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THE TEACHER

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Abstract. This is a tribute to Alexandr D. Alexandrov on the occassion of the centenary of his birth.

Alexandr Danilovich Alexandrov, Full Member of the Academy of Sciences of the USSR, an outstanding mathematician, head of the Russian school of geometry which came to be known and appreciated worldwide, the disciple of V.A. Fok (Member of the Academy of Sciences of the USSR) and B. N. Delone (Corresponding Member), himself a Teacher for a whole group of scientists, died on July 27, 1999 in Saint-Petersburg, in the age of 86.

I was fortunate enough, being a student, to meet Alexandr Danilovich more than half a century ago, when he came to Almaty to give special courses in geometry in Kirov's State University of Kazakhstan. He gave general lectures on the principle questions of relativity and quantum theories, talking with us, students, during our walks in the foothills of Zailiysk Ala-Tau. My wife and fellow-student Anna Abramovna Zilberberg (unfortunately, she also died in 1999) presented her thesis under Alexandrov's supervision, and later on, when he already became the rector of Leningrad State University (LSU), defended her candidate dissertation there.

Grigory Moiseevich Idlis (1928–2010) was the head of the department of the history of physics and mathematics in S. I. Vavilov's Institute of the History of Science and Technology of the Russian Academy of Sciences; professor of the history of science department of the Russian State University of Humanities, doctor of physics and mathematics, professor of astrophysics. This is an authorized English version of an article in Russian which appeared in *Академик Александр Данилович Александров. Воспоминания. Публикации. Материалы.* Ред.: Г. М. Идлис, О. А. Ладыженская. М.: Наука, 2002. The English version of the article and the poems it contains were produced by the author's granddaughter, Julia B. Idlis, a graduate of Lomonosov Moscow State University.

Idlis, G.M., The Teacher.

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She was never a very fit person and tired very quickly during mountain trips; then Alexandrov simply carried her in his arms.

Wherever he happened to be, Alexandr Danilovich was always the center of everyone's attention and interest, he invited people to communication. His scientific works also were marked with openness, immediate appeal to the interested readers and invitation to further addition to and generalization of his results; I mean such works as, for instance, his book *Convex Polyhedra* (1950). This book was absolutely unique; alongside with stating the results achieved the author pointed out the possible generalizations and formulated new tasks and questions (by the way, one of these questions was taken as the dissertation theme by my wife). Later on many of the questions outlined in this book were tackled by Alexandrov himself and by his disciples and followers.

Such openness was also characteristic of Alexandrov's seminar in geometry which was held in LSU for many years. It presupposed systematic reports and discussions not only of the already-completed research, but also of the research in progress. All the participants were active and friendly while cooperating in the field. It is interesting to note that V. A. Zalgaller, who for many years had been a senior student of the seminar, a direct disciple and one of the closest collaborators of A. D. Alexandrov, prepared for publication a manuscript of a new revised version of Alexandrov's book *Convex Polyhedra*, Berlin etc.: Springer-Verlag, 2005, with Zalgaller's own commentary and an appendix including two articles by Yu. A. Volkov and an article by L. A. Shor. The publication of this book (both in Russian and in English) is very desirable indeed, since it is going to be a well deserved scientific monument to Alexandrov, this mathematician of genius.

After Alexandrov had visited Almaty for quite a few times there appeared a special seminar on convex polyhedra in the State University of Kazakhstan. Among the members of the seminar were E. P. Sen′kin, A. A. Zilberberg, M. E. Kvachko, V. V. Ovchinnikova, myself and others. Later on Sen′kin, Zilberberg, Kvachko and Ovchinnikova became Alexandrov's post-graduates.

In 1953 Alexandrov published an article in collaboration with Ovchinnikova, which had principal significance: "Observations on the Foundations of Relativity," *Herald of LSU: Mathematics, Physics, and Chemistry* (1953) **11**:4, 95–110.

In 1953 in collaboration with Academicians A. N. Kolmogorov and M. A. Lavrentiev, Alexandrov prepared for publishing a monograph in three volumes under the title *Mathematics, its contents, methods and meaning*, aimed at the mass reader. This was a unique voluminous definitive edition; among its authors were Academicians I. M. Gelfand, M. V. Keldysh, A. I. Malcev, K. K. Mardzhanishvili, S. M. Nikol′skii, I. G. Petrovskii, S. L. Sobolev, D. K. Faddeev, and Alexandrov's Teacher Corresponding Member of the Russian Academy of Sciences B. N. Delone. The monograph first came out in very small numbers (only 350 copies), but, as Semen S. Kutateladze noted, it averted the threat of ideological massacre of Soviet mathematics, which was very real indeed at the time. Only in 1956 the book came out in 7000 copies, and it immediately became a sensation in the literature on mathematics worldwide (suffice it to say that the book saw three new editions only in English).

One of the immediate disciples of Alexandrov, Academician Yu. G. Reshetnyak, wrote an article dedicated to the 75th anniversary of his teacher (*Science in Siberia*,

30.07.1987), where he listed significant quotations from a book by an American geometrician G. Busemann *Convex Surfaces* (1964):

> The aim of this book is to bring the theory of convex surfaces to a wide circle of mathematicians; the theory of convex surfaces has been developing during the recent 25 years, mainly in the USSR, but it remained practically unknown in other countries, at any rate in the USA.
>
> Generally speaking, the main results of the present book, including chapters I and II, belong to A. D. Alexandrov, and the other part of the material appeared under the direct influence of his works.
>
> In the field of the geometry of convex surfaces there can be no doubts as for the priority.

During the last years of his work Alexandrov made important contributions into creation of new textbooks on mathematics for high schools and institutes, which competed with those by Academician A. V. Pogorelov, his former student.

Of special significance were and still are Alexandrov's works on methodological questions of theoretical physics. These concern chronogeometry, axiomatics of relativity, its interpretation as the theory of absolute space-time, and defining the absolute speed of bodies relative to the general field of radiation.

Alexandrov's interests lay outside pure mathematics; he was deeply interested in natural sciences, up to the leading questions of humanities. This can be illustrated by several of his works, for instance, *Scientific Research and Religious Faith* (1974), *Reflection on Economics and Ethics* (1986), *Truth as Moral Value* (1987), *Talks on the History of Science* (three essays published in 1988), and many others. Alexandrov considered mathematics to be a humanitarian science, since it studies "elementary human actions."

He was highly educated erudite, intellectual and outstanding scientist, an expert in world culture with phenomenal memory, a subtle connoisseur of painting, music, poetry, himself a poet, author of beautiful verse, a true Teacher of life and a man of immense courage and surprising willpower, who stood upon his course always and everywhere, with unfailing spirit and passion.

A master of sports in mountain climbing, he celebrated his 70th birthday and the 50th anniversary of his mountaineering practice in 1982 by climbing the Panfilov peak (4300 meters) in the Mountains of Tian Shan.

"Sports interest me, because it make one overcome oneself," he said.

This can be seen in a passage from his long poem *Ascending* which he wrote 10 years before climbing the Panfilov peak, published in his book *Problems of Science and a Scientist's Standpoint* (Nauka Publishers (1988), 507–508):

THE PEAK

The tired hand grabs the last ledge; the effort
Is made. An easy way stretches ahead.
We're on the peak, and this is our glory.
Here we can look around and take a breath.
There is a valley with green meads way down,
The slopes are covered with a thick wood's shawl,
The warmth and peace of this place spreads and tempts us
To choose sweet sleep instead of work and strain.
But close to us, and all around, and further,
Where skies have got over the earth's sharp edge,
There heaves a mass of mountains clad in whiteness,

Shackled in rocks and cliffs and armor of ice.
They bear sharp forms, and sinister cold threatening,
And bold ascent of the forbidding heights,—
The challenge and the call and the hunger of passion,—
Seductive everlasting beauty's call.
The mountains shine with all their diamond facets
And knit the brows of angry beetling rocks;
They call and mesmerize with rigid order
To come to them, to struggle, and to search
The ways for new ascents and climbing upwards,
To fight the obstacles, with difficulty though,
To strive forward again in aspiration,
To calculate, to go, and to risk.
Though there were part most hard to be climbed over,
Where every nerve was tense and strained as string,
We did ascend, o'ercome it all, and here
We are on top. The victory's great flame
Burns in our hearts, the mountains enchant us
And cast their spell of miracle unseen,
Of a fantastic image of creation,
Of inspiration, ecstasy, and charm.
There beams above with eternal joy and power
The space of blue for which there are no words;
The sun caresses us with rays of happy brightness
And burns our skin and dazzles our eyes.
But happiness is transient everywhere;
An hour has passed; it's time for us to leave.
We start again on our long way down.
Farewell, the peak! Ye, mountains, wait for us!

It is cosmic power and ineradicability of the Great (and human) Spirit that he expressed in a poem published about the same time (the same source, p. 508-509)

THE SPIRIT OF MAN

When the last cataclysm causes explosion,
The Earth will perish like a nova, aflame;
Mankind will vanish in the space forever
Without a memory, monument, or funeral feast.
Then scorching gas will whirl at great speed
Into the boundless interstellar space;
The Spirit will leave the Earth anew to wander;
And this will not be the last time it does.
Some day somewhere it will appear again
In flesh and blood for suffering and struggling,
For searching and materialization,
For running upward and returning back.
Thou, Spirit of eternal striving forward,
Which borne the Evil and the Good alike,
Which nothing in the world left outside
The sphere of knowledge and will to transformation,—
Thou, Spirit, do create and convert Nature
Into a battlefield of mighty forces
Which thou begot thyself, so that thou couldst
In struggle gain thee everlasting freedom
And cause a cataclysm, or death, perhaps,

To the inert, stagnant, and worthless matter,
But make the impossibility come true
And once again rise unto life anew.

In all those years Alexandrov often came to Almaty to visit our Mountain observatory of the Astrophysical Institute of the Kazakhstan Academy of Sciences, where I worked after graduating from the university. After 1973 we moved to Moscow and I started working in the Institute of Engineering and Electronic Technology of the Russian Academy of Sciences, and Alexandrov always stayed at our place during his systematic visits to the capital. His visits, contacts with him, edifying conversations about various scientific and general themes and things always were a holiday for us, our children and grandchildren. We witnessed him overcoming all his serious illnesses: the consequences of vernal encephalitis, leg erysipelas, and chronic pneumonia.

Alexandrov has always been and is my unfortunately unattainable ideal of a true scientist, citizen and person. We could only envy his enthusiasm in science, the power of his mind and exceptional efficiency.

In 1945, in the age of 33, before he was elected Corresponding Member of the Academy of Sciences of the USSR, he published 14 scientific works during the span of one year, and in 1956 (11 years, after a period typical of solar and creative activity) he published even more than 17 articles. At the time he already was the rector of Leningrad State University. Every scientist understands how much energy is required for such productive work. Suffice it to say that in 1961, when I was 33 (the age typical of acme), and was working as a vice-director of the Institute of Astrophysics in Almaty, and often was to substitute for the director (V. G. Fesenkov) even before I was appointed director, I managed to publish only 12 scientific works in the space of a year. It was my personal record then, and I was able to break it only in 1997.

Many people were interested in Alexandrov's opinion concerning very different matters. It is said that once his students asked him which scientist could be considered the greatest of all. He answered that it depended on the accepted standards, on the measure and the unit of greatness. If we take for it the time that took people to understand the work of a great man, than Archimedes is the greatest, because he could already integrate. Then, on second thoughts, Alexandrov added: however, if Jesus Christ was a real person, it is he that must be considered the greatest, since he formulated the necessary moral commandments which mankind is yet not ready to grasp. This was not an incidental phrase with Alexandrov. He repeatedly expressed the idea about the true greatness of Christ (and Buddha as well) in his reports and articles.

By the way, in the personal archive of Alexandrov's daughter, D. A. Medvedeva, there is a commandment, formulated by him in the same style on January 23, 1982:

> I do not tell thee to believe blindfold, but to turn to the grasping of what is and how it is; and do not put forth thy prejudice, because in what is and how it is there shines God's wisdom, and in thy prejudice there is only thy wit. And thou cannot put thyself above your God.

Alexandrov himself could not confine himself to the Procrustean bed of narrow specialization in any field of knowledge, and even in the limits of one of the two opposing disciplines— the natural sciences or humanities. He was a "physicist" and a "lyricist" in the best and highest sense of these words, which denote the combination

of the corresponding qualities so rarely seen. He was interested in exceptional ideas in very different fields of knowledge, even paradoxical ones. In those he strived for singling out a rational core (which not every scientist can do because of their narrow specialization). This made him, for example, to help organize L. L. Vasiliev's parapsychological experiments and publish N. A. Kozyrev's controversial works on the so called causal mechanics. In Novosibirsk he took with great interest Yu. I. Kulakov's theory of physical structures and tried hard to publish the corresponding work on mathematics of one of Kulakov's disciples (G. G. Mikhailichenko) in the *Doklady* of the USSR Academy of Sciences, since it was of fundamental significance for the theory.

Alexandrov was keen on discussing the so-called anthropic principle, which was introduced in the modern cosmology in 1957 by me.

Alexandrov was also interested in my deductive conclusion about the necessary mathematical induction of the interconnected periodic systems of ideal fundamental structural elements of matter on the main levels of its natural self-organization: physical, chemical, biological and psychological (mental) levels. He sent an article written by me to Vice-President of the USSR Academy of Sciences Yu. A. Ovchinnikov in order to publish it in the *Doklady* of the Academy in the section of biochemistry.

In 1984 they exchanged letters on this matter, unfortunately, without much effect, because Yu. A. Ovchinnikov could not grasp my rather elementary mathematical arguments:

To Vice-President of the Academy of Sciences of the USSR, Academician Yu. A. Ovchinnikov. Moscow, March 16, 1984

> Dear Yuri Anatolievich,
>
> I enclose a short article written by an old friend of mine—Doctor of Physics and Mathematics, Professor Grigory Moiseevich Idlis "The Common Periodic System of Genetically Encoded Standard Aminoacid Remainders of Biopolipeptides and the Standard Nucleotides of DNA and RNA which Genetically Encode the Former." I told you about this article yesterday when we met at the General Meeting of the Academy, and I would like to ask you to submit it to the *Doklady* of the Academy of Sciences of the USSR in the section of biochemistry.
>
> G. M. Idlis has managed to discover three natural general characteristics with consecutive natural meanings for genetically encoded standard aminoacid remainders of biopolipeptides and the standard nucleotides of DNA and RNA which genetically encode the former. The common system worked out for them turned out to be symmetrical to the limit: it is quadratic as for the number of non-hydrogenous atoms and as for the range of atoms of all kinds and ions in their radicals. Interestingly, according to the latter characteristic, the system turned out to be cyclically closed, that is, periodical.
>
> As far as I can tell, this is an important work, which could become the beginning of a whole new era in understanding the deterministic nature of bioorganic structures. I hope you would consider the article with interest and attention and would think it worth publishing in the *Doklady* of the Academy of Sciences of the USSR as a significant achievement in your field of soviet science.
>
> With best regards, Academician Alexandrov.

Vice-President of the Academy of Sciences of the USSR, Academician Yu. A. Ovchinnikov. April 17, 1984

> Dear Alexandr Danilovich,
>
> I read with great attention the article by Professor G. M. Idlis "The Common Periodic System of Genetically Encoded Standard Aminoacid Remainders of

> Biopolipeptides and the Standard Nucleotides of DNA and RNA which Genetically Encode the Former" enclosed in your letter. Unfortunately, the article has been written by a professional mathematician in a very specialized style. That is why it seems difficult for biochemists, whom the article has been meant for, to understand the arguments. I am not an expert in the given field, and it is hard for me to appreciate the results of the author's research and to recommend the article for the *Doklady* of the Academy. It may be advisable to rewrite the article in order to make it more comprehensible for the majority of chemists and biochemists without sacrificing its mathematical thoroughness before negotiating the publishing.
> Yours, Yu. A. Ovchinnikov

To Vice-President of the Academy of Sciences of the USSR, Academician Yu. A. Ovchinnikov. June 11, 1984

> Dear Yuri Anatolievich,
> Thank you for your kind letter concerning the article by Professor G. M. Idlis "The Common Periodic System of Genetically Encoded Standard Aminoacid Remainders of Biopolipeptides and the Standard Nucleotides of DNA and RNA which Genetically Encode the Former," as well as for advising to rewrite it so that it would be more intelligible for most chemists and biochemists without sacrificing its mathematical thoroughness. I informed the author about your recommendation, and hope that he would rewrite the article according to it, in order to submit it for your consideration once again.
> With greatest respect, Academician Alexandrov

I remembered the way this coordinator of the Soviet biology reacted to extraordinary ideas of other authors (particularly, the works of L. B. Mekler and R. G. Idlis), and I decided not to waste time and effort on trying to convince Yu. A. Ovchinnikov in anything; all the more so that he, as he himself had put it, "was not an expert in the given field" (although it was he who introduced the term "physicochemical biology" in the 1970s, thus stating the necessity of the physicochemical approach to biology in this day and age). I just included the article into more general publications.

In the years of T. D. Lysenko's rule in the Soviet biology, as well as in the subsequent lengthy period of biology in this country under abnormal direction and regulation from above which was exercised by Yu. A. Ovchinnikov, biology had "shrunk" to an extent that one could not help feeling uncertain about its revival being advisable and indeed possible at all. In this respect Leningrad State University was a real oasis of genetics when Alexandrov was its rector.

To celebrate Alexandrov's 87th birthday (he lived up to it only but for a week) the newspaper *Science in Siberia* published an article by seven authors in his memory. Among the authors were three doctors of sciences (Yu. F. Borisov, V. A. Zalgaller, and S. S. Kutateladze) and four Academicians of the RAS (O. A. Ladyzhenskaya, S. P. Novikov, A. V. Pogorelov, and Yu. G. Reshetnyak). In their article, while writing about Alexandrov's scientific contributions, they noted the following:

> With the rise of *perestroika* there appeared people who tried to blame Alexandrov for "Lysenkoism" (being a supporter of Lysenko's policy), which stirred repulse on the part of scientific community. Alexandr Danilovich was deeply moved by the statement of Leningrad Mathematical Society as of March 28, 1989, which read: "Leningrad's scientists remember A.D. Alexandrov's numerous good deeds: his attempts helped to save science and scientists in the years of hardship, which required great personal courage on his part." In October 1990 A. D. Alexandrov, the only mathematician in a group of biologists, was awarded the Order of the Red

> Banner of Labour for his special contribution to the preservation and development of genetics and selection. This unusual reward was caused by the sweeping majority of the country's scientific community estimating highly A.D. Alexandrov's noble work.

Alexandrov showed personal courage while working in Siberia, supporting the grandson of his teacher B. N. Delone—Vadim Delone (1947–1983) who was persecuted by the government for remedial actions, and receiving then disgraced poet Andrey Voznesensky (1933–2010) at his place in the Golden Valley (the academic campus in Novosibirsk) together with Alexandrov's first wife, Marianna Leonidovna Alexandrova.

There are two volumes of Voznesensky's poems in the family archive of A. D. Alexandrov (*The Gaze. Rhymes and Poems.* Moscow: SP, 1972; *Axiomatics.* Moscow: SP, 1990). The first volume was presented by the poet to the Alexandrovs then and the second—later, in 1990, in Tokio, on returning from a trip to Japan with Alexandrov. The books were supplied with the words of the poet which were kindly given to me for publication by Alexandr Danilovich's widow, Svetlana Mikhailovna Alexandrova.

Alexandrov painfully suffered the unjustified attacks of L. Infeld (1898–1968) on V. A. Fok's views[1] upon the bases of general relativity, which some physicists in this country propagated, and initiated our joint work concerning V. A. Fok's contribution to the relativity theory of space, time and gravitation.

Being a true scientist Alexandrov took nothing on trust, questioned and tested everything, but he was a man of wide views and deep judgments. I always liked him. At the very outset, despite the age difference (Alexandrov was 16 years elder than me) we became real friends and could quite seriously discuss any questions be it scientific, philosophical, social-political, or daily. We had much in common. Like Alexandrov, I began my university education at the faculty of physics in LSU. After finishing my first year there I decided to enter the faculty of chemistry as well in order to broaden my scientific horizons. However, the dean of the physical faculty, professor S. È. Frish (1899–1977), who had been Alexandrov's dean, advised me to study at the faculty of mechanics and mathematics instead, deepening my understanding of mathematics. When my parents moved to Alma-Ata I became a student of the Department of Physics and Mathematics in Kazakhstan University; having taken the advice, I studied at two departments there at once: the department of physics and that of mathematics. Both of my dissertations (in physics and in mathematics) were written at the department of theoretical physics under the supervision of assistant professor N. M. Petrova, who was an immediate disciple of Academician V. A. Fok and his former student. One of the dissertations (the mathematical one) *On the Inertial Nature of Harmonic Coordinates in General Relativity* dealt with the question originally raised and investigated by V. A. Fok himself, one of Alexandrov's teachers, who, by the way, was only 14 years elder than his student. Once, when Alexandrov came in Kazakhstan University, another one of his teachers, an older one, came to Almaty. It was Corresponding Member of the USSR Academy of Sciences B. N. Delone (1890–1980), and the moment I saw him I knew who gave Alexandrov his special intonation and expressiveness of speech. Later I worked together with B. N. Delone's daughter, A. B. Delone, in the Institute of Astrophysics of the Kazakhstan Academy of Sciences in Alma-Ata.

[1] V. A. Fok (1898–1974).

As Alexadrov himself admitted, his ideal of industriousness was his father, Danila Alexandrovich Alexandrov, director of a gymnasium. He worked till late hours, was never proud of his noble origin and was eager to lecture in auditoriums and working class clubs.

Like Alexandrov, I had two teachers: Alexandr Danilovich and Academician Vasilii Grigorievich Fesenkov (1889–1972), who in the hard years accepted me as his postgraduate student in the Institute of Astophysics of the Kazakhstan Academy of Sciences and then made me his successor in the institute. Both of us—Alexandrov and myself—made our choice and specialization at last under the continuing influence of our second Teacher, but could not help feeling gratitude to the first. What one gets in one's green years remains with one for the rest of one's life, although one cannot always realize it.

As science progresses its scale is systematically growing in geometric progression, and it is becoming more and more difficult to grasp the full of it. One cannot help turning to the sources of science, to its beginning, and analyze them closer. It is not only the famous biblical saying: "In the beginning was the Word" (the Gospel of John).

Alongside with the basic meaning of the popular but extremely poly-semantic and rather conventional verbal language it should be taken into consideration that the real ultimately refined and universal, and at the same time quite definite (or monosemantic and unconditional) language is that of mathematics. It must be noted in this connection that geometry is first and foremost thought of as this kind of language, although geometry is characterized by the principle of ambivalence of corresponding ultimate concepts—points and platitudes, as well as by Heisenberg's uncertainty principle or Bohr's principle of complementarity in physics and the whole of natural sciences.

It is not without reason that the motto of the Plato's famous Academy was "Let none but geometers enter here." Hence the necessity to turn again and again to Euclid's *Elements*, to Newton's *Mathematical Principles of Natural Philosophy*," to Einstein's special relativity. By the way, in 1959 Alexandrov wrote an article *Relativity as the Theory of Absolute Space-Time*, which dealt with axiomatic cause-effect foundations of the latter.

As Immanuel Kant wrote in his *Metaphysical Foundations of Natural Science* (1786), "natural science in the proper sense of the word suggests first and foremost the metaphysics of nature." At the same time, while dividing natural science (the science about nature) into a rational science in the proper sense of the word similar to mathematics (that is, the a priori pure fundamental science) and science in the transferred sense similar to systematic art (that is, empirical, applied science), he maintained that "any particular doctrine about nature contains as much science in the proper sense of the word as it contains mathematics."

Similarly, according to Paul Lafargue (1842–1911), Karl Marx (1818–1883) thought that "science only achieves perfection when it uses mathematics."

Natural science appears particularly effective when approached systematically and mathematically. Kant in his early but outstanding work on natural science *Universal Natural History and Theory of the Heavens or An Essay on the Constitution and the Mechanical Origin of the Entire Structure of the Universe Based on Newtonian Principles* (1755) made a rightful observation: "He who investigates various spheres of nature purposefully and regularly discovers such

properties which remain concealed and unnoticed when observations are made without order and system."

Of course there are systems and there are other systems; however, according to René Descartes (1598–1650), in the long run everything is interconnected:

> One should realize that all sciences are bound together so tightly that it is easier to study them in the aggregate than to treat any of the sciences separately. Consequently he who strives for perceiving truth must not choose a single discipline—for they are interconnected and interrelated—but care only for the increase of the natural light of reason, and the light of reason must be used not simply to solve various scholastic difficulties but to give man's will the power to guide him through everyday fortuity.

D. I. Mendeleev (1834–1907), who concentrated all his efforts on chemistry which, according to Kant, was a systematized art rather than a science in the proper sense of the word, and who was the first to suggest the periodic table of elements, had a right to say: "It's easy to say anything, but one should also be able to prove one's point!"

Atoms of chemical elements made scientists remember the ancient hypothesis that runs through the whole history of natural science already since Leucippus, Democritus, and Plato.

Natural science is actually impossible without the notion of regular—correct—disposition of elements. It was therefore only natural for Plato to equate the traditional four Pythagorean elements (air, earth, fire and water) and one extra substance (distillation "ether") with five known rectilinear convex polyhedrons (tetrahedron, octahedron, icosahedron, cube, and dodecahedron). Plato even maintained that elements can transform into each other while retaining their identical rectilinear convex "triangular" surfaces (something like the theory of conservation of energy!). However, the cube with its square faces and the dodecahedron with its pentagonal faces obviously dropped out of Plato's system of transformation of solids into each other.

In fact not only Plato's solids can be regular—symmetric in all dimensions. The corresponding nonconvex polyhedra, also five in number, are regular too (taking into account the Pacioli—Kepler stellated octahedron which consists of two crossed tetrahedrons and usually is not treated as separate rectilinear polyhedron). Among those ten regular convex and nonconvex polyhedra five (tetrahedron, convex and nonconvex octahedrons and icosahedrons) have identical triangular surfaces. Consequently they can transform into each other.

By the way, as it was shown by the author of this article, the ten solids mentioned above heuristically correspond to the most stable atomic nuclei, electronic atom shells and all typical features of periodic classification of the elements right up to the so-called magic numbers that connote stable atomic and nuclear structures.

Furthermore, on every of the four possible levels of natural selforganization of substance (i.e. physical, chemical, biological, and mental levels) cyclically enclosed periodical systems, analogous in terms of their symmetry and deductively determined due to indispensable mathematical induction of fundamental structural elements of substance begin with the most symmetrical initial system of elementary particles (leptons) and subatomic particles (quarks and antiquarks) whose various charges (colour, electric, and weak) in a certain charge space are set at the corresponding apexes of those four regular convex octahedrons.

The author of this article unintentionally became interested in regular convex polyhedrons apparently at Alma-Ata geometrical seminar based on Alexandrov's monograph *Convex Polyhedra*. At that seminar not only convex polyhedrons were considered but also some regular non-convex polyhedrons were used as visual aids.

Regular convex and nonconvex polyhedra with identical triangular faces are associated with the initial concept of atoms (the indivisible elements of nature that can transform into each other); moreover, they serve as invariants of certain discontinuous transformations (quantum transitions).

It is not without reason that Richard Feynman (1918–1988) in his famous course of lectures paid special attention to the atomic hypothesis which runs through the whole history of natural science:

> If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis (or the atomic fact, or whatever you wish to call it) that all things are made of atoms—tiny particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling if squeezed into one another. In that one sentence, there is an enormous amount of information about the world, if just a little imagination and thinking are applied.

I still remember many episodes of Academician Alexandrov's life. He is as clear in my mind as he was when I sent him the following lines written to his seventy-fifth anniversary:

THE TEACHER
To Academician
ALEXANDR DANILOVICH ALEXANDROV,
my wife's scientific supervisor in her diploma
paper and candidate dissertation,
to our Teacher and old friend of ours,
on his 75th birthday.

What is this vision?
The marvel of being,
Constantly moving,
Climbing, ascending;
Always in search for
The truth and the meaning:
General history,
Ancient aporiae,
Axiomatics of
All mathematics,
Physical principles,
Lyrical sources,
Morals and ethics,
Modern genetics—
All polyhedral
Vividly given
Interconnected
Areas of knowledge.
Incessant, insistent
In thinking and feeling.
Your cross to bear is
The gift of creation,
The torture of daring,
The thirst for knowledge,
The power of longing.
Each peak that you conquer
Makes you see everything
Which is around you
Clearer, distinctly.
But in a moment,
Like a sign or an omen,
There distantly rises
A new peak.
Farther and further,
Over rocks and steep slopes,
Under landslides and stonefalls,
You're headed towards it,
If only not down!

Alexandr Danilovich used to say that "mountain climbing (like life itself) is not a worship for peaks but a conquest of them." He did not worship anything but

truth. At the same time alongside with vital and concrete scientific questions he was always concerned with eternal problems of existence and relationship between science and morality: could morality be scientific or science moral? In 1974 he published a special brochure on this problem: *Scientific Research and Religious Faith*. During my studies of interrelated periodical (cyclically enclosed) systems of fundamental structural elements of substance, presented at four levels of its natural self-organization (physical, chemical, biological, and mental levels), I came to think that there must exist initial—zero—elements with zero values of main characteristics. Such elements must exist at each of the four levels beginning with neutrino (though ignored by physicists for a long time), neutron and antineutron elements of substance still neglected by chemists (though there proved to exist neutron stars) and finally Supreme Reason or Absolute Spirit whose existence was violently denied by orthodox materialists. The first one to share my ideas was Alexandr Danilovich. Just like his father he was a confirmed atheist and got nothing on faith (although as V. I. Vernadsky (1863–1945) had rightly noticed atheism is also a fact of faith). Being no "militant atheist," unlike many of our pseudoscientific journalists, philosophers, and some physicists who deny everything that does not fit the Procrustean bed of orthodox scientific concepts, Alexandr Danilovich did not regard my views as some kind of gibberish. On the other hand, he confided to me that once he had a heavenly vision (a cross); he treated it as an omen of all his misfortunes being deserved by himself (by the way the same thing he told Marianna Leonidovna later).

Corresponding and symmetrically similar definite periodic systems can be deductively defined due to indispensable mathematical induction; moreover, they turn to be cyclically enclosed and not only each taken separately but also as a whole. All these ideas are included in my original syllabus *The Concepts of Contemporary Natural Sciences* (1997) and in some other books on the same subject: *Natural Sciences* (1996) and *The Biography and Genealogy of the Electron* (1997). Actually, the so-called "main issue of philosophy" of whether matter is primary to spirit or vice versa becomes irrelevant. They coexist and cyclically transform into each other. The answer to the question about their relations can therefore resemble the dialectical principle statement of Alexandrov, which Yu. F. Borisov adduces in his memoires: "One of the last statements Alexandr Danilovich made on existential problems was that matter is fundamental and spirit is primary." By the way, the recently deceased B. V. Raushenbach (1915–2001) shared the same idea when talking about the dualism of matter and spirit.

Since the course *The Concepts of Contemporary Natural Sciences* became compulsory for all humanitarian departments of colleges more than a hundred of manuals by different authors have been published in this country. Still one of the best introductions to that course are Alexandrov's "Discussions on the History of Science" written by him as far back as 1971 while preparing the course of lectures on the history of science at Novosibirsk University (published in 1988) and the three studies: *Science from Its Birth to the Present Time*, *Rise of the Modern Science*, and *Science of Today*. These works are published in the supplement to the Russian edition of the collection of articles in memory of A. D. Alexandrov.

As he got older his charm got no weaker. No matter whether he looks back at human history staying by the Pyramid of Khufu after having returned from India via Egypt, or represented as a patriarch in the vast expanses of his land, or

as a mountain-climber, swinger, scientist, tribune, or thinker—in all his photos he invariably arouses admiration.

Having become the rector of Leningrad State University A. D. Alexandrov (according to his personal records) visited foreign countries 17 times altogether.

1. Italy. September, 1953. A conference on differential geometry.
2. Denmark. December, 1954. Lectures at the University of Copenhagen.
3. GDR. January, 1955. A conference on relativity.
4. Poland. May, 1955. Anniversary of Warsaw University.
5. Switzerland. 1956, June, 1955. A conference on relativity.
6. India. February, 1956. A conference on mathematical education.
7. Italy. March, 1957. Cultural delegation, Conference Italy–USSR.
8. Canada. July–August, 1957. Lectures at summer school.
9. England. September, 1958. Mathematical congress.
10. USA. April, 1959. Delegation to Harvard University.
11. India. January, 1960. A conference on mathematical education.
12. Italy. 1961. Boltzan prize committee.
13. Italy. March, 1961. Political delegation.
14. Switzerland; Italy. March, 1962. Bolzano prize committee and lectures in Rome.
15. Switzerland. June, 1963. Conference on differential geometry.
16. Greece. November, 1963. Delegation.
17. India. December, 1964. UNESCO lectures.

After he was forced to resign his post of the rector had to move to Siberia to the Siberian Division of the Academy of Sciences of the USSR for almost a quarter of a century. In August 1966 he managed to visit the Czechoslovak Republic (conference on differential equations); after that he in fact was prohibited to leave this country. In 1975 he was elected a member of the eldest Italian National Academy of Sciences of the Forty (XL) which was found as far back as 1782. Only in 1990 Academician Alexandrov got an opportunity to come to Rome to a session of the Academy of Sciences of the Forty.

Григорий Моисеевич Идлис (1928–2010)