

Mikhail Lomonosov

and the dawn of Russian science

Vladimir Shiltsev

**Curiously unsung in the West,
Lomonosov broke ground
in physics, chemistry, and
astronomy; won acclaim
as a poet and historian;
and was a key figure of
the Russian Enlightenment.**

Figure 1. Mikhail Vasilevich Lomonosov, 1711–65. (From the collection of the Peter the Great Museum of Anthropology and Ethnography [Kunstkamera], MJ1-41, Russian Academy of Sciences.)



On 7 December 1730, a tall, physically fit 19-year-old, the son of a peasant-turned-fisherman, ran away from his hometown, a village near the northern Russian city of Archangel. His departure had been quietly arranged. He had borrowed three rubles and a warm jacket from a neighbor, and he carried with him his two most treasured books, *Grammatica* and *Arithmetica*. He persuaded the captain of a sleigh convoy carrying frozen fish to let him ride along to Moscow, where he was to fulfill his dream of studying “sciences.” He left behind a kind but illiterate father, a wicked and jealous stepmother, prospects of an arranged marriage into a family of means, and his would-be inheritance—a two-mast sailboat named *Seagull*. The young man’s name was Mikhail Vasilevich Lomonosov (figure 1).

He thought that ahead of him lay a month-long trek along a snowy, 800-mile route. In fact, it was the beginning of a much longer journey that would usher in the modern era of Russian science. Young Lomonosov couldn’t have known that after years of hardship and a decade of scientific training, he would become the first Russian-born member of the Saint Petersburg Academy of Sciences, a nobleman, and Russia’s most accomplished polymath. And although his name was forgotten in scientific circles for nearly 50 years, he has reemerged during the past two centuries as a cult figure in Russian science.

Russia’s native son

Lomonosov was born 19 November 1711 into a family of peasants of the state. His mother died when he was nine, and his stepmothers despised his adoration of the village’s few available books, including the Bible and *Lives of the Saints*, both of which he had learned to read in the village’s church. Reading, they claimed, distracted him from being a proper help to his father.

Not long after Lomonosov’s departure, his father tracked him down in Moscow at the boarding school of the Spassky Monastery, where he had been admitted under the false pretense that he was the son of a nobleman. His father asked him to come back, but the young runaway chose instead to continue his studies, even though that meant half-starving on a daily stipend of three kopeks—roughly \$4 today—and being ridiculed for being considerably older than his classmates. In four years he had nearly finished an eight-year course in Latin, Greek, Church Slavonic, geography, history, and philosophy, but when his true parentage was revealed, he was threatened with expulsion. It was only by virtue of his impressive academic record that he was allowed to continue the course, and in 1736 he was transferred as one of 12 top students to continue his education at the Saint Petersburg Academy of Sciences.

Lomonosov’s talents were quickly recognized at the academy as well, and in the fall of 1736, he

and two other students were sent to the University of Marburg in Germany. For three years he studied natural sciences and mathematics with Christian Wolff, a renowned encyclopedic scientist, philosopher, and epigone of Gottfried Leibniz. (On his own initiative, Lomonosov also studied German, French, art, dance, and fencing.) From Wolff he acquired a logical, schematic style of scientific thought, which served him well throughout his life.

In the summer of 1739, Lomonosov and his classmates traveled to Freiberg, Germany, to study practical mining with Johann Henckel. Within a year, having acquired a great deal of knowledge about mineralogy and metallurgy, Lomonosov left Freiberg and spent a large part of 1740 chasing the Russian ambassador through Germany and Holland in search of funds to return to Russia. Later that year, in Marburg, he married Elizabeth Zilch. In 1741 Lomonosov returned to Russia and was appointed an adjunct professor of physics at the academy, an institution with which he would remain affiliated until his death on 4 April 1765.

The Saint Petersburg Academy of Sciences was founded in 1724 by a decree of Emperor Peter the Great. In its early days, it consisted of a dozen or so academicians (or professors) and a similar number of adjuncts instructing in the natural sciences, rhetoric, history, and law. Fully supported by the state, the academy enjoyed auspicious beginnings; its liberal scientific environment and more-than-generous salaries resulted in the influx of the highest-caliber scholars. Daniel Bernoulli and Leonhard Euler were the most notable of the first wave of faculty members. The ultimate goals of the academy were to train Russian scientists and to establish the country’s science and education. In its infancy, however, the academy was dominated by foreign-born scientists and, due to continual budget issues, limited in its educational activities.

By the time of Lomonosov’s arrival, the academy was in a state of crisis due to financial problems, bureaucratic infighting, and the departure of Euler, Bernoulli, Joseph Nicholas Delisle, and other luminaries. The task of educating Russian students had been mostly neglected, and by the end of its second decade, the academy had only three Russian adjuncts. Lomonosov, elected an academican in 1745 and later appointed to the academy’s triumvirate chancellery, fought hard to improve the situation. He succeeded in increasing the number of scientific publications and lectures in Russian, as opposed to Latin or German; recruiting more Russian interns and students to the academy’s gymnasium; and by 1765 bringing the number of Russian-born faculty up to 10, including 7 academicians.

A corpuscular world

As a scientist, Lomonosov was equal parts thinker and experimenter. He tested his theories and hypotheses

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Figure 2. Circulating atmospheric flows like the ones depicted in this 1753 sketch were speculated by Mikhail Lomonosov to be the root cause of lightning. He conjectured that friction between warm updrafts and cool downdrafts caused charge to accumulate on microscopic atmospheric particles. (Adapted from ref. 6.)

with experiments that he planned and carried out himself. Although proficient in math, he never used differential calculus. He would work on research topics for years, even decades at a time, always with an eye toward turning discoveries into new practices or inventions.

Lomonosov believed physical and chemical phenomena were best explained in terms of the mechanical interactions of corpuscles—“minute, insensible particles” analogous to what we now know as molecules.¹ Giving name to the philosophy, he coined the term “physical chemistry” in 1752.

He is perhaps best known for being the first person to experimentally confirm the law of conservation of matter. That metals gain weight when heated—now a well-known consequence of oxidation—confounded British chemist Robert Boyle, who had famously observed the effect in 1673. The result seemed to implicate that heat itself was a kind of matter. In 1756 Lomonosov disproved that notion by demonstrating that when lead plates are heated inside an airtight vessel, the collective weight of the vessel and its contents stays constant. In a subsequent letter to Euler, he framed the result in terms of a broad philosophy of conservation:

All changes that we encounter in nature proceed so that . . . however much matter is added to any body, as much is taken away from another . . . since this is the general law of nature, it is also found in the rules of motion: a body loses as much motion as it gives to another body.

In analogous experiments 17 years later, French chemist Antoine Lavoisier progressed further, showing that the increase in the weight of the metal is exactly offset by a reduction in the weight of the air’s oxygen. But contrary to Lavoisier, who considered heat to be a “subtle caloric liquid,” Lomonosov understood it more accurately as a measure of the linear and rotational motion of corpuscles. In 1745,

more than a century before Lord Kelvin introduced the absolute temperature scale, Lomonosov proposed the concept of absolute cold as the point at which corpuscles neither move nor rotate.

The corpuscular framework also led the Russian scientist to correctly predict a deviation from Boyle’s law: Because the particles themselves occupy a certain volume of space, argued Lomonosov, the air pressure wouldn’t remain inversely proportional to the gas volume at high pressures. Lomonosov’s deductions presaged molecular kinetic theory, which wouldn’t be fully developed until the 19th century.^{2,3}

Electricity in the air

Lomonosov began studying electricity with Georg Wilhelm Richmann in late 1744. Together, they pioneered a quantitative approach: Lomonosov had proposed a technique that called for measuring an object’s charge based on the electrostatic forces it exerts on a metal scale; Richmann’s simpler but more effective invention, a silk thread connected to a vertical metal rod, might be considered the first electrometer. The angle of the thread’s tilt gave a measure of the rod’s charge.

In 1753 their progress in understanding atmospheric electricity suffered a tragic interruption. While performing an experiment in a heavy thunderstorm, Richmann was killed by ball lightning.

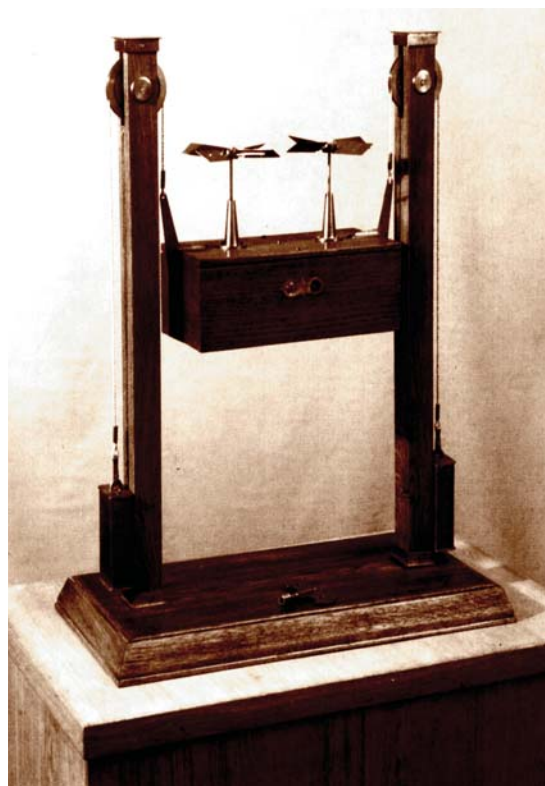


Figure 3. A modern-day reconstruction of Mikhail Lomonosov’s “aerodynamic machine,” which he had hoped to use to loft meteorological instruments into the sky. In a 1754 demonstration, Lomonosov’s contraption mustered a lift force of about 0.1 N but never made it far off the ground.

Lomonosov, who had been simultaneously performing a nearly identical experiment just three blocks away, reported having “miraculously survived” thanks to being momentarily distracted by his wife.

To prevent the impending cessation of the academy’s atmospheric-electricity studies and to eulogize his friend, Lomonosov wrote *A Word on Atmospheric Phenomena Proceeding from Electrical Force*. In it, he theorized that lightning was electricity generated by friction between warm, upward-flowing air and cool, downward-flowing air, with the electric charge accumulating on “oily” microparticles (see figure 2). He described the vertical drafts as resulting from air-density gradients, which he could estimate based on temperature and pressure profiles. All of that marked an advance beyond Benjamin Franklin’s earlier discovery of the connection between lightning and electricity. (See box 1 for a comparison of the two men’s lives.)

Looking to loft meteorological instruments and electrometers into the air, Lomonosov designed and built the contraption shown in figure 3. A forerunner to the helicopter, it boasted two propellers—powered by a clock spring—that rotated in opposite directions to balance out torque. During its demonstration to the academy in July 1754, the model managed to lift itself slightly, but no practical device emerged.

In 1756 Lomonosov compiled 127 notes on the theory of light and electricity, presented a mathematical theory of electricity, and in a public meeting of the academy read his paper on the wave nature of light and on a new theory of the colors that constitute light.

Venus’s atmosphere

The transit of Venus across the Sun’s disk on 6 June 1761 afforded a rare opportunity to measure the Earth-to-Sun distance using Edmond Halley’s method, which calls for comparing various apparent paths of the transit as measured from different Earth latitudes. As a leader of the academy, Lomonosov helped to organize a worldwide observation effort that included more than 170 astronomers dispatched to 117 stations, 4 of which were in Russia. He was alone, however, in having realized that a dense Venusian atmosphere, if one existed, would bend the Sun’s rays to produce a visible aureole, or ring of light, during the very beginning and very end—the ingress and egress—of the transit. Expecting the aureole to be faint, he viewed the ingress and egress using only a weak optical filter; to mitigate the considerable risk of damage to his vision, he observed the process in brief glimpses and only with well-rested eyes.

To his excitement, he observed an arc of light lining Venus’s shadow at the end of ingress and at the beginning of egress. Later, several other astronomers confirmed seeing the arc, but only Lomonosov recognized its significance. Within a month he published a report summarizing the observations and explaining how the atmosphere refracts light to produce the aureole, or “bulge,” as he called it (see figure 4). He proclaimed that “Venus

Box 1. The parallel lives of Lomonosov and Franklin

Mikhail Lomonosov is often compared with his American contemporary Benjamin Franklin; both are

considered scientific patriarchs and key figures of the enlightenments of their respective homelands. They each lived in the epoch of their nations’ emergence into Western civilization—Russia through wars and reforms initiated by Peter the Great, the American states through prerevolutionary developments and the War of Independence.

The biographical similarities between the two scientists are striking: Both devoted their lives to scientific observation and experiment, both made major discoveries regarding electricity and lightning, and both were deeply interested in public education. Lomonosov founded Russia’s first university and played a leading role in the Saint Petersburg Academy of Sciences; Franklin was the founder and first president of the American Philosophical Society. Both men tried to reform their languages’ grammars; Lomonosov succeeded, Franklin did not. And both were interested in geography: Lomonosov worked on finding an Arctic path to America; Franklin discovered the Atlantic Ocean’s Gulf Stream.

Lomonosov and Franklin are widely regarded as self-made men. Born into working-class families, both fled restrictive environments—and told lies as needed—in pursuit of opportunity. Both married their landlords’ daughters, unsophisticated women who did not share their husbands’ interests. Both were accomplished polymaths who rose to prestigious national rank, shaped their countries’ scientific cultures, and left enduring legacies. The religious views of Lomonosov, an enlightened Russian Orthodox who regarded God as a “wise clock-master,” were close to those of Franklin, a well-known deist.

Although they never met, the two men knew of each other, and each held the other’s scientific reputation in high regard. Lomonosov laboriously explained to his contemporaries the difference between his theory of atmospheric electricity and that of the “celebrated master Franklin.” Franklin advised Ezra Stiles, an amateur scientist and cofounder of Brown University, on how to best communicate with Lomonosov about temperature regimes in the Arctic Sea.

Franklin, however, enjoyed the advantages of being an Englishman (until 1776!) and a citizen of Philadelphia, perhaps the most liberal city in the world at the time. He flourished in a society that asserted, as a matter of principle, every man’s right to self-realization. Lomonosov, by contrast, lived in the backward society that defined Russia after Peter the Great. As one important Russian scholar put it, “Russia could not have produced a Franklin. But what an opportunity Lomonosov would have had, if he had been born in America!”⁹

is surrounded by a distinguished air atmosphere, similar (or even possibly larger) than the one around Earth.”⁴

In an addendum, Lomonosov suggested that there might be life on Venus—a possibility that he argued wasn’t necessarily at odds with the Bible. Moreover, he contended Venusians might not necessarily be Christians. It was a bold stance to take in 18th-century Russia, where just 20 years earlier the Holy Synod had gone out of its way to denounce as heresy the heliocentric Copernican model of the universe.

The academy quickly published 200 copies of Lomonosov’s report in German and sent them abroad in August 1761. Inexplicably, they went virtually unnoticed in Europe. Other astronomers, including American David Rittenhouse, made similar observations of the aureole during the 1769 transit. But for nearly two centuries, the discovery of Venus’s atmosphere was credited to German-born

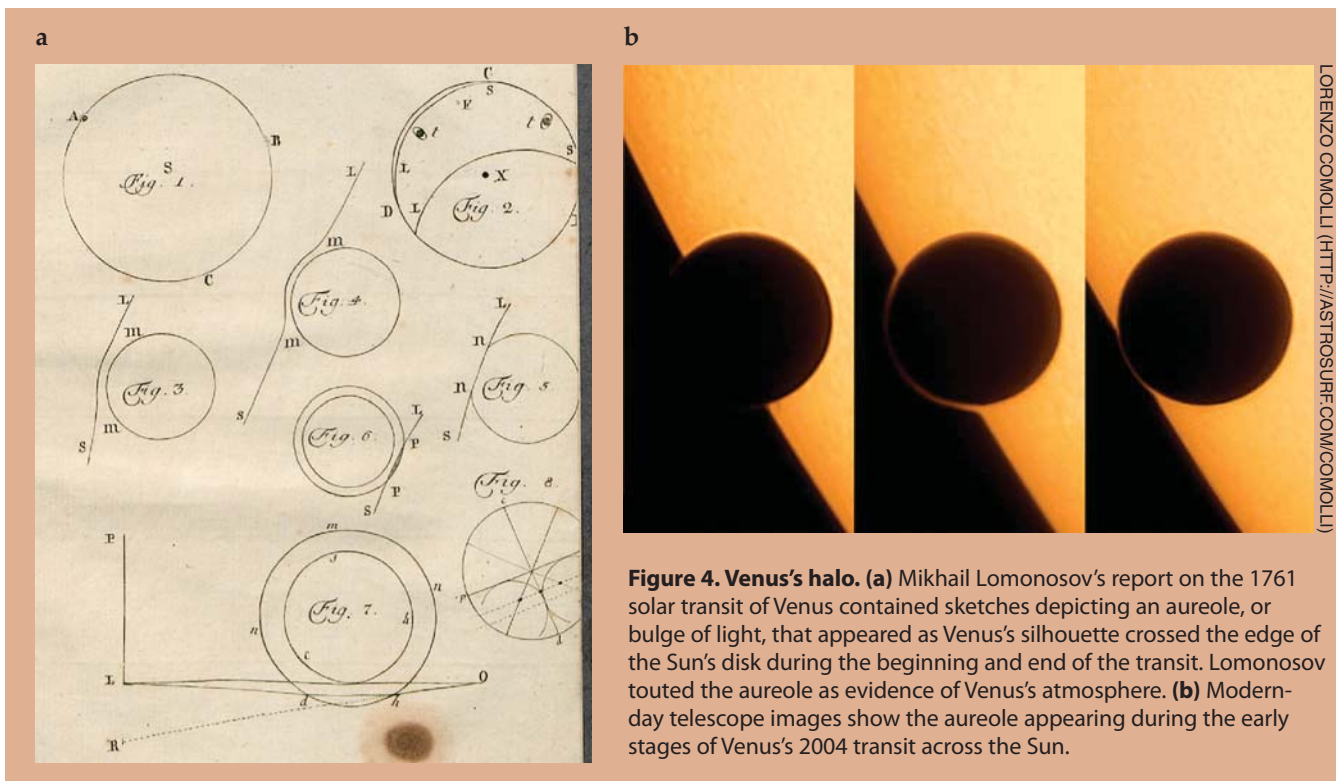


Figure 4. Venus's halo. (a) Mikhail Lomonosov's report on the 1761 solar transit of Venus contained sketches depicting an aureole, or bulge of light, that appeared as Venus's silhouette crossed the edge of the Sun's disk during the beginning and end of the transit. Lomonosov touted the aureole as evidence of Venus's atmosphere. (b) Modern-day telescope images show the aureole appearing during the early stages of Venus's 2004 transit across the Sun.

astronomers Johann Schröter and William Herschel, who—unaware of their predecessors' work—observed a different effect related to Venus's atmosphere in 1790. Lomonosov's priority wasn't widely acknowledged until the mid 20th century.

Similarly overlooked was Lomonosov's 1756 invention of a single-mirror reflecting telescope. Isaac Newton's reflecting telescope, invented a century prior, consisted of two mirrors: a curved primary one and a small, diagonally oriented secondary one that reflected the primary image into a viewing piece. But given the low reflectivity of the brass mirrors of the day, the two-mirror scheme presented a substantial cost to brightness. Lomonosov obviated the secondary mirror by tilting the primary mirror 4° so that it formed an image directly in a side eyepiece. In 1789, however, Herschel used a similar approach to build what was then the world's largest telescope, and what might have been appropriately known as a Lomonosov–Herschelian telescope is now named solely for Herschel.

Another of Lomonosov's inventions, the so-called night-vision tube, sparked so much controversy that his colleagues at the academy rushed to publish theoretical tracts proving its implausibility. Demonstrated in 1756 and used during the Russian navy's Arctic expeditions of 1765 and 1766, the simple telescope had just two lenses—to minimize optical loss—and a large objective aperture. Crucially, the short-focus lens at the eyepiece had a larger-than-usual diameter of about 8 mm, roughly the size of a fully dilated human pupil.⁵

His colleagues saw no novelty in the design. At first glance, Lomonosov's tube looked no different from the familiar Keplerian telescope, and it was well known that brightness can't be increased by

magnification. Lomonosov, however, argued that the device's increased optical flux actually had allowed him to see better in the dark. He invited his critics to test the apparatus for themselves, but they remained unconvinced. The controversy survived until 1877, when Ricco's law established that the minimum brightness detectable by a human eye is inversely proportional to the area of the image formed on the retina. Lomonosov was vindicated, and nowadays anyone can see the effect even with ordinary large-aperture binoculars.

During the severe winter of 1759, Lomonosov and colleague Joseph Adam Braun used a mixture of snow and nitric acid to chill a thermometer to -38°C and obtain—for the first time on record—solid mercury. Upon hammering the frozen metal ball, they found it to be elastic and hard "like a lead." Mercury, shrouded in mystique at the time, was shown to be not all that dissimilar to the more common metals. It was among the most widely discussed discoveries in Europe.

A firm, lifelong believer in corpuscular mechanics, Lomonosov was suspicious of Newton's gravity and its action at a distance. The Russian spent the last five years of his life carrying out pendulum experiments in a futile attempt to overthrow it; his efforts were documented in hundreds of pages of logbook notes.

A peculiar polymath

At more than six feet four inches tall and physically strong, Lomonosov reminded many of his idol, Peter the Great. Anecdotes of the scientist's exploits depict a daring existence. He and two other Russian interns are said to have so out-reveled German students in Marburg that the city sighed with relief

when the trio left for Freiberg. German hussars once got him drunk and enlisted in the Prussian army, which he later escaped. And as a 50-year-old academician, he once fought off three unlucky sailors attempting to rob him; he beat the men and stripped them of their clothes.

Lomonosov was also known to argue fiercely with inept colleagues at the academy. For one quarrel that ended in physical violence, he paid dearly. Then just an adjunct, his salary was halved, he was placed under house arrest for eight months—one of the most scientifically productive periods of his life, he later noted—and he was freed only after a public apology. Lomonosov's hot temper and rebellious character were integral to his rise as a legendary figure, as were his immense self-esteem and dignity, rare traits in imperial Russia.

He once admonished his patron, Count Ivan Shuvalov, saying, "Not only do I not wish to be a court fool at the table of lords and such earthy rulers, but even of the Lord God himself, who gave me my wit until he sees fit to take it away." Had it been said to a less-enlightened count, such a statement might have been met with severe repercussions. Shuvalov, however, remained a lifelong friend. It was he who embraced Lomonosov's character of the first Russian university and who convinced Empress Elizabeth to sign a decree establishing Moscow University on 25 January 1755, a day still celebrated annually in Russia as Students' Day.

The university offered education to a wide stratum of Russian society and was key to the country's intellectual progress. In 1940 it was named after Lomonosov.

Originally, Lomonosov was recognized mainly as a historian, reformer of Russian grammar, rhetorician, and poet. His eulogistic odes to empresses were well accepted at the court. One of them earned him 2000 rubles, three times his annual academic salary at the time. For almost a century, Lomonosov's poetry overshadowed his natural philosophy—not only abroad, where his science often failed to make an impact, but even in Russia.

As Lomonosov himself used to say, however, "Poetry is my solace; physics, my profession." With a 1500-ruble grant from the Russian senate, he set up Russia's first research chemical laboratory, which he led for eight years. He also won a 4000-ruble grant to start a mosaic factory and, subsequently, an 80 000-ruble commission (roughly \$12 million today) to create 17 mosaics celebrating the deeds of Peter the Great. Only one was finished before he died—the grandiose *Battle of Poltava*, now displayed in the Russian Academy of Sciences.

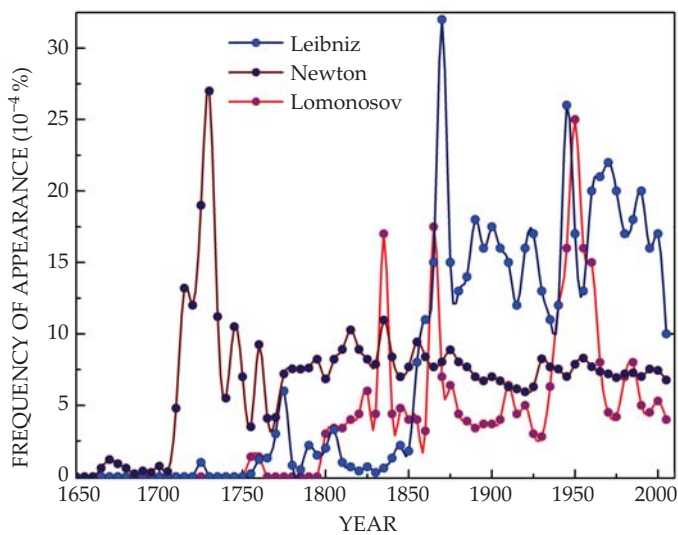
Only in the mid 19th century did his scientific accomplishments begin to be fully appreciated in Russia and abroad. Through the works of Boris Menshutkin,² Nikolai Vavilov,⁶ Nobel laureate Peter Kapitza,⁷ and many others, Lomonosov has reemerged as the most renowned figure in Russian

Box 2. Genius, society, and time

The chart shown here illustrates the evolving popularities of Gottfried Leibniz, Isaac Newton, and Mikhail Lomonosov—the three key figures of the national enlightenments of Germany, England, and Russia, respectively. The plot shows the frequency of appearances of each man's last name as a fraction of the sum total of words published in his native language in a given year. By that metric, the three men are the most frequently recurring names among representatives of the natural sciences, and the chart illustrates their unique paths to fame.

Newton (1642–1727) enjoyed enormous recognition during his lifetime, a peak in celebrity during the decade right after his death, and then centuries of posthumous recognition. Leibniz (1646–1716) rose to fame in more dramatic fashion. Presumably due to having lost the argument with Newton over priority in developing differential calculus, Leibniz went unrecognized for almost 150 years after his death. Not until the second half of the 19th century, when a unified German state was created, did he gain fame. Since then, Leibniz's prominence in the literature of his native tongue is unrivaled by any other scientist, likely owing to consistent scientific awareness on the part of German society.

Lomonosov (1711–65) rose to prominence via an equally remarkable path. He was posthumously forgotten in the Russian literature for some 40 years but then reemerged in the early 1800s during Russia's cultural awakening, of which the appearance of renowned author Alexander Pushkin was the climax. Since then, Lomonosov has consistently been the most fre-



quently mentioned scientist in the Russian literature, followed by Dmitri Mendeleev, creator of the periodic table, and Nobel laureate Ivan Pavlov, pioneer in understanding physiological reflex mechanisms.

Lomonosov's peaks in popularity during the 1860s and 1950s correspond to publicity campaigns—the most recent initiated by Joseph Stalin to popularize science and technology and to venerate Russia's scientific heritage. Notably, those brief surges did not change the baseline level of Lomonosov's popularity. The true value of a person in a nation's eyes, it would seem, holds steady through the decades and centuries. (Chart produced using Google's Ngram Viewer. See ref. 10.)

science (see box 2). Among his namesakes are a city, an Arctic ridge, lunar and Martian craters, a porcelain factory, and a mineral.

The complete works⁶ of Lomonosov consist of four volumes on physics, chemistry, and astronomy; two on mineralogy, metallurgy, geology, Russian history, economics, and geography; two on philology, poetry, and prose; and three of correspondence, letters, and translations. Lomonosov's tercentennial in 2011 was celebrated statewide by a decree of the Russian president.

How could such an accomplished figure remain so obscure for so long? Kapitza pointed to Russia's relatively primitive scientific society, in which few people could appreciate Lomonosov's genius, and to Lomonosov's weak personal connections with most influential European scientists. Lomonosov never left Russia after he was a student, and he had a sustained exchange of ideas only with Euler, who was in Berlin at the time.⁷ Robert Crease adds that polymaths tend to be underappreciated due to their breadth, a shortcoming in the eyes of the public, and that Lomonosov in particular was rarely written about in English.⁸ Also, Lomonosov lived a relatively short life; he died at age 53, while many of his contemporaries, including Newton, Bernoulli, Franklin, and Herschel, lived to see 70, 80, or more. Moreover, he chose to divert much of his energy into promoting Russia's science and education and modernizing its industry and military.

Another factor bears consideration: Lomonosov's natural philosophy was based on Cartesian explanations of mechanical models,

whereas his European counterparts at the time were increasingly turning to Newtonian-inspired reasoning that relied on caloric, electric, and other "imponderable fluids." (Euler was an exception.) Only 19th-century physics, buttressed by the mechanical theory of heat and wave optics, provided the requisite background to appreciate Lomonosov's discoveries and ideas.

This article is an edited version of a talk given at Fermilab in November 2011 on the occasion of Mikhail Lomonosov's tercentennial anniversary.

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