrestrial magnetism. Unfortunately, these observations did not last long. Lebedev was not noted for his robust health. And the resignation from Moscow University, which had taken all his time for a long time, was the last straw. He passed away in March of 1912 at the age of only 46. His heart failed. The news of his death shook everyone who valued progress in the natural sciences [6]. An irreplaceable loss for science!

Lebedev's investigations received international recognition. The Royal Society, London, elected him an Honorary Member. Only one scientist from Russia had been so highly

Philanthropist: Al'fons Leonovich Shanyavskii

appreciated prior to him — D I Mendeleev. I am certain that the first-ever research on the experimental discovery of light pressure and its author would have been awarded a Nobel Prize. O D Khvol'son and W Wien nominated Lebedev for this award [17]. Wien's nomination read: "In his carefully executed, repeatedly modified observations he demonstrated how it is possible to obviate the interference of extraneous forces and carry out the quantitative measurements of the pressure of light. These observations are of paramount importance for the theory of radiation."

However, he did not live till the beginning of the consideration, and this prize is not awarded posthumously. Ironically, Lebedev was not awarded the Nobel Prize alongside the many other scientists who undoubtedly deserved it.

Soon after Lebedev's death, M I Tsvetaeva wrote a poem entitled "To the Generals of 1812" [18]. This poem was written for another occasion, but its verses fit a large group of talented Russian people:

For you no summit was too high
And no piece of bread was stale,
Oh, youthful generals, divine,
And sovereigns of their fates!

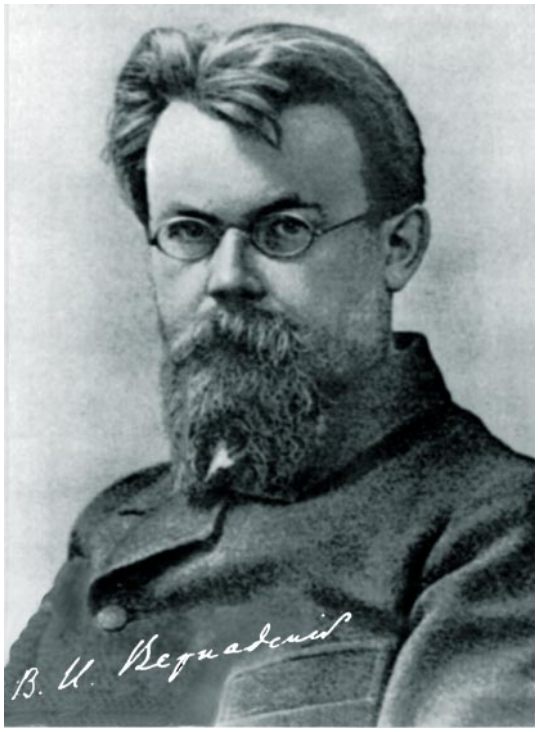
V I Vernadskii (1863–1945), an assistant to the chancellor of Moscow University and a member of the Ledentsov Society, had good relations with Lebedev and resigned from the university for the same reason [19]. In 1914, Vernadskii wrote: "*Science in Russia is in neglect*" [2, p. 2]. Such an assessment also applies to the present. Vernadskii was an active and polymathic person. In 1910, in his speech to the General Meeting of the Academy of Sciences, he said: "Scientists have turned their attention to phenomena that are supposedly destined to exert a profound impact on the life of humanity and commence a new era in its history.

Thanks to the discovery of radioactivity phenomena we have learned about a new unexpected energy source. New sources have come to light; as regards power and importance, the force of vapor, the force of electricity, and the force of explosive chemical processes pale into insignificance beside them.... The energy released in the transformation of one gram of radium is equal to the energy released in the combustion of 500 kilograms of black coal" [20].

Even in 1905, in his Nobel lecture, Pierre Curie emphasized that the new energy source must not fall "into the hands of great criminals who are leading the people towards war" [21]. Even prior to the onset of World War I, the English writer H G Wells realized what mortal danger will be brought by an 'atomic bomb' (this was precisely how Wells termed the terrible weapon based on radioactivity): it will threaten the entire civilization on the globe [22]. Wells's prediction about the horrific power of atomic weapons was borne out three decades later, when the United States of America dropped two atomic bombs on the Japanese towns Hiroshima and Nagasaki. As a result, hundreds of thousands of people perished or were crippled....

So, what happened to Lebedev's laboratory, created with donations from philanthropists, some of whom wished to remain unknown [35, p. 486, 82]? After Lebedev's death, Lazarev became the head of the laboratory. It was under his supervision that the building of the Physical Institute of the Moscow Science Institute (PI MSI), which had been conceived by Lebedev, was erected in 1917 [82]. Over the years, the institute was variously named (Institute of Biological Physics, Institute of Physics and Biophysics [83]), but it was invariably headed by Lazarev [83] from its inception till his arrest on 5 March 1931 [84]. When World War I broke out, Lazarev organized — a novelty at that time — a mobile X-ray station, which operated in field hospitals.

In 1916, Lazarev was nominated to the Academy of Sciences. He was recommended by the mathematician V V Steklov, the mechanics scientist A N Krylov, the physiologist I P Pavlov, the chemist N S Kurnakov, and the geochemist V I Vernadskii. Physicist Lebedev's opinion about



Thinker: Vladimir Ivanovich Vernadskii

him was sited above. The elections were successful for Lazarev: on 4 March 1917, he was elected.

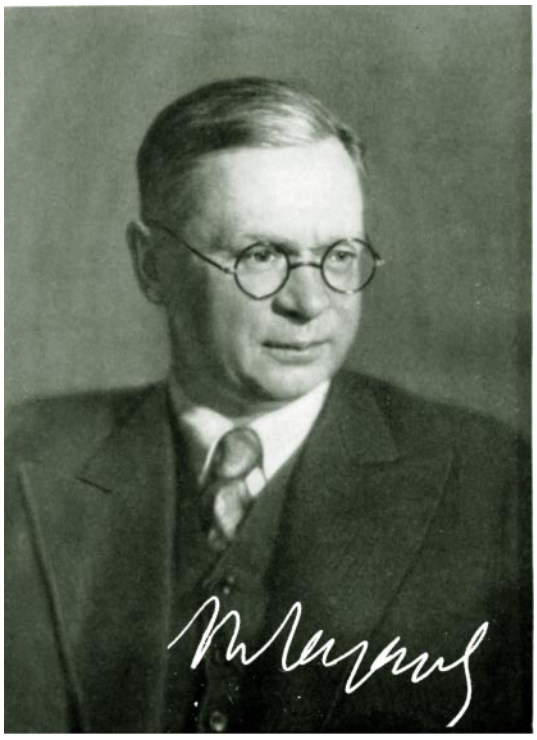
World War I was going on. And then revolution and civil war befell the country. This all resulted in innumerable human and material losses, a breakdown of the economy and scientific relations. Under the circumstances, there was no time for the development of physics.

But there remained responsible people who recognized the indispensable role of science. For a long time, the functions of the secretary of the Academy of Sciences and of its virtual manager were invariably fulfilled by S F Oldenburg [23] (he was the minister of public education in the Provisional Government of Russia and Vernadskii was his deputy). Later, Oldenburg wrote to Lazarev: "The Academy is facing an imminent black cloud.... No one and nothing, of course, will ever demolish science as long as at least one man is alive, but it is easily shattered.... The demolition of the Academy of Sciences will bring disgrace upon any power" [24].

As stated by Vavilov, "the versatility in science, which Lazarev represented throughout his life, is quite extraordinary and hard to accomplish. His work pertains to basic physical problems, biological physics, physiology, medicine, physical chemistry, and geophysics.... He left a large heritage" [25].

For several years, Lazarev supervised the Physical Laboratory of the Academy of Sciences. He also set up the X-ray Institute and supervised it, and headed the Institute of Meteorology. He worked in the Institute of Experimental Medicine and the Institute of Theoretical Geophysics. During the Civil war, he took up the problems of military camouflage and decamouflage, both optical and acoustical.

He discovered that the rate of a photochemical reaction is proportional to the amount of absorbed light. Lazarev was the first in Russia to engage in biophysics; he constructed the theory of the ion-induced excitation of sense organs and was occupied with the application of thermodynamics to biological processes. He was an excellent lecturer, delivering successful public lectures on physics, biophysics, and geophysics, and he published articles on the history of science. In 1918, Lazarev instituted the journal *Uspekhi Fizicheskikh Nauk* and was its editor-in-chief until 1931 [14].



Creator: Petr Petrovich Lazarev

Lazarev organized and carried out an integrated study of the Kursk magnetic and gravitational anomaly [26, 27]. Initially, this work was pursued in the framework of the Academy of Sciences, and subsequently under the auspices of the Supreme Council of Peoples Commissars (SCPC). The attention given to science depends on the level of education of the authorities and population of a country. The SCPC Chairman Felix Dzerzhinsky [27] was among the few people in charge who met with scientists, studied the problems of science, and recognized its huge significance for the future. He was also acquainted with Lazarev. Dzerzhinsky arrived at the following conclusion: "The English, the Germans, and the French support and employ science, which we are unable to use.... Raising science to the highest stage and providing friendly working conditions for our technical personnel... is the central problem; without solving this task, we shall not be able to gain an economical victory over bourgeois Europe" [28].

Later, the supervisor of French atomic energy research Joliot-Curie observed that a country that does not develop science is bound to turn into a colony.

We now return to Moscow University. Those who had resigned were replaced primarily by random people. As a result, the teaching standards dropped sharply. However, the struggle to invite talented new scientists gradually gained momentum.

Vavilov, then a lecturer in the Department of Physics and Mathematics, was one of the most ardent supporters of the idea of inviting "the remarkable physicist L I Mandelshtam, whose coming to the department would greatly improve the standard of education and especially research work." In the course of discussions about the invitation (there were also fierce opponents to the idea), Vavilov would convincingly argue that Mandelshtam (1879–1944) was the most suitable candidate by his scientific and moral qualities [9, p. 185].

In the summer of 1924, Mandelshtam, then a consultant in the Radio Laboratory of the Electrical Trust of the Weak-Current Plant in Leningrad, received a letter from Moscow from G S Landsberg [29] (reproduced in Supplement 2). It read: "At issue is your candidacy for the chair of theoretical physics. You are the last hope for the improvement of the Physical Institute of Moscow University. Only the appearance of a person like you can trigger the formation of a circle of people who wish to work and are able to, and will put an end to endless intrigues, which have soaked through every piece of soil in the Institute."

Mandelshtam accepted this offer and started working at MSU in the autumn of 1925. His scientific and moral influence was amazing. Talented people would gather around him. A A Andronov, one of the most remarkable students of Mandelshtam, would later compare him with the artist Levitan and the composer Rubinstein [30].

But the bosses did not meet the newcomer in a courteous manner. Initially placed at his disposal for experiments were only a room and a half and one staff member [31]. The situation did not improve until 1928. In 1929, the lecturers in Mandelshtam's group were Vavilov, Landsberg, and I E Tamm [32].

A photograph of young Mandelshtam and his autograph are given in Ref. [33]. His listeners said: "He has an excellent command of his subject and sets forth his ideas in explicit language as if a preliminarily written text were displaying itself in front of his eyes" [34]. He and other lecturers of his group were more than outstanding scientists. They also shared a benevolent attitude to all, including students, and they were on friendly terms with each other [35].

Mandelshtam continued to visit Leningrad, where he also attended scientific seminars [36, p. 97]. On one of his trips, Mandelshtam happened to be side by side with Vernadskii, and the latter "sensed an outstanding personality" in him [37]. Later, Vernadskii summarized his impressions as follows: "... the noble personality of [Mandelshtam] will remain one of the most positive memories of my life" [38].

In 1940, Vernadskii drew the attention of the Presidium of the USSR Academy of Sciences to the feasibility of mastering the new energy. His report stated that "the technical use of interatomic energy, although it will entail great difficulties, is basically possible" [39]. This persistent attitude had the effect that a committee on the uranium issue was established by the Presidium of the Academy of Sciences on 30 July 1940.

Ten academicians were members of the committee, including Vavilov, Vernadskii, and Mandelshtam. This committee was the world's first organization at that level. Three weeks before Hitler launched the assault of his troops on the USSR, Vernadskii wrote: "The question of uranium as an energy source has now been posed, as the source of real, technological energy, which may radically change the technical power of humanity" [40].

Lebedev once said: "I'd not feel sorry if I have to part with this life. I'm only sorry that with me will die a very good machine useful to people and for studying nature.... I know that some twenty years later these plans will be realized by other people, but what does a twenty-year delay mean for science?" [41, p. 97].

Nineteen years after Lebedev's report had been included in the congress program, Tamm visited his supervisor Mandelshtam. The latter was already working at MSU and lived in apartment No. 103 on the ground floor of a building on Mokhovaya Street. An internal door of the apartment opened onto the corridor of the Physical Laboratory. The neighboring door in the corridor led to Landsberg's optical room. This building presently accommodates the Institute of Radioengineering and Electronics, Russian Academy of Sciences.

It was not long before the host himself appeared, holding a wet, freshly developed photographic plate; he said: "Here is a work for a Nobel Prize." At issue was the combination scattering of light, which he and Landsberg had just discovered. His spouse exclaimed: "How can you talk nonsense when your relative is under arrest!?" And instead of promoting the fresh discovery, Mandelshtam would intercede for his arrested relative.

The 'nonsense' was first reported in the literature by the Indian Raman and his coauthor. The Nobel Prize was awarded to him, although the researchers from India discovered the combination scattering later than the Russian scientists and provided a wrong interpretation of the effect observed. And Mandelshtam and Landsberg remained unawarded. Based on E L Feinberg's words, B M Bolotovskii, who is thoroughly familiar with the history of science, told me about this instructive fact [89].

We continue our story about some worthy people. The role of Landsberg (1890–1957) in inviting Mandelshtam to MSU and in the investigation of light scattering was already emphasized in the foregoing. Combination scattering [42–44], which is necessary both in peace time and in times of war, as well as the books written by Landsberg, live their life and enjoy wide use. His contribution to the discovery of this effect and the application of light scattering is also discussed in Refs [33, 42, 45]. Landsberg's photograph is given in Ref. [42].

He loved and valued his students. However, the benevolent Landsberg, who never raised his voice, was always just and yet strict. When the fault was serious, the guilty had to hear a deserved reprimand presented in a murderously polite form [9, p. 189]. He actively engaged in experimental work. As noted in Ref. [32], "The 1928 discovery [of the Mandelshtam–Landsberg effect] is widely known abroad." Interestingly, this conclusion was drawn prior to the awarding of the Nobel Prize for this effect.

Landsberg's explanations during his lectures were very clear. They provided the basis for his three-volume *Textbook of Elementary Physics*. To date, it has been published 13 times in our country alone. His monograph *Optics* has been published many times. It came to be an excellent textbook for students and a reference book for professionals.

Mandelshtam and the members of his group lectured at different times to A A Andronov, D I Blokhintsev, A M Bonch-Bruevich, F V Bunkin, S N Vernov, V V Vladimirskii, V L Ginzburg, G T Zatsepin, L V Keldysh, M A Leontovich, S L Mandelshtam, V V Migulin, S M Rytov, A D Sakharov, P G Strelkov, V L Fabelinskii, P P Feofilov, E S Fradkin, I M Frank, R V Khokhlov, and P A Cherenkov. All of them were subsequently elected to the Academy of Sciences; Ginzburg, Tamm, Frank, and Cherenkov were awarded Nobel Prizes for their scientific achievements; many became laureates of the Lenin, Stalin, and State Prizes. No other scientific team in our country could take legitimate pride in such a number of the highest government awards.

The Nobel laureates named above were unbelievers (see, for instance, Ginzburg's paper "Faith and Reason" [46]). Here, it is appropriate to recall Anton Chekhov, who wrote: "I have long since lost my faith and give puzzled looks to any intelligent believer" [47].

In 1931, S I Vavilov (1891–1951) became a member of the Academy of Sciences. His testimonial given by Mandelshtam is given in Ref. [48] (see Supplement 3). Much has been written of him in Refs [33, 49, 50].

Vavilov joined Moscow University in 1909 and graduated from it in 1914. His student work, performed under Lazarev's supervision, received a Gold Medal. Vavilov was an active participant in World War I. He later recalled: "In February of 1918 I was taken prisoner by the Germans in the town of Dvinsk" (presently the town of Dougavpils in Latvia) [51]. He was in captivity for only two days, his release brought about by a German officer who turned out to be a physicist by education [9, p. 162]. After that, Vavilov returned to the university and started working there.

About Vavilov, we read in Ref. [32]: "A well-established physicist. Lectured in a circle of materialist physicists, cooperates readily with the press." His scientific interests were related to light. It was Vavilov who introduced the term 'nonlinear optics' and the notion of the quantum yield of luminescence, and conceived and carried out experiments that discovered a new kind of radiation. In this case, the information about vision gained from Lazarev and about radioactivity gained from A P Sokolov, his predecessor in the practical training session in physics at MSU, stood him in good stead.

Student: Sergei Ivanovich Vavilov

For this achievement, early in 1946, Vavilov, together with Tamm, Frank, and Cherenkov, was awarded the Stalin Prize of the First Degree "for the discovery and investigation of the radiation of electrons in their motion with a supraluminal velocity in a substance" [52]. This work was also nominated by Mandelshtam.

Vavilov emphasized that nature had endowed Mandelshtam with an extraordinary, subtle and perspicacious wit, which immediately noticed and comprehended the essence, which the majority indifferently missed. It was well known that Mandelshtam highly appreciated Vavilov's role in nonlinear optics (see Supplement 3) and in the discovery of the radiation produced by an object traveling faster than light in a medium [33, p. 1248]. In 1958, after Vavilov had passed away, the remaining three — Tamm, Frank, and Cherenkov — were awarded a Nobel Prize "for the discovery and interpretation of the Cherenkov effect."

Being encyclopedically educated, Vavilov simultaneously supervised the Editorial-Publishing Council of the Academy of Sciences, the publication of the *Great Soviet Encyclopedia*, the journals *Doklady AN SSSR*, *Zh. Eksp. Teor. Fiz.*, and *Priroda*, and was the first Chairman of the All-Union Society for the Dissemination of Political and Scientific Knowledge. Vavilov wrote a multitude of papers. According to him, over several months of wartime in 1942 alone, he "submitted five scientific papers for publication" [34, p. 724]. Vavilov became head of the Lebedev Physical Institute of the Academy of Sciences (LPI) [85], which moved in 1934 into his native building of the former PI MSI, which had once been conceived for Lebedev. There he organized the joint seminar of the LPI and the Physics Department of MSU.

The Lebedev Physical Institute turned into the main place of employment for Mandelshtam and the lecturers of his group. "All of the scientific work actually moved there from MSU" [35, p. 487]. N D Papaleksi, who had studied together with Mandelshtam and subsequently enjoyed effective cooperation with him, also joined the LPI. Later, it was at the LPI that the first domestic research on masers and lasers was conducted, for which N G Basov and A M Prokhorov were awarded a Nobel Prize; they also became Lenin Prize laureates.

Upon becoming acquainted with Vavilov, Oldenburg made the following observation: "*This is the one to whom I could hand over the administration of the Academy with perfect confidence in its fate*" [34, p. 1090]. These words turned out to be prophetic: Vavilov became one of the best presidents of the Academy of Sciences in its history.

By the way, Vavilov once said to Bonch-Bruevich: "It would be instructive to compare the propagation of light beams generated by sources traveling with different velocities." "Theorists say that nothing depends on the source velocity; Einstein, for instance, thinks so," was the reply. Vavilov's response was as follows: "They may hypothesize, and you can perform an experiment. If its results are in agreement with what the theorists say, this is quite good.... If it turns out otherwise, so much the better!"

There is no escape from recalling Frédéric Joliot-Curie's thought: "The farther an experiment is from theory, the closer it is to a Nobel Prize."

We return to Vavilov. His idea of comparing the velocities of light beams generated by objects with different velocities was implemented. It turned out that theorists' assumption was correct, to within the accuracy achieved in the experiment. Based on the data obtained, Bonch-Bruevich [53] defended his doctoral thesis. He told me about that curious incident himself (this is partly set out in Ref. [54]).

Bonch-Bruevich also said that one day Vavilov looked deeply preoccupied. He had talked to Beria about the fate of his brother Nikolai. According to Beria, it would be quite difficult to mitigate his punishment, because the conviction had been by the Supreme Court, i.e., the highest degree of jurisdiction, but he would nevertheless try to do this. From the published materials [55] it follows that the death sentence for N I Vavilov was commuted to imprisonment at Beria's request. S I Vavilov later said bitterly: "I was assured that [my brother] Nikolai was kept under good conditions, and now it turns out that he died of malnutrition in prison" [9, p. 38].

As regards S I Vavilov himself, according to J D Bernal, "His death harness was probably due to overwork; but he had already contributed more than his share to his country." Here is an estimate of what was accomplished by S I Vavilov, which was made many years later by his former staff member A M Prokhorov: "A magnificent and tragic life" [56].

We now direct our attention to several other scientists. Tamm (1895–1975) wrote in his autobiography [57]: "In L I Mandelshtam I found a teacher to whom I owe all of my scientific development; the scientific relation to him became progressively stronger with the years." About Tamm, we read in Ref. [32]: "a good young physicist."

Tamm graduated from Moscow University in 1918. From 1931 to 1937, he was in charge of the Chair of Theoretical Physics of MSU and was Chairman of the Scientific Council. Together with Mandelshtam, he reformed and modernized the teaching of theoretical physics at the Physics Department [58].

A brilliant and emotional lecturer, Tamm had the capacity to introduce the spirit of quest and keeping up-to-date into the teaching of even the traditional courses. He made a great impact on students and young scientists [1, p. 15]. Tamm set a living example for his students. In difficult real-

Teacher: Igor Evgenievich Tamm

life situations, many of them would ask themselves how Tamm would act in a case like that. He was "the most jovial, the smartest, and the simplest. His qualities are generosity and delicacy, permanent enthusiasm for work, and sincere interest in everything unknown, novel, genuine..., the capacity for true friendship and attentive benevolence to any interlocutor" [1, p. 64]. He participated with enthusiasm in various semi-jocular competitions, was truly happy when he could win and blamed himself when he lost.

Tamm became the founder and first director of the Theoretical Department of the LPI. He thus spoke about his collaborators: "What excellent people they all are in both senses: as scientists and in the quality of character!" He introduced the notion of phonons, i.e., the quanta of sound, and occupied himself with physical optics, solid-state physics, the theory of elementary and nuclear particles, and the problems of thermonuclear fusion.

Tamm's book *Foundations of the Theory of Electricity* has been reprinted many times and is still in demand up to the present time. Thanks to its wonderfully clear and strictly logical exposition and the extraordinary freshness of the whole treatment of the subject, the reader gains both understanding and aesthetic pleasure.

Tamm showed, along with I M Frank, that an electron moving through a medium at a speed exceeding the phase speed of light in this medium should give rise to new radiation. Subsequently, he was awarded a Nobel Prize for that work.

A reference signed by S I Vavilov and P A Cherenkov in 1946 states the following: "I E Tamm is an outstanding theoretical physicist, who continues to work fruitfully and intensively on the central problems of modern physics."

M Romm asked the advice of precisely Tamm when he was shooting a film about physicists, *Nine Days of One Year*, using a screenplay written by Romm and D Khrabrovskii. "The world would be better if more people like Igor Evgenievich [Tamm] were around us" [1, p. 171]. At the end of Ref. [1], we read: "Your mind measures well the crookedness of space, but never will you take unfair crooked ways."

During his last years, Tamm could not breathe on his own and was tethered to a respiratory apparatus. He would say jokingly: "I'm like a pinned beetle." But even then he continued to work with unabated perseverance. To the puzzling questions of the doctors, one famous physicist provided the following answer: "This is the only remedy that helps."

To pass to a younger generation, M A Leontovich (1903–1981) graduated from the MSU Department of Physics and Mathematics in 1923. In 1917, in parallel with his studies, Leontovich became Lazarev's assistant and actively participated in the exploration of the Kursk anomaly [35, p. 65]. Later, he became one of Mandelshtam's first postgraduate students. Mandelshtam's students wrote an excellent article about him, and Leontovich was one of its authors [59]. They greatly appreciated their supervisor. And he carefully selected his collaborators and postgraduate students by their scientific and human qualities. In 1925, Landsberg wrote: "Leontovich is the most talented and best educated among our students" [29]. And here is Mandelshtam's appreciation: "Leontovich is the best expert on thermodynamics in our country" [38, p. 218].

Together with Mandelshtam, Leontovich performed a pioneering theoretical investigation on the tunneling effect. He worked fruitfully in different areas of optics, quantum mechanics, radiophysics, and thermonuclear plasma. He had an irresistible charisma and exerted an extraordinarily strong influence on the people around him. Manifested in this case were the breadth of his scientific and universal interests, an infrequently occurring spontaneity, irreproachable integrity, and a gentle, tongue-in-cheek, and sometimes sarcastic humor. Leontovich was good at laughing.

As observed by E L Feinberg, "a scientist... should think independently. He exists for the purpose of discovering something new, that which others have not seen or not understood... . The absence of blind admiration for the firmly established authorities... and for the prevailing viewpoints is obligatory for him" [35, p. 113].

In 1935, Tamm characterized Leontovich as follows: "[He] belongs among outstanding theoretical physicists. He is characterized by an exceptional clarity of mind and an in-depth critical physical thinking, a rare and all-round erudition; at the same time, he is an unusual example of a physicist who combines a theorist and an experimenter."

In an official document dated 1963, A P Aleksandrov, then the Director of the Kurchatov Institute (and subsequently, the President of the Academy of Sciences) observed: "When characterizing Academician Leontovich, there is no escape from mentioning his civic and human qualities. He is a truly Soviet patriot scientist, for whom the interests of business matters and our science always rank highest. Commonly known among physicists are Leontovich's personal qualities, such as perfect honesty, complete adherence to the principles of scientific verity, a cordial attitude to people, and exceptional modesty without a trace of self-admiration. All who meet Leontovich on business and in common life experience the charisma of his personality" [60]. Aleksandrov said: "He is our conscience" [36, p. 207].

The reference given by S I Vavilov in 1939 states that "Leontovich's lecturing ranks as high as his research work. His lectures on statistical physics and on physical optics enjoy

Fighter: Mikhail Aleksandrovich Leontovich

great popularity among students.'' The ideas expressed in these lectures have been published in Leontovich's books. The material was presented such that the reader could see unresolved problems where everything had seemingly been clarified long ago. His lecturing carried his listeners away and developed their physical intuition. This was a school of physical thinking. Students also highly appreciated the moral qualities of the lecturer. They came up with the idea of ''introducing a unit of integrity — one Leontovich'' [35, p. 466].

Leontovich was a man of explosive behavior. However, he gave vent to his emotions only on serious occasions. His mind revolted against any falsehood, unfairness, or self-interest. Examples are provided by the construction of industrial plants near Lake Baikal, which would inevitably pollute that unique water reservoir; putting a boss on the list of contributing authors without his of her decisive contribution; and silly prohibitions, pseudo-science, and generally making fools of people.

He would tell people the truth in their face irrespective of their rank, standing, or authority. L B Okun' spoke about a characteristic event in the course of elections to the Academy of Sciences in 1964 [61]. On that occasion, in his stentorian voice, Leontovich reminded everyone of the detriment that the nominees had done to the science of our country. The nominees were Trapeznikov, the head of the Science Division of the Central Committee of the Communist Party of the USSR, a highly influential functionary, and Nuzhdin, a comrade-in-arms of Academician Lysenko, a fierce and successful fighter against genetics. Electing such people to the Academy would only further the detriment they had caused. For many years, the voting of the General Meeting of the Academy had been favorable toward the nominees under consideration. However, after Leontovich's annihilating criticism, they fell flat!

He was a hot-tempered man and, what is more, an inveterate tourist. In winter he went skiing with his family. In summer they hiked, boated, or rode horses. Leontovich's sister also participated in the hiking. She became a fine mathematician and the spouse of his friend Andronov.

A A Andronov (1901–1952) was buoyant, loud-voiced, and handsome. He took an avid interest in everything, had an excellent understanding of physics, astronomy, mathematics, engineering, and history, possessed broad knowledge, and spoke figuratively and understandably.

Andronov's labor activity began at the plant where he worked as a quality examiner. He next worked as an electrician at a power plant, and after that became a Red Army man. It was not long before he was pronounced unfit for military service because of a lung, and he entered the Moscow Higher Technical School, from which he transferred to Moscow University. In 1925, he became one of Mandelsham's first postgraduate students.

Mandelsham's opinion of Andronov was as follows: ''My favorite student'' [38, p. 217]. And here is Andronov's opinion: ''Mandelshtam is simultaneously a classic — by the exemplary clarity and completeness of his published works, and by the rigor and exactness of his reasoning, and a romantic — by the desire to share his ideas and guesses with others, by his love for teaching, by the power of his live word, which is capable of attracting the rapt attention and delightful excitement of the audience'' [38, p. 100].

In real oscillatory devices, as observed in Refs [62, 63], quite definite period and amplitude set in, and therefore these devices cannot be considered linear. It is therefore necessary to turn ''to the physical notions and mathematical methods that are adequate for nonlinear systems'' [62]. Andronov pointed out that certain investigations made by Poincaré and Lyapunov are related to precisely such cases.

Andronov was an acknowledged expert on the dynamics of machines and nonlinear effects in oscillations. He introduced the term 'auto-oscillations.' Andronov worked efficiently in the realms of radiophysics, education, and the history of science [64]. He was ''a man of inexpressible charm, with an avid and strong mind and unbounded humaneness'' [35, p. 112]. Andronov interacted easily and willingly with those clever people whose basic concern was science. His thoughts ranged from watches, acyclic and

Postgraduate student: Aleksandr Aleksandrovich Andronov

commutator machines to stars with periodically varying brightness.

It was Andronov who became the prototype for the main character, Academician Dronov, in the movie entitled *Vse Ostaetsya Lyudyam* (Everything Remains with the People) (director G Natanson, scriptwriter S Aleshin) [65]. Leontovich was depicted there under the guise of a priest, a relative of this academician. In one of the film scenes, Dronov stops an illegal ejection from an apartment. A similar case also took place in Andronov's deputy practice: an influential factory director tried to occupy the apartment of a helpless old man, but this attempt did not meet with success owing to the resolute interference by Deputy Andronov [66]. Another consequence of deputy's uncompromising attitude was his own hospitalization. Mathematician L S Pontryagin said: "[Andronov] is not only an outstanding scientist but also a remarkable person. Like no one else, he felt responsible for what was going on in the country, and in this sense possessed high civic consciousness, and set the perfect example of a human for me" [67, p. 136].

Those discussed in the present paper were outstanding scientists and were concerned about people, about the country, and sometimes about the entire humankind, which was becoming progressively more vulnerable due to the development of military and civil technologies.

But certainly not all scientists are like that. The reader surely knows from his or her own experience that education and position do not alter the main views of a person. The physicist Marie Curie noted (this applies to genuine researchers): "a scientist in his laboratory is not only an expert. He is also a child facing the phenomena of nature, which amaze him like a fairy tale" [68, p. 176]; and selfish bureaucrats are certain that "A man occupied with science... in everyday matters is like a small child and is subject to being meticulously cheated" [86].

The Soviet Union saw the successful work of different scientific schools. Here, I mention A F Ioffe, P L Kapitsa, L D Landau, and their students. Ya B Zel'dovich, for instance, "belonged to one such school. He arrived at the conclusion that life showed the fruitfulness of the line running from Lebedev through Rozhdestvenskii and Vavilov, Mandelshtam and Tamm, Cherenkov, Frank, Ginzburg, Prokhorov, and Basov" [69].

Lebedev was addressed in the foregoing. Rozhdestvenskii [70] was on good terms with Mandelshtam, and the scientific activity of Basov and Prokhorov commenced under the supervision of Leontovich, one of Mandelshtam's first postgraduate students at MSU. We recall that Vavilov and Tamm were his collaborators at the time of that postgraduate study. Photographs of Basov and Prokhorov, reprints of some of their papers and of the papers of their successors are given in Refs [71, 72].

In his letter dated 1905, Shanyavskii writes: "The country is facing the prospect of running wild" [7, p. 73]. Ledentsov's thoughts: the means for improving life on Earth "consist only in science and in the fullest possible assimilation of scientific knowledge by all people" [7, p. 65]. In the lecture on the pressure of light, it was noted that "Any progress in the applied area is caused exclusively by the advances in science." And here is H G Wells's thought: "Where should we be now but for the grace of science?" [22, p. 287].

More than half a century after that lecture, a new edition of S I Vavilov's book about the Sun came out. There is an assertion in it: "On the path towards understanding the nature of light, humans gained microscopes, telescopes, range finders, radio, Roentgen rays: this investigation has helped in mastering the energy of atomic nuclei" [73].

Another half a century later, Prokhorov said: "For some reason, basic research in our country is tenaciously separated from applied research. Without basic science our country is doomed to failure" [74]. And the French scientist J-M Legay noted: "National safety cannot be ensured without basic research" [75, p. 101].

The statement that basic science is extremely important for any country and the opinions of well-informed and farseeing people given in the foregoing still hold true.

Here is the opinion of many people concerned about preserving science in Russia: "*That which takes place in the realm of education today is a disgrace to the state*" [76]. The souls of young people are crushed by the effective popularization of violence and drugs. Evidently, something is wrong in our realm. The book *Qui a peur de la science*? (Who is Afraid of Science?) [75] states: "a campaign against science has been launched, which is either carried on or tolerated by the government, on the radio, on the TV, or in the press at large. The peril is not in the potentialities acquired by people by way of hard labor, by learning the laws of physics and biological phenomena. The peril lies with the lagging of social phenomena and the inability to control them."

"Supporting basic science is a risky business. However, when hopes are justified, the gain can be tremendous" [7, p. 701].

I complete the stories about scientists exploring the nature with a statement made by M V Lomonosov, the 300th anniversary of whose birth is commemorated this year: "Nature is all the more surprising as, being most artful in its simplicity, it produces from a small number of origins countless images of properties, changes and phenomena" [77].

The preparation of the manuscript was largely facilitated by the reminiscences and aid of many people. At least some of them should be mentioned. I express my deep appreciation to B M Bolotovskii, A M Bonch-Bruevich, P G Kuznetsov, O V Rudenko, V A Sadovnichii, A M Shirokov, as well as to M S Aksent'eva, V M Berezanskaya, Yu N Vavilov, V P Volkov, N N Ledentsov, A M Leontovich, T S Mandelshtam, G Yu Mikhailov, V M Mysova, M V Ragul'skaya, I G Terakanova, and V S Chesnokov.

Supplement 1

The role of basic science according to Lebedev in 1896

Never before has a discovery in the area of physics aroused such interest and been so thoroughly discussed in the periodic press as Roentgen's discovery of a new, previously unknown kind of ray....

Two to three weeks after Prof. Roentgen made a "preliminary report" about his discovery to the Physical-Medical Society in Würzburg (in December of 1895), all the European press began to write about X-rays.

The reason for this interest should be sought with the applications of Roentgen rays for medical purposes and those bold hopes pinned on the new diagnostic technique, as well as with the feasibility of taking photos by a quite simple and easily accessible technique, of objects invisible to the eye....

Naturally, only an expert in physics who is well familiar with the modern state of science can estimate the significance

of the new discovery and clearly envisage the special place occupied by X-rays among all other kinds of energy propagation known to us, and understand the role which they may play in the solution to a number of problems. For people unfamiliar with physics, Roentgen's discovery is of a different, and maybe greater, interest, allowing them to go in their imagination to the laboratory of a scientist and to follow step by step the progress of research and the sequence of separate experiments....

The application of X-rays in medicine, the possibility of seeing what seemed to be concealed from the human eye forever — the skeleton of a live man, the very advent of this almost magic diagnostic tool, all this is a crystal-clear demonstration of the frequently forgotten verity that any progress in applied science or technology is underlain exclusively by advances in the realm of basic sciences, in the realm of pure knowledge.

Petr Lebedev

Supplement 2

Letter to Mandelshtam in Leningrad dated 18 June 1924

Dear Leonid Isaakovich!

It has been a long time since I decided to address myself to you with this letter, but a certain ambiguity of the situation has kept me from doing this.... At issue is your candidacy for the Chair of Theoretical Physics at Moscow University.

You must have learned, one way or another, that we proposed your candidacy after the death of S A Boguslavskii, [1] along with the candidacies of Epstein [2] or Ehrenfest [3].... Today, at last, during the meeting of the subject committee it was declared, according to the chancellor's words, that if you, Ehrenfest, or Epstein agree to occupy this chair, the administration will not raise objections against the filling of the position. It is quite obvious that neither Epstein nor Ehrenfest will come here. So, everything boils down to your consent. In this connection, you will probably receive an official inquiry in a few days. As for me, expressing the public opinion and the opinion of many of my university friends, I decided to additionally address myself to you with this letter.

You certainly know the situation at Moscow University and know the people who play first fiddle there. The negative aspect of Moscow is therefore familiar to you. The other aspect of the matter is as follows: according to the firm belief of many of us, you are the last hope for the improvement of the Physical Institute of Moscow University. Only the appearance of a person like you can trigger the formation of a circle of people who wish to work and are able to, and will put an end to endless intrigues, which have soaked through every piece of soil in the institute....

According to S A Boguslavskii's thoughts, the Chair of Theoretical Physics was established as a "Theoretical Physics Study with a Laboratory," and therefore the possibility opens up to you to launch several experimental investigations.

At present, there are only two rooms at the disposal of the theoretical physics study. If more workspace is needed after your coming, I am certain this will be possible to obtain. So, I believe that in Moscow you will find a number of people who can't wait for your arrival, and you will form a working circle of them around you....

As for accommodations, it seems to me that you may well make it a condition that you be given an apartment. I think the university will find it possible to put an apartment at your disposal.

Excuse me for taking the liberty of writing about all this: it is terrible to think you would decline the proposal straight off.

All the best!

Respectfully yours,

G Landsberg

[1] S A Boguslavskii (1883–1923), a dean at MSU [78].

[2] P S Epstein (1883–1966), a theorist who studied at Moscow University and was Lebedev's collaborator [79].

[3] P S Ehrenfest (1880–1933), a theorist who had earlier lectured in St. Petersburg [33].

Supplement 3

An extract from Vavilov's reference written by Mandelshtam on 14 March 1932

Vavilov's work, which primarily pertains to optics, is a highly important contribution to several areas of this important physical discipline.

The scientific activity of Vavilov is extremely productive. A highly valuable feature inherent in Vavilov's investigations is that they are aimed at elucidation of problems of fundamental importance. His investigations yield not only new experimental material valuable in itself but also new data for theoretical generalizations and constructions.

Sometimes, these data make it possible to solve some previously posed theoretical problems, sometimes they form the foundation for constructing a theory, which is not infrequently given by Vavilov himself or elaborated by his collaborators. Lastly, some of his papers give accounts of his newly discovered phenomena, which are of much interest.

The bulk of Vavilov's investigations are dedicated to the problems of fluorescence and phosphorescence. It is valid to say that Vavilov is one of the leading authorities on these issues both in our country and abroad.

A number of Vavilov's investigations are concerned with other optical problems and adjacent areas. Regarding general problems, he investigated the question of whether the optical constants of bodies depend on the intensity of light, a question of fundamental importance.

Apart from Vavilov's research activity, mention should be made of his extensive fruitful popular-science work, which has played an important and prominent part in the popularization of physical knowledge. Of high value is Vavilov's work concerning the history of physics. Among this is our first translation of Newton's *Opticks* and his optical memoirs.

The scientific significance of Vavilov's research and his exceptional erudition place him among the highest-ranking physicists in the USSR.

14 March 1932

L Mandelshtam

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