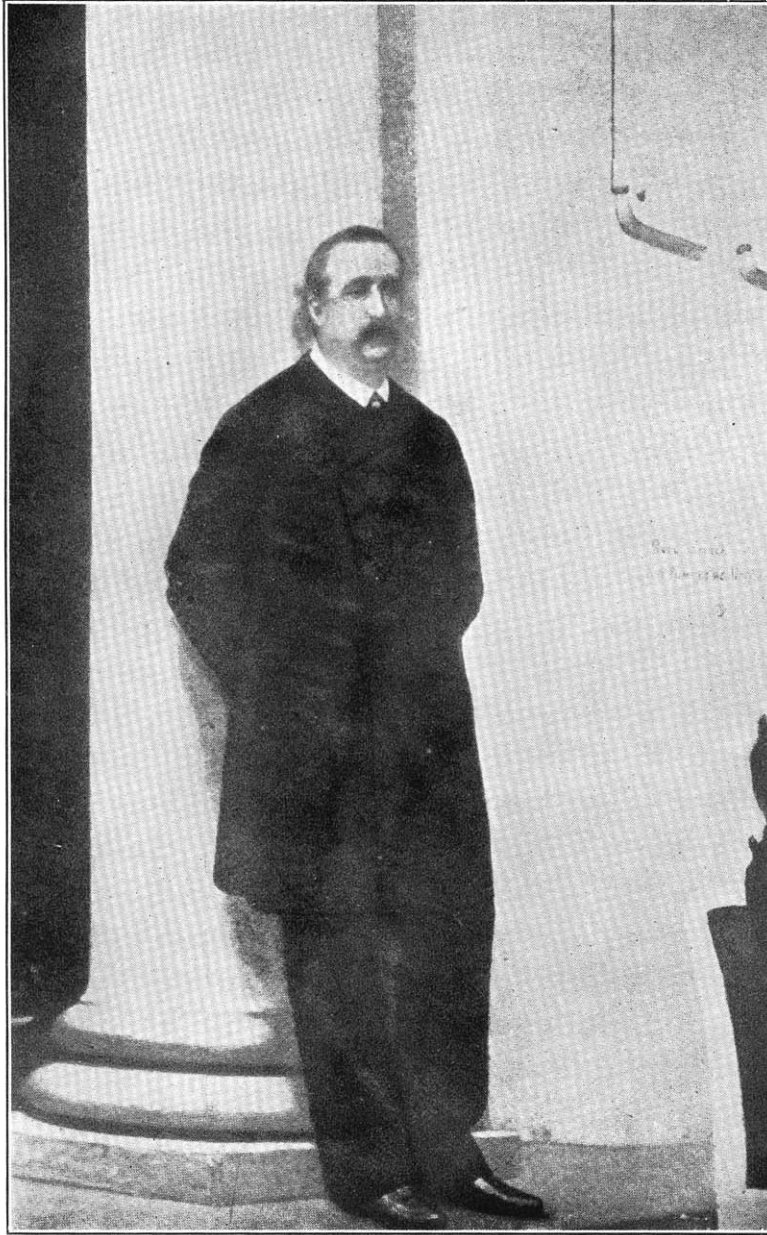


Alexander Borodin

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PORTRAIT OF BORODIN FROM PAINTING BY RYEPIN

ALEXANDER BORODIN—CHEMIST AND MUSICIAN

FREDERICK H. GETMAN, HILLSIDE LABORATORY, STAMFORD, CONNECTICUT

Alexander Borodin (1834–87) although better known as a composer was educated as a physician and entered upon the career of a chemist. He became professor of chemistry in the Medical Academy in St. Petersburg where he spent fifteen fruitful years in the pursuit of chemical research and in training young men to become chemists. Endowed with exceptional musical talent, which had been carefully cultivated from boyhood, he produced during the spare hours of his mature years many works of musical art which are conceded to rank with the best compositions of the nineteenth century. He was also closely identified with various philanthropic causes, chief among which was the movement to secure for the women of Russia the privileges of university education.

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“Who can lead two lives at once?” was the question which the young musician, William Herschel, asked himself when, as organist of the Octagon Chapel at Bath, he began to realize that his earlier love for music was gradually being supplanted by an absorbing interest in astronomy. Even though Herschel became convinced of the impossibility of such a dual existence, and despite Pope’s conclusion that

“One science only will one genius fit:
So vast is art, so narrow human wit,”

Alexander Borodin was able to say in middle life that “he loved chemistry as much as he did music.” Although a chemist by profession he found time to cultivate his remarkable talent for music without apparent detriment to his scientific studies. At first it may seem strange that a mind which was attracted to an exact science, such as chemistry, should also be susceptible to the subtle appeal of an art like music. Yet, as one of his biographers has said: “This stimulating imaginative quality in Borodin’s chosen scientific field is not, after all, so greatly in contradiction to his musical temperament.”

Although Borodin is undoubtedly more widely known as a musician than as a chemist, it is nevertheless true that he never regarded music as more than an avocation, while chemistry was the subject to which he devoted himself assiduously throughout his intensely active life.

Alexander Porfirievitch Borodin was born in St. Petersburg on November 12, 1834, as the natural son of Prince Guedeanoff, a descendant of the hereditary kings of Imeretia. At the time of his birth his father was sixty-two and his mother twenty-five years of age. From these parents the child inherited the delicate constitution which proved a handicap throughout his life. It is of interest to note that just nine months before the birth of Borodin, Dmitri Ivanovitch Mendeléeff was born in Tobolsk,

Siberia. While Borodin came of royal lineage, Mendeléeff's heritage was most humble. Notwithstanding the differences in their circumstances, the two lads were destined to be thrown together as fellow students and later, through exceptionally brilliant careers, to reflect glory upon their native land.

Imeretia, the birth-place of Borodin's father, was an independent kingdom of Georgia lying south of the Caucasus Mountains between the Black and Caspian Seas. Prior to its annexation to Russia in 1810, it constituted a part of the governments of Tiflis and Kutais. The kings of Imeretia traced their lineage backward to King David; in fact the sling with which David slew Goliath, the Philistine, and the harp with which he calmed the perturbed spirit of Saul, adorned the ancient coat-of-arms of the kings of Imeretia. Who shall say that Borodin's musical gifts may not have come down to him through uncounted generations from the simple shepherd of Israel who is accredited with having been "a cunning player on the harp"? Certain it is, that to the racial stock from which Borodin sprang can be traced many of his oriental instincts together with his gift for creating exotic melodies fraught with the atmosphere of the East. Borodin's father, as a scion of Imeretian royalty, was the recipient of a liberal pension from the Russian government and was thus enabled to live a life of leisure and to devote himself to cultivating young Alexander's marked musical talent. At the early age of nine the boy began composing, and at the age of thirteen had written a concerto for flute and piano, as well as a trio for two violins and 'cello, based on themes from one of Meyerbeer's operas. He not only learned to play the piano, but also mastered the flute and violincello, and could perform creditably upon both the oboe and clarinet as well as upon several of the brass instruments. The father apparently felt that a youth of royal lineage should not enter upon a musical career and, therefore, determined that his son should be trained for the profession of medicine. Accordingly young Borodin was sent to school to prepare for his professional studies. Among the boy's classmates was a lad by the name of Schtchigleff who later became a successful teacher of music. At this time young Schtchigleff was a little prodigy and in the interval between chemistry lessons the two boys would hasten to the piano and play the symphonies of Haydn and Beethoven in duet arrangements. In due time Borodin was enrolled as a student in the Medico-Surgical Academy of the University of St. Petersburg. Notwithstanding the fact that his program of studies was a full one, he found time to attend concerts and to continue his practice of the flute and violincello. During his career as a student in the medical school it is recorded that on one occasion his love for music led him to absent himself from his classes for an entire day, and to devote nearly twenty-four hours to the uninterrupted performance of chamber music. For this he was severely reprimanded by his professor

of chemistry who charged him with "trying to hunt two hares at the same time"! This professor, none other than Zinin, the well-known organic chemist, had already recognized Borodin's natural ability and later came to regard him almost as an adopted son. Deeply conscious of the justice of Zinin's reprimand, Borodin threw himself into his work with redoubled energy and soon regained the good opinion of his teacher. Although a number of his professors feared that his passion for music might seriously hinder his success in his chosen profession, he was duly appointed surgeon to an army hospital in 1856, and two years later, at the age of twenty-four, received the degree of doctor of medicine. After a brief period of practice, Borodin was appointed to the chair of chemistry in his alma mater and shortly afterward, along with Mendeléeff and several other Russian scientific students, was sent to Europe to study chemistry under some of the eminent masters of the science.

Borodin entered upon his post-graduate studies at a time when many of the chemical doctrines which he had been taught to accept were being supplanted by newer theories. Thus, Kekulé's views on valence were rapidly taking the place of the then familiar type theory, while Cannizzaro was making his eloquent plea for the universal acceptance of Avogadro's hypothesis as a basis for a rational system of both atomic and molecular weights. Borodin and his Russian companions made their way to Heidelberg where Bunsen and Kirchoff were then perfecting their spectroscope; where Roscoe, under Bunsen's direction, was carrying out his pioneer work in the realm of photochemistry; and where Kekulé and Erlenmeyer were conducting brilliant investigations in organic chemistry. Among the young men enrolled at Heidelberg at this time, who were destined to become eminent chemists, may be mentioned Baeyer, Volhard, Lothar Meyer, Beilstein, and Quincke. With this interesting group of scientific students the young Russians were privileged to associate. Mendeléeff, with characteristic eccentricity, did not work in the university laboratory, but established a small private laboratory of his own where he occupied himself with the determination of physical constants of different chemical compounds, apparently securing data upon which to base certain of the striking predictions he was later to make in connection with his enunciation of the periodic law. Borodin pursued the study of organic chemistry under Kekulé and Erlenmeyer, presumably according to Zinin's advice. He remained in Europe for three years, the greater part of which were spent in Heidelberg. During the vacations the young Russians, with knapsacks strapped to their backs, tramped far and wide. Mendeléeff gives an interesting account in his diary of one of these nomadic excursions. Thus, he wrote:

We started with light baggage, one knapsack between two of us; we wore blouses and tried to pass ourselves off as artists, which, in Italy is always advantageous to the

traveller's purse. We bought ourselves linen en route, and when it became soiled left it by way of tips to the waiters. In this manner we visited Venice, Verona and Milan in the spring of 1860, and Genoa and Rome in the autumn of the same year. On our first trip we had an interesting adventure. Near Verona, our carriage was visited by the Austrian police in search of an Italian prisoner who had made his escape. Borodin's southern type attracted the attention of the police who believed they had found in him the man they were seeking. They ransacked our luggage from top to bottom and questioned us; but they soon found we were peaceable Russian students and thereupon left us alone. Scarcely had we passed the Austrian frontier and entered the States of Sardinia, when our travelling companions began to make much of us, to embrace us, to cry "Evviva" and to sing at the top of their voices. We then discovered that the prisoner was amongst us and had passed unobserved. Thanks to the suspicions aroused by Borodin's physiognomy, the prisoner had escaped the clutches of Austria!

During his residence in Heidelberg, Borodin spent much of his spare time in attending concerts and in making the acquaintance of musical people. It was here that he met and fell in love with Catharine Sergeievna Protópova, a Russian concert pianist. This romance culminated in the marriage of these two gifted musicians shortly after Borodin's return to Russia. In one of Borodin's letters to his wife written in later life, he recalls the days of their courtship at Heidelberg with a tenderness and passion suggestive of the letters of Robert Schumann to Clara Wieck. The entire married life of this couple proved to be a model of conjugal felicity.

Before returning to Russia, Borodin went to Paris where Wurtz was conducting his celebrated investigations in organic chemistry at the École de Médecine. It is more than probable that it was during this time that Borodin first became interested in the study of condensation reactions of aldehydes, the field of research which he so successfully cultivated in later years.

In 1862, at the conclusion of his three interesting *Wanderjahre*, Borodin returned to St. Petersburg to assume his duties as professor of chemistry at the Medical Academy. One of his students wrote in his diary the following account of the new professor:

One day a young man nonchalantly entered Zinin's private office, and soon the report was circulated in the laboratory that this was Borodin of whom we had heard much and whose return from abroad we had been expecting for some time. While Zinin was friendly with all his pupils, for Borodin he evinced a regard which was almost paternal and with him he shared his views on all current scientific topics. Borodin spent whole days in the laboratory with his students and was never too busy to answer any questions which they might wish to ask relative to their work. We could always approach him and discuss our problems with him without fear of being repulsed or receiving evasive replies. He was a man of a very even temper and his uniform consideration and kindness of manner won our admiration and affection. The only signs of impatience which he ever exhibited were provoked by our negligence or lack of care. "Little father," he would say, "if you continue to work in that manner it will not be long before you will destroy our fine collection of apparatus." Or at another time he would exclaim, "How can you produce such foul odors in this beautiful laboratory?"

and thereupon would banish the offender to another room. His relations with his students did not cease at the threshold of the laboratory for most of us were received into his house as friends, and always took our meals there when we worked over hours. Borodin was ever on the lookout for positions for his students and it was proverbial that those requiring the services of trained chemists could not meet him without being solicited for places for his former pupils.

The year following Borodin's return from abroad he and Mlle. Protopova were married and took up their residence in the laboratory building. Their home soon became a veritable Mecca to all of his students. An interesting glimpse of Borodin's life at this time is given by his friend, Rimsky-Korsakoff, the eminent composer, who writes:

I became a frequent visitor at Borodin's; often staying over night as well. We discussed music at length and he played his projected works and also showed me sketches of his symphony. He was better informed than I on the practical side of orchestration, since he played the 'cello, oboe and flute. Borodin was an extremely cordial and cultured man, pleasant and oddly witty to talk with. On visiting him I often found him working in the laboratory which adjoined his apartment. When he sat over a retort filled with some colorless liquid and distilled it by means of a flame from one vessel to another, I used to tell him that he was "transfusing emptiness into vacancy." Having finished his work, he would go with me to his apartment, where we would resume musical operations or conversations, in the midst of which he would jump up, run back to the laboratory to see whether something had not burned out or boiled over. Meanwhile he would fill the corridor with incredible sequences of ninths or sevenths. Then he would come back and we would proceed with the music or the interrupted conversation. Catharine Sergeievna was a charming, cultured woman, an excellent pianist, and she worshipped her husband's talent.

It is quite apparent from this reminiscence that Borodin had already commenced to combine serious creative work in music with his program of teaching and chemical research.

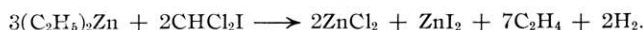
During the decade following Borodin's return from Europe he carried out a number of important investigations, mostly in the realm of organic chemistry and in the course of these researches he discovered aldol almost simultaneously with Wurtz. In 1862 he published a paper giving an account of his experiments on the tendency exhibited by fluorides to form double compounds and on the behavior of fluorides of the organic radicals. He was led from these studies to conclude that the tendency of monatomic fluorides to form double fluorides is limited to the production of acid inorganic fluorides and double salts, and that the monatomic fluorides combine only with hydrofluoric acid. He showed that the fluorides of sodium and potassium exhibit such a marked tendency to form acid fluorides that they readily yield half of the metal to a weaker acid, as indicated by the equation



The organic fluorides were found to resemble the corresponding chlorides more closely than the inorganic fluorides resemble the inorganic chlorides.

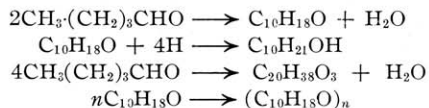
Hydrofluoric acid was shown to behave like water in its tendency to combine with solid inorganic salts, and the resulting compounds, containing hydrofluoric acid of crystallization, were found to decompose when heated.

This paper was followed shortly by another in which Borodin records the results of a study of the action of zinc ethyl on chloriodoform. His fellow-countryman, Beilstein, a short time previously, had described a satisfactory laboratory method for the preparation of zinc ethyl and Borodin undertook an investigation of its action upon chloriodoform. He found that when these two substances were mixed, a violent reaction ensued. In order to carry out the reaction satisfactorily, it was necessary to pre-cool an ethereal solution of the zinc alkyl and then add it drop-wise to the chloriodoform. The reaction was found to be represented by the equation



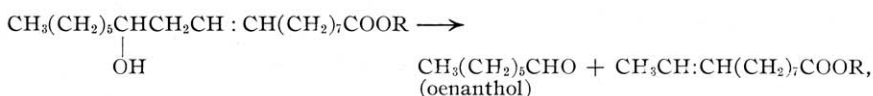
In the same year Borodin also published a brief note on the solubility of benzene in solutions of sodium ethylate. He found that when such solutions were heated they gradually lost their original dark brown color and deposited crystals of diphenylglycollic or benzoic acid, $(\text{C}_6\text{H}_5)_2\text{C}(\text{OH})\cdot\text{COOH}$.

He next took up the investigation of aldehydes, a field of research which continued to engage his attention throughout the remainder of his life. His first communication bearing upon this subject was concerned with the action of metallic sodium on valeraldehyde. The results of this investigation may be briefly summarized as follows: sodium was found to displace hydrogen in the aldehyde, and the resulting product resembled a mixture rather than a single substitution product. On treatment with water it was found to decompose, yielding, along with sodium hydroxide, amyl alcohol and valeric acid, two other substances which, on analysis, were found to correspond to the empirical formulas, $\text{C}_{10}\text{H}_{22}\text{O}$ and $\text{C}_{10}\text{H}_{18}\text{O}$. The former compound proved to be a monatomic alcohol corresponding to capric acid, $\text{C}_{10}\text{H}_{22}\text{O}_2$. The investigation of the other product was reserved until later, and the results are described in a subsequent communication. His next paper, treating of certain derivatives of capric acid, was followed by another article on the action of sodium on valeraldehyde. In this he showed that the primary action of the metal is to remove water from the aldehyde, while secondary effects are attributed to the presence of free alkali and nascent hydrogen. Several polymers corresponding to the formulas, $(\text{C}_5\text{H}_{10}\text{O})_n$, $\text{C}_{20}\text{H}_{38}\text{O}_3$, and $\text{C}_{10}\text{H}_{18}\text{O}$ were identified. The latter compound, which he had obtained in a previous investigation, was described at about the same time by Riban and Kekulé. On oxidation this compound was found to yield an acid, $\text{C}_{10}\text{H}_{18}\text{O}_2$, identical with an acid which he had previously isolated and identified as isocapric acid. The various condensation reactions described in these experiments may be represented by the following equations:

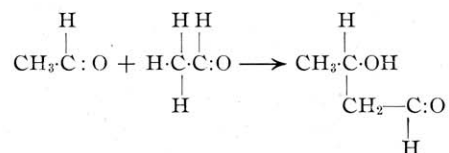


The latter polymeride was found to be an oil boiling at 250°C. The action of caustic potash at 0° was found to produce an oily polymeride lighter than water and incapable of combining with NaHSO₃. On distillation it yielded isovaleraldehyde and the compounds C₁₀H₁₈O and C₂₀H₃₈O₃. The latter substance, when left in contact with a solution of sodium carbonate, was found to form a crystalline compound which, on analysis, corresponded with the formula, C₂₀H₄₂O₅.

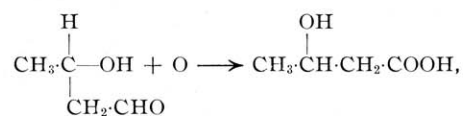
When castor oil, which may be regarded as the glyceride of ricinoleic acid, is heated to a high temperature it breaks down, yielding heptaldehyde, or oenanthol, as represented by the equation



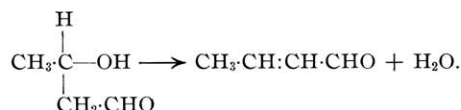
where R denotes one-third of the glycerol radical. From this aldehyde, oenanthol, Borodin obtained a series of products resembling those which he had derived from valeraldehyde. By the action of solid caustic potash in the cold there were formed two polymers of oenanthol, the one a crystalline solid and the other an oil. Both were found, on distillation, to yield oenanthaldehyde and other condensation products resulting from the splitting off of water. It was during this series of investigations that he was led to study the action of hydrochloric acid on ordinary aldehyde and thus obtained aldol, according to the familiar reaction represented by the equation,



As has already been mentioned this same substance was discovered almost simultaneously by Wurtz. On oxidation it was found to yield β-oxybutyric acid, as indicated by the equation



and when heated with a solution of sodium acetate, water and crotonic aldehyde are formed according to the equation



Borodin next directed his attention to the aromatic aldehydes and in the course of these studies became especially interested in the reaction between benzoic aldehyde and ammonia. It will be recalled that when ammonia and acetaldehyde are brought together they combine to form aldehyde-ammonia, $\text{CH}_3\text{CH}(\text{OH})(\text{NH}_2)$, whereas benzoic aldehyde reacts with ammonia to form hydrobenzamide, $(\text{C}_6\text{H}_5\text{CH})_3\text{N}_2$. Borodin studied the transformation of this compound into amarin and at the same time sought to establish the constitution of both substances. He showed that all of the hydrogen in hydrobenzamide is bound to carbon, whereas in amarin some of the hydrogen atoms are directly attached to the ammonia residue. Since hydrobenzamide is readily converted into amarin by heating, he suggested that we have here a complete analogy with the conversion of tertiary amines into secondary and primary amines, as had previously been established by the work of Hofmann and Martius. Both cases involve the transfer of hydrogen from carbon to nitrogen, giving rise, on the one hand, to an ammonia residue and, on the other, to complex carbon groupings of a higher order. He next prepared the hydramid of cuminic acid and its isomers. He found that when the hydramid was strongly heated, or by adding aqueous ammonia to cuminol and heating to $120\text{--}130^\circ$ for several days, there is formed a crystalline base which on analysis gave the formula, $\text{C}_{30}\text{H}_{36}\text{N}_2$. By the treatment of a hot concentrated solution of amarin acetate with an aqueous solution of potassium nitrate acidified with concentrated acetic acid, he obtained nitrosoamarin. On heating the nitroso compound to 150° , it was found to undergo decomposition with formation of lophin and a small quantity of liquid rich in oil of bitter almonds. While both amarin and lophin had been prepared by Laurent in 1844, Borodin's study of these compounds contributed to the elucidation of their molecular constitution as indicated by the formulas



It is to be deplored that the increasing demands upon the time and strength of this gifted man made by numerous committees, both within and without the university, should have been allowed to interfere with his chemical research and his creative work in music. While the chemical investigations we have briefly outlined constitute a valuable contribution to the science one cannot but wonder what might have been achieved



SPECIMEN OF BORODIN'S MANUSCRIPT

had his life been spared, and had he been relieved of the routine duties which a less gifted person could have performed equally well.

At about the time of Borodin's marriage he began to devote himself assiduously to the study of musical composition under the guidance of both Balakireff and Moussorgsky, and through his friendship with these two musicians was introduced to two other kindred spirits, Cesar Cui, a military engineer, and Nikolay Rimsky-Korsakoff, an ex-naval officer. It is little short of miraculous that this group of amateur musicians should ultimately come to be known as the "Great Five" of Russian composers. Early in his career as a professor of chemistry, Borodin began work on his first symphony, and during the next five years he labored spasmodically to complete it. The composition was first performed by the Russian Musical Society in 1869 and was accorded an enthusiastic reception. During the time that he was working on his symphony, Borodin also wrote a number of songs, of which "The Fair Garden," "A Dissonance," and "The Sea," are especially noteworthy for their originality and charm. He would commence work on a composition and then suddenly abandon it to develop some other musical conception which for the moment seemed more promising. Thus, we find him launched on the high sea of opera and then sailing on the quiet waters of song. By the end of 1876, however, he had completed his second symphony and early in the following year it had its première in St. Petersburg. A competent critic wrote of this performance: "Of Borodin's two symphonies the second is the greater work, and owes its force to the maturity of the composer's talent and especially to the national character with which it is impregnated by its program." In 1877 Borodin made another trip to Europe, visiting Weimar in the course of his journeyings. Here he met Franz Liszt who greeted him most cordially with the words: "Only two days ago I played your symphony to the Grand Duke who was charmed with it. The first movement is perfect. Your *Andante* is a masterpiece. The *Scherzo* is enchanting." Later Liszt placed Borodin, whom he called, "The Chemist from St. Petersburg,"

Lundi

Mon cher Monsieur,

Je ne pourrais pas venir vous serrer la main au concert, puisque je suis toujours à la bataille de Boudjars. C'est donc maintenant que je m'empresse de vous remercier et de vous dire que vous avez joué pour moi que ma symphonie fut bien exécutée. Aussi, grâce à cette exécution en maître, elle produit un effet auquel je ne m'attendais pas. Je vous remercie encore davantage pour l'intérêt personnel que vous avez pour mon œuvre et pour l'opinion flatteuse que vous avez pour ma musique en général. L'appréciation de ma musique par un musicien de valeur comme vous est d'une grande importance pour moi et je ne saurais trop vous en remercier. Merci tout bien cher maître et j'espère que je vous envoie à votre
 cher maître et j'espère que je vous envoie à votre
 A. Borodine

LETTER FROM BORODIN TO MONSIEUR TH. RADOUX, DATED JANUARY 25, 1886

Translation

Monday

My dear Sir:

I could not come to shake your hand after the concert because I saw you were being jostled on all sides.

Hence it is that I now hasten to thank you for all the care you took in order that my symphony should be well performed. Also thanks for the masterly manner in which it was executed thereby producing a result beyond my expectation.

I do thank you much more for your personal interest in my work and the flattering opinion you have of my music as a whole. Appreciation of my music by a musician of note like yourself is of great value to me and I cannot be too grateful to you.

Take good care of your health dear master and think sometimes of

Your devoted
 A. Borodin

among the greatest musicians of the age and used his influence to make the works of this young Russian better known in Europe.

Shortly after returning from his visit to Liszt, he resumed work on opera, "Prince Igor," but soon laid it aside to write the familiar symphonic poem, "On the Steppes of Central Asia," which was destined to become the most popular of all his musical creations. In 1880, in connection with the celebration of the silver jubilee of Czar Alexander II, a series of tableaux illustrative of Russian history were given in the Imperial Theatre. One of the musical numbers rendered on this occasion was Borodin's symphonic poem descriptive of a caravan crossing the vast expanse of the Russian Steppes under a guard of soldiers. This fascinating tone poem has been briefly described by F. H. Martens in the following words:

Below the long continued notes of the violins, which express the arid monotony of the endless plain, moves a peaceful Russian folk-tune, presented by the clarinet, and subsequently taken up by the horn. From the distance comes the sound of trampling

The image displays two systems of a musical score for the piece "Dans les Steppes" by Alexander Borodin. The score is arranged in two systems, each containing staves for various instruments. The top system includes parts for Oboe (Ob.), Clarinet in G (Cingl.), Clarinet in Bb (Clar.), Bassoon (Fag.), Cor Anglais (Cor.), Violin I (Vl.), Viola (Vla.), Violoncello (Vc.), and Contrabass (Cb.). The bottom system includes parts for Oboe (Ob.), Clarinet in G (Clar.), Bassoon (Fag.), Cor Anglais (Cor.), Violin I (Vl.), Viola (Vla.), Violoncello (Vc.), and Contrabass (Cb.). The score is written in a key signature of two sharps (D major or F# minor) and a 3/4 time signature. The music features a variety of rhythmic patterns, including eighth and sixteenth notes, and rests. Performance instructions such as *pp*, *ppp*, *div.*, *unis.*, *arco*, and *pp cantabile* are present throughout the score. The bottom system also includes the instruction *sempre sul G* for the Violin I and Viola parts. The score is identified by the number E. E. 4405 at the bottom center.

PAGE FROM SCORE OF "DANS LES STEPPES"

hoofs and accompanying it, a plaintive oriental melody. As the caravan advances, the Russian melody swells in volume and then dies away again as it recedes in the distance. Then the aboriginal Mongol melody is heard once more mingling with the occidental folk-air, until both are lost in the far reaches of the sandy sea.

It has been said that the epic strength and the Oriental coloring of the orchestration in this symphonic poem place it among the most notable musical achievements of the nineteenth century.

The opera, "Prince Igor," although commenced in 1871, was not completed during the composer's life; fortunately, however, the work had been fully sketched and enough of the orchestration completed so that two of his friends, Rimsky-Korsakoff and Glazunoff, were able to finish it. The opera had its première in St. Petersburg in 1890 and its first rendition in New York in 1915; in both cities it received an ovation.

In addition to the larger works we have mentioned, Borodin wrote a number of lesser compositions possessing that Oriental character which lends a peculiar charm to all of his music.

In order to appreciate the colossal genius of this man it must be emphasized that his musical activity was confined to his leisure hours, and that he never regarded music in any other light than as a pastime. He very modestly referred to himself as a "Sunday musician," and in speaking of his opera, said: "Igor is my natural child: I take care to keep him well hidden!" His incessant labor weakened his none-too-strong body but, nevertheless, he accepted illness most philosophically and made light of poor health. On one occasion when confined to his apartment with an attack of grip, he said:

In winter I cannot compose unless I am sick and obliged to give up my lectures. So my friends, contrary to custom, never say to me, "Try and keep well!" but rather, "Try and fall sick!" When my head is bursting, when my eyes are filled with tears and I have to take out my handkerchief every minute, then it is that I compose.

Borodin was among the first to recognize the injustice done to the women of Russia by withholding from them the educational and social privileges accorded to its men. He, therefore, espoused the cause of university education for Russian women and, from 1872 until the day of his death, gave gratuitous instruction in chemistry at the Medical School for Women which had been established through the efforts of Professor Rudneyeff and Madame Farnooskaya.

Although the Borodins had no children of their own, they were continually adopting unfortunate and orphan children and bringing them up. Their hospitality and sympathy for the poor and needy made their home a veritable eleemosynary center in the city of St. Petersburg. Money was apparently a matter of indifference to this kindly couple and without pretense or formality they welcomed all who came to their door.

Borodin's wife was a sufferer from asthma and in the summer vacations it became their custom to migrate to the country where, in a rented *izba* or peasant's hut, they lived the simple life. One of their musical friends who paid them a visit during one of these periods of rustication wrote a description of their life in the following words:

At their summer home they live queerly. They usually rent an *izba* without having seen it. They bring with them few belongings, have no hearth plate and do their cooking in a Russian oven. Their mode of living is extremely uncomfortable in crowded quarters with all kinds of privations. The ever-sickly Catharine Sergeievna goes bare-foot all summer long for some reason.

Nevertheless, it was this simple manner of life which he lived during his summer vacations that enabled him to recuperate for the strenuous days and nights of the academic year and the ever-increasing demands of his official and outside duties.

Rimsky-Korsakoff gives a vivid picture of Borodin's home life and its distractions as he saw it shortly before Borodin's death; from this we quote as follows:

Rarely did I find him in his laboratory, still more rarely at composition or at the piano. Usually it turned out that he had just gone to or was just returned from a meeting; that he had spent all day driving about on those same errands, or else had been writing business letters, or working over his account books. Add to these (activities) his lectures, the various meetings of the academic conference and other meetings, and it will become clear that there was no time at all left for music. Thanks to the charitable hurly-burly, his time was frittered away on trifles that could have been attended to by such as were not Borodins. Moreover, knowing well his kind and easy-going nature, medical students and all sorts of student-youth of the fair sex, besieged him with every manner of solicitation and request, all of which he tried to fulfil with characteristic self-denial. His inconvenient apartment, so like a corridor, never allowed him to lock himself in or pretend that he was not at home. Anyone entered his house at any time whatsoever and took him away from his dinner or his tea. Dear old Borodin would get up with his meal or his drink half-tasted, would listen to all sorts of requests and complaints and would promise to "look into it." To this must also be added that Catharine Sergeievna was a constant sufferer from asthma, passed sleepless nights and frequently arose at midnight. Alexander Porfirievitch had a difficult time with her at night, rose early and did not have sufficient sleep. Their whole home life was one unending disorder. Dinner time and other meal times were most indefinite. Once I came to their house at eleven in the evening and found them at dinner. Leaving out of account the girls, their protegées, of whom the house had never any lack, their apartment was often used as a shelter or a night's lodging by various poor (or visiting) relations who picked that place in which to fall ill or lose their minds. Borodin had his hands full with them but he doctored them, took them to hospitals and then visited them there. In four rooms of his apartment there often slept several strange persons of this sort; sofas and floors were turned into beds. Frequently it proved impossible to play the piano because some one lay asleep in the adjoining room. At dinner and tea, too, great disorder prevailed. Several tom-cats that found a home in Borodin's apartment were wont to parade across the dinner-table, sticking their noses into plates and unceremoniously leaping onto the diners' backs. These cats basked in Catharine Sergeievna's protection; various details

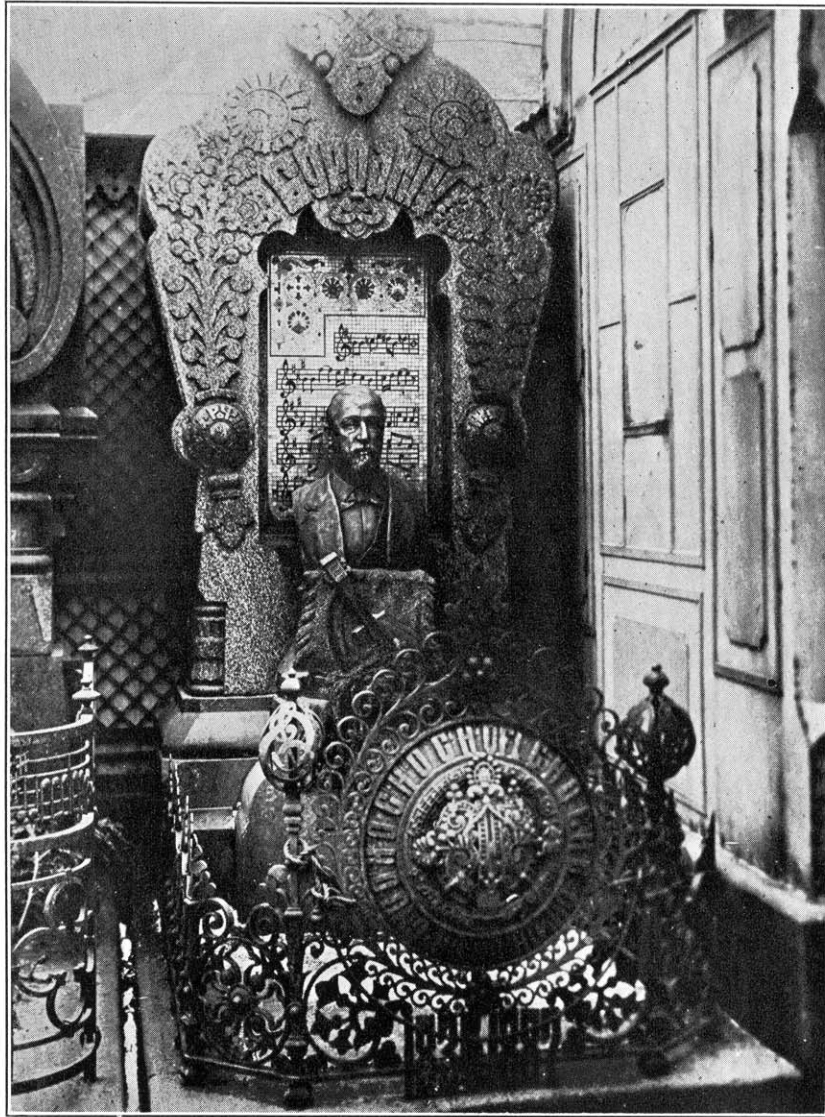
of their biography were related. One tabby was called *Rybolov* (Fisherman) because in the winter, he managed to catch small fish with his paw through the ice-holes; another was called *Dlinyenki* (Lanky) and he was in the habit of fetching homeless kittens by the neck to the Borodin's apartment and they in turn would harbor them until they could find a home for them. Then there were other and less remarkable specimens of the *genus felis*. You might be sitting at their tea-table—when behold! Tommy marches along the board and makes for your plate; you shoo him off, but Catharine Sergeievna invariably takes his part and tells some incident from his biography. Meantime, zip! another cat has bounded at Alexander Porfirievitch's neck and twining itself about it, has fallen to warming that neck without pity. "Listen, dear Sir, this is too much of a good thing!" says Borodin, but without stirring the cat lolls blissfully on. Borodin was a man with no whims and easy to get along with. He slept little, but could sleep on anything and anywhere. He could dine twice a day, or go dinnerless altogether, both of which happened frequently. He would drop in on a friend during dinner and being invited to join in the meal, he would say, "As I have already dined today, and, consequently, have formed the habit of dining, I might as well dine once more." He would be offered wine and would reply, "As I don't drink wine as a rule I may treat myself today." Next time it might be just the contrary. Having vanished and remained lost all day, he would drop in at evening tea and calmly sit down near the samovar. His wife would ask him where he had dined and only then would he recollect that he had had no dinner at all. Dinner would be served, and he would eat it with gusto. At evening tea he would drink cup after cup without counting and when his wife would ask him if he would have another he would ask, "How many have I had?" and on being told would reply, "Well, then I've had enough."

Borodin's death occurred with tragic suddenness on the evening of February 16, 1887. He had invited a group of friends to his apartment to celebrate the closing of the mid-winter carnival. He played for them excerpts from his third symphony, which he was then writing, after which informal dancing was proposed and Borodin, who was an excellent dancer, welcomed the proposal with youthful enthusiasm. Later in the evening, while engaged in an animated conversation with one of his guests, an ominous pallor suddenly overspread his countenance; he tottered and fell to the floor. Medical assistance was promptly summoned and restoratives were administered but without avail, instant death having ensued as the result of aneurism of the heart. Thus, at the height of a brilliant career and in the midst of a life of exceptional usefulness,

"A soul, that in music, as a flower in light,
Did'st gem and bloom and vanish with a breath."

Borodin was buried in the cemetery of the Alexander Nyevsky Monastery, not far from the graves of Dostoievski, Tschaikowski, and Rubinstein. On his casket was a silver plate, sent by the women physicians to whom he had given gratuitous instruction, and on this plate was inscribed:

"To the founder, protector and defender
of the School of Medicine for Women."



GRAVE OF BORODIN

The grave of Borodin is marked by an interesting memorial given by his many friends and admirers. In designing this monument, the artist has sought to epitomize the outstanding achievements of this singularly talented man. A rather elaborately carved and slightly recessed granite shaft serves as the background for a finely sculptured bronze bust of Borodin. Directly behind the bust, selections from the composer's music are reproduced in exquisite mosaic. It is of interest to note the excerpts chosen by the artist; they are—the opening theme of the first symphony, the chorus of the Polovtsian women from "Prince Igor," the first bars of the "Chanson de la Fôret Sombre," the opening theme of the Scherzo in the third symphony, and the first notes of the symphonic poem, "Les Steppes." On the face of the pedestal upon which the bust rests there is a carved representation of a *kobza*, an instrument with which the Muscovite troubadours accompanied their folk-songs. Borodin being very familiar with many of these native songs and having derived some of his best thematic material from this source, it is appropriate that this symbol of early Slavic music should be wrought into the design of the monument. An elaborate railing of iron surrounding the tomb carries at its center a circular shield which bears around its circumference the empirical formulas of the various chemical compounds isolated by Borodin. Separating the grave from the adjoining burial plot is another iron railing in the border of which the artist has incorporated yet another of the composer's themes.

As one reflects upon the career of this man of many talents, who was ever ready to aid the underprivileged, or to minister to those in distress, despite the allurements of both science and art, one finds it difficult adequately to appraise his contributions to his fellowmen. Some one has said of him:

Borodin, in the nineteenth century, seems like one of those saintly figures, which medieval legend has made familiar to us. He was . . . without any thought of worldly gain or advantage, full of the spirit of self-sacrifice. He lived like an apostle and almost like an anchorite.

His life was one

"Of toil unsevered from tranquility!
Of labor, that in lasting fruit outgrows
Far noisier schemes, accomplished in repose
Too great for haste, too high for rivalry!"

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 "Arabe, Si tu fuis mes regards."
 "Snow-white."
 "The Wrong Note."
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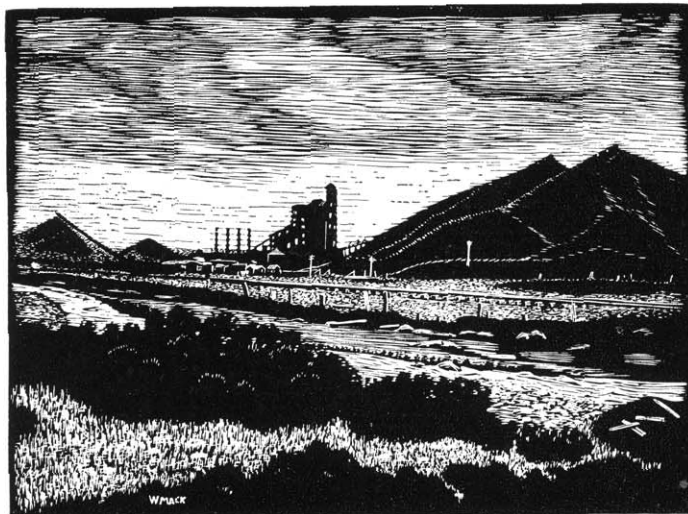
THE FIRST-YEAR CHEMISTRY COURSE

PAULINE G. BEERY,* THE PENNSYLVANIA STATE COLLEGE, STATE COLLEGE, PENNA.

In my mind, teaching is not merely a life work, a profession, an occupation, a struggle; it is a passion. I love to teach. WILLIAM LYON PHELPS

The teaching of the first-year chemistry course in college or high school can be either the most delightful or the most deadening of tasks. The teacher whose classes are merely periods to be passed bores himself even more than he does his students. But the teacher who welcomes the opportunity to introduce his students into one of the most interesting of all sciences experiences satisfaction like that of the bearer of good news.

The teacher who loves to teach first-year chemistry uses his textbook as a servant. He enriches the textbook material, which of necessity is pre-



COAL IS SOMETHING MORE THAN A BLACK SOLID WHICH BURNS

sented in a formal manner, by news items of timely interest, journal articles on related subjects, motion pictures, and trips to manufacturing plants. By so doing he does not find it necessary to place less emphasis on the fundamental principles of the subject. On the contrary, he finds his students better able to understand and more anxious to learn the laws and theories of the subject for having obtained first-hand information on their practical applications.

The teacher of first-year chemistry who does not make the subject alive for his students is a slave to the textbook. To him its chapters are but a series of duties to be done in preparation for the final examination which

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Facing the Music: How Original Was Borodin's Chemistry?

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Aleksandr Porfir'evich Borodin (1833–1887) was a remarkable individual. Born illegitimate in St. Petersburg, Russia, to a Russified nobleman from the Caucasus and his maid, he was educated in that city as a medical doctor at the Medico–Surgical Academy (later home to Ivan Pavlov), studied abroad on a postdoctoral trip in Heidelberg (1859–1862), began a career teaching at his alma mater in 1862, lobbied for higher education for women, and along the way managed to compose two and a half symphonies, roughly twenty songs, two string quartets, a symphonic poem (“On the Steppes of Central Asia”), and an unfinished operatic masterpiece, *Prince Igor*. (The music for the latter formed the basis for the score of the Tony-award-winning *Kismet*.) Although much has often been said about the connection between music and the sciences—especially the physical sciences and mathematics—there are all-too-few historical cases that illustrate a practicing scientist who was a significant musical composer. It is the fascination of this hybrid figure that has drawn a great deal of attention to the man, mostly focusing on whether there was some sort of “conflict” between his music and his science (1–13).

This essay does not address that issue of conflict—or, for that matter, whether Borodin's musical reputation is justified vis-à-vis other Russian composers—but, rather, evaluates the basis of the scientific reputation later commentators (1, 6–9) have assigned to him by returning to the original sources. The intrinsic charm of Borodin's case has prompted some to argue that his status as a chemist was equivalent to those of his more well-known contemporary countrymen—men such as D. I. Mendeleev (1834–1907, of the periodic system of chemical elements), A. M. Butlerov (1821–1886, of the structure theory of organic compounds), V. V.



Figure 1. Photograph taken in Heidelberg ca. 1860: Borodin is the second from left, and the seated person third from left is Dmitrii Mendeleev. (Source: Dobrotin, R. B. et al. *Letopis' zhizni i deiatel'nosti D. I. Mendeleeva*; Leningrad: Nauka, 1984; page 65.)

Markovnikov (1838–1904, of the eponymous rule), or F. K. Beilstein (1838–1906, of the indispensable *Handbuch*). Although Borodin began the 1860s as one of the more promising young chemists of his generation—a reputation based on some striking research while he was abroad at Heidelberg and Pisa—for a variety of reasons his research programs dwindled largely on their own (and certainly not, as has been claimed, due to subterfuge and priority theft by foreigners—although issues of priority were raised and continue to be pressing issues for chemists internationally today). Borodin seems to have left active chemical research owing to a diminution of interest and an increasing desire to devote his time to other issues. The claims for Borodin's status as an exceptional—as opposed to merely good—chemist end not with a bang, but a whimper.

The Heidelberg–Pisa Period

The fact remains, however, that Borodin was very much at the cutting edge of organic chemistry during his stay in Heidelberg and then after his return to Russia for the rest of the 1860s (Figure 1). His productivity while abroad was impressive—a circumstance that was not atypical of Russian students engaged in postdoctoral study abroad and freed from onerous teaching and administrative duties. Borodin's research throughout his career was characterized by two prominent features of this early period: an emphasis on empirical laboratory work on the basic families of organic compounds and a resistance to theoretical speculation. (The second in particular marks him as quite different from the Russian figures with whom he is usually compared.)

Borodin began his career in Heidelberg by quickly settling in at the laboratory of Emil Erlenmeyer (1825–1909)—a *Privatdozent* with a separate laboratory from the much more famous local chemical professor, Robert Wilhelm Bunsen (1811–1899)—to perform research on benzene derivatives, and this research was soon published in Erlenmeyer's house organ, the *Zeitschrift für Chemie und Pharmacie* (14–18). This work is precise and highly competent and helped to establish his credentials as a laboratory chemist.

When his fiancée, for health reasons, had to travel to Italy, he followed her to Pisa, where he worked in the laboratory of de Luca and Tassinari. This was in many ways a relationship born of convenience, since he could continue his research in close proximity to his fiancée; the originality of his chemical research there had similar contingent origins. When he arrived in the laboratory unannounced to ask for a place to do research, he noticed that it was provisioned with extremely expensive platinum retorts, indispensable for working with highly corrosive substances. Delighted at any visitor expressing interest, the directors granted him broad discretion, and he conducted a series of experiments on organic halogen compounds. As Borodin commented to his supervisors back in Russia about his move to Italy, “Italian scholars have not yet become accustomed to an influx of for-

eigners who arrived for the purpose of working, and, with quite different experiences than the German scholars, they have not yet become accustomed to that system of exploitation which is leading science to the level of a craft" (9, p 145). In his most noted work, Borodin reacted benzyl chloride with potassium bifluoride to produce the first (nucleophilic) replacement of a halogen with fluorine. Given that the carbon bond to fluorine is the strongest of its bonds with any other element, and given the difficulty of doing any work with fluorine (owing to its toxicity), this research managed to generate for Borodin a modest but quite respectable reputation among empirical organic chemists. This work was published in Italian—a language Borodin acquired during his brief sojourn in Tuscany—in the *Nuovo Cimento*, but he also sent it to Erlenmeyer so it would be abstracted in the *Zeitschrift*, which was standard practice for Russian chemists (19–20). (This reaction has been retrospectively identified with the Hunsdiecker reaction, published in 1939, apparently without knowledge of Borodin's work. The original publication by Borodin was rather cursory and does not elucidate the mechanism clearly, and thus the reaction did not become widely referred to until after Hunsdiecker's publication, which accounts for the failure to make this particular discovery a feather in Borodin's cap until rather late in the Soviet period.)

Interestingly, in his Italian publications, he fluctuated between older equivalent weights (C = 6, O = 8), and post-Karlsruhe Congress atomic weights (C = 12, O = 16), even though he had attended the Congress in September 1860 and Erlenmeyer himself tended to insist on using the "modern" weights in his journal. This offers a further indication that, contrary to Mendeleev, Borodin was not attracted to the theoretical debates prevalent in organic chemistry, and preferred to use whichever was most ready to hand—a fairly common stance (21). After Borodin's death Mendeleev would describe his friend's prominence abroad during the Heidelberg years, telling music critic and Borodin biographer Vladimir Stasov that Borodin was "a first-class chemist, to whom chemistry owes much" and that when he (Mendeleev) went abroad, chemists would say, "Well, what new thing has your Borodin done?" (22). Although Mendeleev's comments are somewhat unreliable given the lapse of twenty years and the dimming of memory, they do indicate that Borodin began the 1860s as a young chemist to be watched closely.

The Return to St. Petersburg

When Borodin arrived back in St. Petersburg and his post at the Medico–Surgical Academy in 1862, he was well-positioned to follow his chemical mentor Nikolai Zinin (1812–1880) as a central figure in empirical organic research. And so he did, even after his initial meeting with his complementary mentor in music composition Mili Balakirev (1836–1910) and beginning work on his first symphony (completed in 1867).

Besides assuming the reins of the chemical laboratory at the Academy, he undertook the fairly common task of chemical consulting for industrialists and municipalities. In May 1866, Borodin was invited to the town of Khilovo in the Pskov region (southwest of Petersburg) to investigate local mineral water resources and evaluate their possible medical

benefits, and he traveled there for an extended stay during 6–17 September of that same year. Borodin had experience in this area. Zinin had recommended Borodin to Russian industrial magnate V. A. Kokorev (best known for his development of the Baku oil fields) in 1858, and Kokorev engaged Borodin to travel to the salt lakes of Soligalich, about 215 kilometers northeast of the provincial city of Kostroma, where Kokorev owned a property and wanted to exploit its supposedly sulfuric waters to open a spa. Although he enjoyed flirting with local ladies, Borodin did not find the region particularly suitable for a Russian Baden-Baden, largely owing to the lack of sufficient expertise to guide treatments on a case-by-case basis: "Here, as with all treatments, first of all one must have in view the general state of health of the patient, because in the strict sense we never treat the *sickness*, we treat the *sick*. By this, it is also impossible to delineate strictly determined rules for the methodical direction of any kind of mineral waters: for each specific case it is necessary to change these rules, taking into account the given conditions" (23). Borodin's goal in this early work, as in his later trip to Khilovo, was to establish himself as an expert in practical consulting in analytical chemistry—once again a standard and reasonable approach for a chemist beginning to establish a local reputation to complement his budding international one.

The Aldehyde Project

The period from 1864 until 1873 was the period of Borodin's most ambitious research project—into the nature of aldehydes—and the source of the strongest claims by later writers that he was truly a chemist of equal standing to his illustrious peers (6, 10, 11). There are three points at issue in historically assessing this research project: Borodin's original contributions, the role of international priority disputes, and his reasons for abandoning it. The first is less significant than typically supposed, the second is virtually nonexistent, and the third is often misunderstood. All revolve around the issue of priority.

The priority dispute over aldehydes is complicated to unravel, because it unfolded in two stages: one concerning the German chemist August Kekulé (1829–1896) and one concerning the French chemist Adolphe Wurtz (1817–1884). Borodin and subsequent Russian-language literature emphasize the first, German stage—even blaming the fight with Kekulé delaying the completion of Borodin's unfinished opera *Prince Igor* (although that work was incomplete at Borodin's death *fifteen years* after the conclusion of the priority dispute!) (24). English-language historiography emphasizes the second stage. Both were fairly typical cases of individuals working in related areas coming across similar findings, and all claims to Borodin's priority stem from the fact that he was working on aldehydes before Kekulé or Wurtz were, and they should have respected his terrain. Avoiding someone else's area was indeed standard practice at the time, but its bounds depended on the size of one's claimed domain. Was claiming aldehydes as a topic analogous to claiming a specific issue (like the photoelectric effect), or a general area (electrical conductivity)? The dispute—abortive and inconsequential as it was—revolved around this issue more than results.

Kekulé had begun a research program in the late 1860s on the condensation of aldehydes. His first publication on this topic (in 1869) was a rather laconic announcement of preliminary results (25). Since Borodin had already published articles in 1864 (26, 27) on the action of sodium on aldehydes, he instantly became agitated, writing to his wife on 3 October 1869:

I just barely avoided an unpleasant run-in on the chemical field with Kekulé, who in one of his works broached the area in which I am working. True, he came to it from completely different beginnings and was completely not onto the same things as I, but nevertheless, in the future course of his researches, he could easily happen upon the same ideas as I did. As a warning of the possibility of a run-in, yesterday I communicated my work at a meeting of the Chemical Society, although the work was far from rounded off. [28–30] All the chemists found it, however, very interesting both from the factual side and from the theoretical development of ideas. These days I have been busy from morning to evening working out the literature collected on this subject. [31, I, pp 150–151]

Notice how weak Borodin's claims actually were. He admitted that Kekulé was not intruding on his area and did not find the same results, but expressed agitation at what might potentially happen in the future. Elevating this into a priority dispute might seem unwarranted, but that is just what Borodin was eager to do. Given that Borodin's productivity was so low that one could very easily have assumed that he had ceased to work on the topic, Kekulé responded to Borodin's complaints with uncharacteristic amity:

In each chemical work one sets up for oneself, and today much more than earlier, the danger that the very same research will be carried out simultaneously and independently in other places and by other chemists. Naturally, one is not speaking of the regrettable custom of seizing others' work, namely, that many consider it appropriate that another person's investigations already begun and made known through preliminary announcements can be seized and carried further.

When I some time ago delivered the news that crotonaldehyde is formed through the condensation of aldehydes, I had also set forth another research with valeraldehyde. I had obtained an aldehyde that boils somewhere over 190°, from which one can obtain an acid through oxidation, which after analysis with silver salts arrived at the formula $C_{10}H_{18}O_2$. A short while ago now [Jacques] Riban and Borodin have simultaneously announced that they have begun to work on the same situation, and I will thus provisionally not continue the research with valeraldehyde. [32]

And so, it would seem, things turned out in Borodin's favor: Kekulé had retreated.

That was not how Borodin read Kekulé's article. On 9 March 1870, Borodin penned another frantic letter to his wife after returning from a Chemical Society meeting, where he learned something very unpleasant:

Kekulé (in Bonn) is reproaching me that I stole the work on valeraldehyde (which I am working on now) from him

(i.e., not the work itself from the factual side, but the idea of the work). He printed this in the *Berichte* of the Berlin Chemical Society. This step forced me to make an announcement in the same place about the facts I have discovered and to show that I have been studying these questions already since 1865 and Kekulé stumbled on them only in August of last year. There's German honesty for you! Although the [Russian] Chemical Society knew all this, I considered it necessary to state it [33], so that it would then be communicated, by the established order, to the Berlin Society. [31, I, p 201]

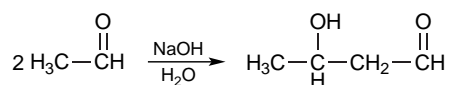
His fury seems to have waned quickly, and Borodin two weeks later wrote to his wife that “[w]ith Kekulé I decided not to answer, but simply to continue the work, and then he will think that I was really scared by his announcement. When the work is finished I will make a note in passing on Kekulé, by the by—that is much more tactful” (31, I, p 211). With all the heat of his initial reaction, it quickly became apparent that, in terms of a priority dispute, there was simply no case: Kekulé had not found the same results, and Borodin could not reasonably insist that no one else research in the entire field of aldehydes.

The Issue of Aldol

Nevertheless, his ears were tuned to claims of people stealing his ideas, and he began to react much more quickly. Not that he was publishing articles. It is in fact quite noteworthy that with the turn of the 1870s Borodin's article production essentially dried up to nothing; when he published he did so as abstracts to the Russian Chemical Society, and seemingly never found the time to write up the full articles. One such announcement, in the wake of the Kekulé conflagration, would become the seed of another supposed priority dispute with Wurtz. After a burst of laboratory productivity, Borodin made three announcements at a Russian Chemical Society meeting of 4 March 1872. First, he continued his research on the action of sodium on valeraldehyde—“undertaken with the goal of clarifying the means of appearance of the products of the reaction, described by him already in 1864”—apparently glancing over one shoulder at Bonn. Here he found something interesting: it seemed that an incongruous product emerged that was seemingly an alcohol, but yet had some divergent properties. He described this body's supposed properties without attempting to clarify its structure. He also, in an aside, found that one of the aldehyde reaction products was “obtained simultaneously by Borodin, Riban (34, 35), and Kekulé.” His second announcement was on the action of sodium on ethanol, and the third “concerns regular aldehyde, from which one also obtains analogous products. A product is incidentally obtained completely similar to that recently described by Wurtz (36, 37). The physical properties and conditions of formation are the same,” but there was a slight difference in the chemical properties. “However, the circumstantial research of this body is set aside in view of the fact that Wurtz is already studying it, and that its study does not have a direct connection with the rest [of the products outlined above]” (38). Borodin conceded priority on all fronts here: he granted to Kekulé equal priority with the earlier product, and graciously backed out of research when he found he was encroaching on Wurtz's. Indeed, to

most organic chemists today—except for the few who have written on Borodin—aldol is credited to Wurtz without mention of Borodin.

Yet this single episode has perplexingly been treated by almost every single writer on Borodin as a case of Wurtz usurping Borodin's legacy (2–9). There are two primary reasons for this. The first is that the finding in question is the discovery of “aldol”, so named for having both an aldehyde and an alcohol functional group. In anachronistic modern terms—which were certainly not the terms in which either Borodin or Wurtz was thinking—aldol (3-hydroxybutanal or used as a general term for β -hydroxy aldehydes) is formed by the combination of two acetaldehyde molecules in the following reaction:



(This dehydrates fairly quickly into crotonaldehyde and water.) Aldol is also an important reaction stage of the so-called “aldol condensation”. Part of the reason why a priority dispute has retrospectively been staked here is that this was a big prize, and thus vital for a credible claim for Borodin's originality.

There exists a solitary quotation that offers evidence that Borodin was uniquely agitated by the loss of priority over aldol, and this quotation has been replicated in biographical articles on Borodin repeatedly. The quotation, however, is apocryphal. Over a decade after Borodin's death, a former student, M. Iu. Gol'dshtein, published an encyclopedia article on his teacher where he described Wurtz's “theft” of aldol's discovery from the composer–chemist and reported Borodin commenting: “My laboratory scarcely has the means which are [necessary] in its order: I don't have a single assistant, meanwhile Wurtz has enormous means and works with 20 hands thanks to the fact that he is not embarrassed to dump dirty work on his lab assistants” (39). There is no other source corroborating this quotation. The tone does not sound like Borodin, and he made no related or similar comments in his correspondence or to the recollection of any of his peers, including that of his son-in-law, protégé, and successor Aleksandr Dianin. A solitary piece of evidence like this, which so contradicts *all* available original documentation, has to be treated as unreliable. Yet so many have based their interpretations of the man on just this one line. Why? According to Gol'dshtein, it was precisely because of Borodin's continually losing international priority disputes that individuals think of him as a composer primarily and only secondarily as a chemist. These, then, are the stakes: It became important for his contemporary chemists upon his death to see him as great so that they could reclaim his legacy for the history of science, as opposed to merely the history of music. Later commentators have continued this tradition.

Borodin's chemical researches did not stop with the end of his work on aldehydes, although they clearly slowed down. After his disappointment there—a disappointment, again, that had more to do with not being fast enough rather than feeling swindled—Borodin returned to another earlier topic on the reactions of amides. He reported the results of this work in 1873 at the Congress of Russian Natural Scientists and Physicians in Kazan, detailing the transformation of

hydramides into bases isomeric with them, following an analogy with August Hofmann's work on the transformation of tertiary amines to secondary and primary amines (40, 41). This Kazan meeting was an important personal moment for Borodin, for it was here, and really only here, where Borodin received public recognition from his peers as one of their most valuable colleagues, based on their evaluation of his recent scientific work and especially on his vigorous activities for women's education, and with barely a comment about his music. As he wrote to his wife on 24 August 1873 from Kazan, “I am surrounded by unimaginable attentiveness, everywhere I meet the most pleased reception, at each step people demonstrate honor and respect with the most flattering signs!” He was later toasted with a cry of “Borodin! Raise [glasses] to Borodin! He is not only a good honest scientist but also a good honest person!” He then found his “fat body” raised in the air and carried about the hall (31, II, pp 37–38). Borodin, validated, continued his research on nitrogen compounds, publishing his last original full article in 1875 on this topic, thirteen years before his death (42).

Borodin published very little on the nitrogen research, but his development of a simple but accurate device to measure the quantity of urea in animal urine proved significant. Borodin published a brief abstract in the *Journal of the Russian Chemical Society* in 1876 that described a device consisting of two inverted burets placed inside each other; in the inner buret the urea was reacted with sodium bromide salt and the released volume of nitrogen was measured and thus the quantity of urea accurately calculated, even at small volumes and low concentrations. The finding was so promising that it was reported immediately in the *Berichte* of the German Chemical Society (43). And then, quite simply, Borodin ceased to publish on this topic—or on any other topic, for that matter. Aside from a brief flirtation with hypnotism, reported many years later by the niece of his principal biographer, Vladimir Stasov, essentially all mentions by Borodin and his contemporaries of the man's interest in original scientific research vanish (44).

Conclusion

Despite all the attempts by individuals from the moment of Borodin's death to claim for him an exceptional status in chemistry, one is forced to conclude that his reputation was merely very good, much like many other, less well-known members of the Russian Chemical Society. Had he not also been a distinguished composer—although not, certainly, as innovative as his friend Modest Musorgskii or his acquaintance Petr Chaikovskii—it is likely that his name would be known only to esoteric specialists in the history of chemistry, instead of being invoked in chemistry classrooms around the world as an interesting example of chemical polymathy. Note the ease with which Borodin resigned himself in terms of priority disputes, his nitrogen program, and his urea-detection device. He seemed almost relieved that he would not have to pursue his research further. He established his nationalist bona fides by contesting with Kekulé (however half-heartedly), promptly conceded to Wurtz, and then rapidly faded out of original research. Instead of casting Borodin in the role of original chemist, it is time to recognize that this was not a laurel he particularly coveted for himself. He was

happy to devote the last decade-and-a-half of his life not to the production of science, but to the production of *scientists*, as he engaged in a thorough overhaul of chemical education at the Medico–Surgical Institute and also continued his activism on behalf of medical courses for women—substantial achievements that deserve attention in their own right—and also to the composition of music. Borodin was unquestionably an original man and composer. It is, however, a stretch of the historical evidence to *also* claim for him status as an original chemist. He had striking potential in his youth, but he chose to invest his limited temporal resources otherwise. His reputation stands on the music and his educational activism; his chemistry is at best historically interesting, but not outstandingly so.

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Original communications

The life and death of Professor Alexander P. Borodin: Surgeon, chemist, and great musician

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Music is one of the most effective and most beautiful means of communication between peoples. However characteristically national the music may be, it will penetrate to the hearts of all receptive listeners regardless of outlook, provided that it has real beauty.¹

SEVERAL EMINENT COMPOSERS HAVE flirted with the art of medicine. Hector Berlioz studied medicine in Paris.^{2,3} Franz von Suppe attended medical school for 1 year before settling down to the more serious work of composing frothy operettas.² On the other hand, many physicians became more or less proficient in music.⁴ Perhaps the most prominent of them was Theodor Billroth, who became a pianist of high standing.⁵⁻⁷ His lifelong friendship with the famous composer Johannes Brahms, who dedicated his String Quartet, opus 51, to Billroth, is well known.^{6,7} The two Opus 51 quartets in C minor and A minor have come to be known by musically inclined surgeons as the Billroth I and II.⁶ However, life is such that very often one thing must be sacrificed in favor of another. For instance, Billroth once invited Brahms to listen to an amateur orchestra of physicians. After a few minutes, Brahms stood up and rushed away saying, "No, no, no! I would rather give the Vienna Philharmonic Orchestra to operate on me!" Professor Alexander Borodin combined the roles of medical doctor, chemist, and composer of major rank.⁸⁻¹⁷

It was my good fortune to study at the Military Medical Academy in St. Petersburg. As first-year students we spent a lot of time studying chemistry at the same laboratory where Professor Borodin was



Fig. 1. Alexander P. Borodin, MD, 1834-1887. (From the archives of the Military Medical Academy, St. Petersburg, Russia.)

working a century ago. We were told many stories and anecdotes about Borodin himself, his medical career, and the various opinions he had on different topics. Since that time I have maintained an interest in Borodin's life, which resulted in this article.

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LIFE

Alexander P. Borodin (Fig. 1) was born on Oct. 31, 1834, as the illegitimate son of Prince Gedianov, who registered Alexander as the legal son of one of his servants. In this way Borodin was the serf of his own father. Alexander was a very curious boy. Once when he was about 2 years old he stuck his head in the parapet of the balcony; the scar on his forehead remained with him for the rest of his life.^{1,18} Borodin's father died in 1843 and granted freedom to his son shortly before his death. He also provided Borodin and his mother with a four-story house and money.

Borodin's mother was an intelligent woman and did her best to provide her only son with a thorough education. Alexander was taught French and German privately. Soon he made a great friend, Mikhail Shchiglev, the son of a famous mathematics teacher. All tutors were employed at Shchiglev's father's recommendation, and both boys were taught by "teachers who were specialists in their particular subjects."^{1,18}

Early on, Borodin developed an equally strong passion for chemistry and music. By the time he was 13 years of age, Alexander had built a laboratory at home in various corners of his flat and was able to make his own watercolors.

In 1850 Borodin entered the Medico-Surgical Academy. During the first 2 years at the Academy, Borodin developed a deep interest in chemistry while attending the brilliant lectures given by Professor Nikolai N. Zinin (1812-1880). Zinin conducted a large-scale research study on nitroglycerin, which was first synthesized in 1846 by Italian chemist Ascanio Sobrero.¹⁹ Zinin's special interest was aniline, an organic base, which is used today to make dyes, drugs, explosives, and plastics. Aniline was first obtained in 1826 by destructive distillation of indigo, and Zinin was the first to synthesize it. His pioneer work in aniline derivatives led mankind to the entire world of synthetic dyes, and Zinin became known as the "magician of nitrates."^{20,21} Alfred Nobel lived in St. Petersburg from 1842 to 1863, from 9 years of age to age 30 years. Nobel studied privately in Zinin's laboratory, which was located within 15 minutes' walking distance from Nobel's apartment and, by the age of 17 years, became a rather skilled chemist.²¹ It is in Zinin's laboratory that Nobel first learned about nitroglycerin. Nobel left Russia in 1850 and, after 5 years of studying and working abroad, returned to St. Petersburg. He continued to work in Zinin's laboratory and his father's factory until the latter went bankrupt in 1859. At about the same time,

Borodin, a third-year student, began work of an advanced nature in Zinin's laboratory.

Borodin, who was exceptionally shy and sensitive, could not bring himself to approach Zinin for some considerable time, but now that he was in his third year, he at last went to see him, and explained that he would very much like to work in his laboratory under his supervision. Zinin was a little suspicious at first, but soon saw that he had not only a sound knowledge of chemistry, but also some acquaintance with experimental techniques. From that moment onwards, he never ceased to be Borodin's teacher, friend, and guide.²²

Whether Nobel and Borodin met each other while working in Zinin's laboratory is unknown. During the Crimean War (1853 to 1856), Zinin made a powerful explosive based on nitroglycerin. Zinin's ideas on physiologic and medical chemistry determined Borodin's priorities.^{23,24}

SURGEON

On April 6, 1856, Borodin was graduated from the Medico-Surgical Academy cum examia laude and was appointed house surgeon to the Second Military Hospital. Those first 3 years, until 1859, were very difficult for him as a young surgeon. Once, for instance, the coachman of some high-ranking official was brought into the hospital, and Borodin had to remove a bone that was choking him. While he was operating, the rusty instrument he was using broke while in the patient's throat. However, the young surgeon kept his presence of mind and, after a few unsuccessful attempts, removed the broken fragments of metal and the bone at the same time. Borodin said that, "the coachman went down on his knees before me, and it was as much as I could do to restrain myself from doing likewise. Just think what might have happened if the broken piece of forceps had stuck in his throat! You can bet that I would have been courtmartialled and ended up in Siberia."^{1,18}

Alexandrov gave the following account for another unpleasant incident: "In his first year as house surgeon at the hospital, my brother happened to be on duty one day when they brought in six serfs belonging to Colonel V... who had flogged them for locking him in the stables because of the cruel way he treated them. Borodin had the job of pulling out the splinters from their backs. He fainted three times at the sight of the skin hanging in tatters from their backs. In the case of two of them, their bones were visible."^{1,18}

It was during this time that Borodin first met Modest Musorgsky, an officer of the Preobrazhensky



Fig. 2. Military Medical Academy: Second Military Hospital and Department of Chemistry with Zinin's laboratory (author's photograph of 1994).

Guards, one of Russia's most aristocratic regiments. Borodin left a vivid picture of how they met:

I was a raw recruit in the army medical service and house surgeon at the Second Military Hospital. Musorgsky... looked very new to the job; he could not have been more than 17 at the time. We first met in the hospital, in the hospital orderly room. I was duty doctor and he duty officer. The room was like any other of its type, and neither of us liked being on duty. Neither of us was reserved and we naturally started up a conversation, and very quickly became friends. That night we had both received an invitation to a party the next evening by Popov, the Head Doctor at the Hospital. He had a grown-up daughter, and it was for her sake that he frequently threw parties, and of course the duty officers and doctors had to be invited.

There was something absolutely boyish about Musorgsky; he looked like a real second-lieutenant of the picture books... a touch of foppery, unmistakable but kept well within bounds. He was wearing a brand-new and tight-fitting uniform, he stood well, and his hair was well-groomed. He had the manners of a gentleman, and spoke through his teeth; he interlarded his speech with French turns of phrase, and rather flowery ones at that. His courtesy and good breeding were exemplary. All the women fell in love with him... He sat down at the piano and played... very gently and graciously, with occasional affected movements of the hands, while his listeners murmured, 'charmant, délicieux!' and so on.^{1,18}

Although the surgical duties left Borodin little time for music, the hospital was conveniently located, adjacent to the Department of Chemistry (Fig. 2). This made it easier for Borodin to continue his work in chemistry. All of his spare time was taken up with laboratory work.

CHEMIST

On May 15, 1858, Borodin received a doctorate for his dissertation, "On the Analogy of Arsenic and Phosphoric Acids." In October 1859 Borodin went abroad as a delegate of the Medico-Surgical Academy, together with Mendeleev, Sechenov, and Botkin. Zinin insisted that Borodin should spend some time abroad to gain the necessary experience for the post of Adjunct-Professor of Chemistry, which he would take up on his return. Thus it came about that Borodin was able to abandon his surgical career, which had seemed to him in any case the wrong choice.

In accordance with Zinin's instructions, Borodin was to work in Heidelberg in Bunsen's laboratory. However, when he got to know the conditions there, Borodin decided that it was unsuitable and spent most of his time in Heidelberg working with his friends, Mendeleev, Sechenov, and Botkin, in the laboratory of young Privatdozent E. Erlenmeyer.²⁵

The periodic table of elements of Dmitry I. Mendeleev (1834-1907) is well known today to everyone from secondary school. The final version of the periodic table was introduced in 1871. Although Mendeleev's textbooks ran to many editions in many languages, the periodic theory remains his chief monument. Ivan M. Sechenov (1829-1905) was one of the founders of the Russian school of physiology. Both Sechenov and Sergei P. Botkin (1832-1889) created their own scientific schools; their contributions to Russian medicine cannot be overstated. Among their students were Nobel Prize winner Ivan P. Pavlov, Vladimir M. Bekhterev, and many other prominent physicians. What about Borodin? His musical activities were viewed with disfavor by those who saw in him the makings of a brilliant chemist. Once, for instance,

Zinin said, "Dr. Borodin, it would be better if you gave less thought to writing your songs. I have placed all my hopes in you, and want you to be my successor one day. You waste too much time thinking about music. A man cannot serve two masters."^{1,18}

At the end of 1860, Borodin went to Paris and remained there until the spring of 1861, carrying out the studies he had planned in accordance with Zinin's instructions. On returning to Heidelberg in May 1861, Borodin met his wife-to-be, a 29-year-old Russian woman, Katerina S. Protopopova, who came to Heidelberg to be treated for tuberculosis. She was a brilliant pianist and a well-educated woman.

In September 1861, Borodin left Heidelberg to take part in a congress of German chemists and naturalists. It was at this congress that his friend Butlerov gave his famous report on aspects of the structure of chemical combinations, which was the beginning of structural chemistry. On returning to Heidelberg, Borodin learned that his fiancée was seriously ill. She wrote, "I again became ill after a respite of the summer. I developed a heavy cough, and blood came from my throat. It seemed as though my chest was bursting; I grew paler and thinner, as pale as death."¹ Borodin took her to see Professor Friedreich, a well-known Heidelberg physician, whose conclusion was: "She will not see the month out, if she does not go to a warm climate. Pisa is warm at this time of the year; let her go there."¹

They left for Pisa with no delay. Borodin continued his work with two well-known chemists in Pisa, Lucca and Tassinari. Borodin and his fiancée arrived in St. Petersburg at the end of September 1862. Borodin was appointed to the post of Adjunct-Professor in December 1862 and began lecturing to the students of the Academy. Borodin's lectures and his brilliant, fascinating personality produced a deep impression on the students.^{1,18,22,26} On April 17, 1863, Borodin was married to Katerina. Despite her chronic ill health and the fact that they had no children, their marriage was happy. Borodin became full professor in April 1864.

Borodin's enthusiasm for teaching students at the Academy was related by one of his students, who wrote:

He spent whole days there in the midst of his students. Possessed of a very even temper, he was always ready to break off his work to answer the questions of his pupils, who all felt quite at home with him. We could always approach him, display our ideas and give free rein to our thoughts without fear of being repulsed or of receiving an evasive answer. The only signs of impatience which he

showed were provoked by our negligence or want of care. "My dear old chap," he would then say, "if you continue to work in that style, you will not be long in destroying our fine collection of instruments," or "How can you make such bad smells in such a beautiful laboratory?" And he would send the careless pupil to work in another room.²⁶

Borodin played an active role in the administration of the Medico-Surgical Academy and, together with Botkin, Sechenov, and other professors of the Academy, helped to found the first medical course for women in Russia in 1872. This started out as a course in obstetrics based in the Academy and developed into a course of higher medical education for women. Borodin devoted a considerable amount of his time to this course.

COMPOSER

In autumn 1859, Borodin again met Musorgsky, this time at the home of Professor Ivanovsky. Borodin wrote about this:

He was just as smartly dressed, and still the perfect gentlemen, but there was no trace of foppishness. We were introduced to one another, but of course we immediately recognized each other, and went on to reminisce about the times when we first met at Popov's. The conversation automatically turned to the subject of music. I was still mad keen on Mendelssohn, and at that time hardly knew anything about Schumann at all. Musorgsky was already acquainted with Balakirev, and had an eye for all the new things that were going on in the musical world, of which I had not even slightest idea. He played me extracts from the E flat major Symphony of Schumann. When he came to the middle section he broke off with the words: "That is where the musical mathematics begins." It was all new to me and I liked it. Seeing that I was interested, he played something else that was new to me. I also learnt that he was writing music himself. Naturally I was fascinated, and he began playing me a scherzo of his. When he came to the trio, he muttered: "Look, this is oriental," and I was astonished by this strange kind of music, which was like nothing I had ever heard before.^{1,18}

In the late autumn of 1862, Musorgsky introduced Borodin to Balakirev at Professor S. P. Botkin's house. Balakirev, a mathematician and an almost exclusively self-taught musician, became the head of young composers, which at that time consisted of Musorgsky, a former military officer, Nikolai Rimsky-Korsakov, a former naval cadet, and Cesar Cui, an officer of the corps of engineers and, subsequently, a professor of fortifications in the Engineer's Academy. Together with Borodin, they formed the group known as the "The Mighty



Fig. 3. Borodin (*fifth from right, back row*) and Mendeleev (*second from left, back row*) during founding meeting of Russian Chemical Society on Jan. 5, 1868. (From the archives of the Military Medical Academy, St. Petersburg, Russia.)

Handful," dubbed "Five." The group drew its inspiration from the wealth of Russian folk music and an example from Glinka, the father of Russian music.

Balakirev wrote about the acquaintance with Borodin: "Our acquaintance has had a special significance in that he had regarded himself before only as a dilettante, and had not taken seriously his own efforts at composition. It appears that I was the first to point out to him that his real vocation was composition."^{1,18} This had an important effect on Borodin, who was occasionally overly self-critical, and whose powerful intellect and deep critical sense at times got in the way of his creative work.

Borodin himself always regarded his clinical, laboratory, and teaching activities as far more important than composing. He wrote, "I must point out that I am a composer, looking for the unknown. I am almost ashamed to confess to my composing activity. Others have the composition of music as the goal of their lives. For me, it is only rest, fun which takes time from my serious business as a professor. I am absorbed in my affairs, my science, my academy and students. Men and women students are dear to me."²⁷ Borodin composed music in his spare time: "When I am so ill I must sit at home and can do nothing important, my head splitting, my eyes filled with tears so that every moment I must take out my handkerchief, then I compose music."^{1,18}

A famous Russian composer, Rimsky-Korsakov, was similar to Professor Zinin in his belief that

Borodin "wasted his time." In his book, *My Musical Life*, Rimsky-Korsakov wrote about Borodin:

During my visits to him, I frequently found him in his laboratory, which was connected with the apartment, sitting silently before his tubes, retorts and other queer looking chemical implements. When he had finished his experiments, he returned to the apartment and again began to work on music. But the trouble with Borodin was that he was never at one place; either he jumped up and went to see whether something had not boiled over and spoiled in the laboratory or somebody wanted to see him. Borodin was forever attending meetings, making reports or speeches and giving most of his free time to the movement in behalf of women. Besides all this, he was conscientiousness itself regarding his lectures and clinical work. Then there were his students whom he could never refuse. Lastly there were his country relatives and friends. His apartment looked like a hospital and often he could not even find time to eat his meals. Besides this, his wife suffered from asthma. My heart ached to see how a great genius wasted his time on such matters and could not accomplish his real work.²⁸

Balakirev had been invited in the autumn of 1867 to take up the post as conductor of the Russian Musical Society. In 1868 he arranged for a private performance of Borodin's First Symphony, along with other new works by Russian composers. The symphony was a failure because the parts, which had been copied in a hurry, contained numerous mistakes.

In early December 1868, Borodin took part in

the founding meeting of the Chemical Society (Fig. 3). After the event he wrote, "This was a very nice and happy occasion for me. The second session has been fixed for January 9." Borodin was occupied by his research at the time; however, he had to correct the First Symphony in preparation for its first public performance at the concert of the Russian Musical Society. This work required great accuracy and precision and provoked exasperation from the composer. He wrote to Balakirev:

What a devil of a lot of mistakes! It is a general rule that you never know where you are with a symphony until it is performed. We all had our works played at the Free School concerts, and only mine was a flop. They got their performances through in good time, but I had to wait 3 years for mine. Haman did the copies for the others, but some real son of a bitch has done mine. It would not surprise me if they bombard the composer with rotten apples.²²

After correcting the mistakes, Borodin sent the symphony to Balakirev and wrote, "You have never seen such a bungled job in all your born days... Apart from the intentional harmonic peculiarities, I came across most extraordinary sequences of minor seconds, diminished fifths, clashes of major and minor, and the devil only knows what... Well, old chap, I never realized correcting parts could be such a hellish business."²²

The First Symphony "of a composer seeking oblivion," as Borodin put it, was conducted by Balakirev on Jan. 4, 1869. On Jan. 9, Borodin made several scientific reports for the Chemical Society. Both events were a great success.

In 1869 Borodin adopted a 7-year-old girl, Liza Balaneva, and later another girl, Elena Guseva. That same year he began to work on a three-act opera, *Prince Igor*, based on the twelfth century prose-poetic saga *Slovo o polku Igoreve (the Story of Igor's Army)*. The progress with the opera was slow because his musical work was constantly subordinated to his professional activities. After autumn 1881, *Prince Igor* appears to have been neglected altogether for about 5 years.

The international fame of Borodin's music came after 1877, when he met Franz Liszt while on a trip to Jena.² Liszt was sympathetic toward the "new Russian music"; he was very much impressed by the Second Symphony in particular and, subsequently, became active in promoting performances of Borodin's works in Germany. Borodin corresponded with Liszt frequently and managed to spend a month with him in Magdeburg and Weimar in 1881 and an additional few days in 1885. The symphonic sketch, "In the Steppes of Central Asia,"

composed in 1880, achieved great popularity in not only Russia but also Europe generally.² Liszt was so taken with it that Borodin dedicated it to him and, while in Weimar, Borodin and Liszt arranged it as a piano duet and performed it together at a private party given by Princess Wittgenstein.^{1,26} "But I am only a Sunday composer, Herr Liszt!" Borodin once said. "aber Sonntag ist immer ein Feiertag, Herr Borodin!" was the response. Sunday is always a feast day, so Franz Liszt summed up the contribution of medicine's greatest composer.

The interest in the new Russian music was particularly marked in France and Belgium. Borodin traveled to Belgium in 1885 and 1886. He was pleased to discover that his works were accorded great ovations and to find that he was feted as a celebrity.²

DEATH

On March 19, 1887, the following note appeared in the *Lancet*:

Dr. Alexander Porphyryevich Borodin died suddenly, probably from highly diseased coronary arteries. His published works were tolerably numerous and included a number of important articles on the estimation of nitrogen. By means of Professor Borodin's process, combined with that of Kjeldahl's, the physician has a means whereby this estimation may be made with a very moderate amount of difficulty and trouble... In spite of his arduous professional and laboratory work, Professor Borodin found time for cultivation of the art and science of music, in which he was quite adept. He is, indeed, said to have rendered valuable service to the cause of Russian music.²⁹

The last decade of Borodin's life was full of emotional tension and heavy work, but also this was a time when his music gained widespread international acceptance.

On Feb. 9, 1880, Borodin's beloved teacher and friend, Nikolai N. Zinin, died. Borodin helped with the funeral arrangements for "the father of Russian chemistry" and made a heartfelt and impassioned speech at the graveside to the crowd of students gathered there. Borodin headed a commission set up for raising the necessary money for a monument to his teacher to be erected at the Medico-Surgical Academy and personally supervised its construction. As a student at the Academy, I admired this monument, which reflected the truly scientific spirit of a great man.

In the summer of 1880, Borodin wrote, "I cannot remember a time when I had so much urgent and priority work on my hands. It happens very often



Fig. 4. Modest P. Musorgsky (portrait by Ilya E. Repin, 1881, Tretyakovskaya Gallery, Moscow).

nowadays that I do not get to bed before 2 or 3 in the morning, and have to be up again at 4 or 5."²²

On Feb. 24, 1881, Musorgsky became seriously ill. That day he was "in a state of great nervous excitement," saying that "there was nothing left for him, but to go and beg in the streets." In the evening he had three fits of seizures. As a result of his alcoholic liver cirrhosis, Musorgsky had portal hypertension with fever, ascites, jaundice, and renal insufficiency.

When Borodin examined him, Musorgsky had already had fetor hepaticus, a unique musty odor of the breath and urine, and a peculiar "flopping tremor" or asterixis, which are often seen in precoma and in advanced hepatic encephalopathy. Borodin managed to get him to the Nikolaevsky Military Hospital. Musorgsky was at the hospital for about 1 month. Borodin visited him daily and, together with Dr. Bertenson, provided Musorgsky with the best possible treatment.³⁰ With Borodin's urometer described in 1876, they were able to estimate uric acid in the blood and urea. The temporary improvement was achieved from March 15 to March 17, during which time Ilya E. Repin, one of the leading Russian artists of the day, painted his portrait (Fig. 4). Today this portrait is in the Tretyakovskaya Gallery in Moscow and could represent a classic picture of a patient with last-stage alcoholic liver cirrhosis who had encephalopathy, jaun-

dice, and facial edema. Borodin saw Musorgsky for the last time the day before his death. The next day, March 28, the nurse told Borodin that she heard Musorgsky cry out, "All is over!... How unfortunate I am!" His final agony lasted less than 15 minutes. So his old friend, who was "so talented, original, full of so much that was new and vital," died at the age of 42 years. Borodin was very affected by his death and after that moment began to have frequent episodes of angina pectoris.

Although Thomas Lauder Brunton (1844-1916) had already published his observations on the value of amyl nitrite in angina in the *Lancet* in 1867, and William Murrell (1853-1912) advocated nitroglycerin for the treatment of angina pectoris in 1879, the treatment for ischemic heart disease was not well established at that time.³¹⁻³³ Even in 1895, when Alfred Nobel was prescribed nitroglycerin for angina pectoris, he was certainly taken aback. Thus Borodin had to live with it.

Borodin had many talented students. One of them was Nikolai I. Kibalchich (1853-1881), who, as a third-year medical student and also a revolutionary minded member of the terrorist organization People's Will, made nitrogelatin, a powerful explosive for self-made bombs. The aim of People's Will was to force Alexander II to implement constitutional law in Russia. This constitution, if implemented, might possibly have become the germ of constitutional development in Russia. During unsuccessful attempts to shoot him, to derail his train, and finally to blow up the Winter Palace in St. Petersburg, Alexander II had shown unflinching courage based on a fatalist philosophy. However, ironically, on March 1, 1881, when, after much hesitation, the Tsar finally signed the proclamation announcing his intentions, he was mortally wounded by the bombs of Kibalchich. Kibalchich was arrested, tried, and executed. His last will was to write a letter to the Academy of Sciences in which he outlined his design of a rocket-propelled aircraft capable of rising beyond earth's atmosphere. This was the world's first recorded proposal of its kind. Although simple, his ideas are basic to space technology. A crater on the far side of the moon has been named after him.

The advent of Alexander III to the throne was marked by violent reactionary change in Russian political life. To restore order, the Medico-Surgical Academy was renamed the Military Medical Academy and subordinated to the Ministry of War. There were mass arrests of students, and Borodin, who was always closely linked with student life, shared the burden of their misfortune and did all he could to help those who had been arrested. One



Fig. 5. Borodin's sketch of Yaroslavna's scene with chorus from *Prince Igor*, composed 1869 to 1870. (From the archives of the Military Medical Academy, St. Petersburg, Russia)

night in February 1882, he came to his friend's flat "covered in snow and frozen to the marrow; it transpired that he had been going about in a cab, since 8 o'clock that morning, and had been from one institution to another, inquiring after someone who had been arrested... Borodin did not restrict himself to inquiries and investigations, but even went to the length of destroying any material that might have compromised his students."²² One of the casualties of Alexander III's reactionary reign was that the Minister of War refused the use of the military hospital as an academic base for the Women's Medical Course. Borodin and some other professors from the Academy were able to rearrange the course under the aegis of the Ministry of Education. This arrangement lasted for 3 years, from 1882 to 1885, when the course was finally closed by authorities. Borodin was very affected by the closure and was reported to have burst into tears when the chemistry equipment was transferred back to the Academy.

In 1883 Borodin wrote, "Yesterday I started work on 'Igor' very early in the morning; it was just like the old days. And then at 10 o'clock drove to the Nikolaevsky Hospital for a committee meeting... which dragged on till 3 in the afternoon... I sleep disgracefully little, 5 hours a night... Today I got up at 6, and got down to 'Igor' without even bothering to wash."^{1,18}

In 1883 Borodin founded the student orchestra. On Feb. 9, 1885, the fifth anniversary of Zinin's death, a memorial to Zinin was unveiled in the Military Medical Academy. This was largely thanks to Borodin, who had gathered the necessary funds. In fact, his nationwide appeal for funds had raised such a sizable sum that the surplus went toward endowing a Zinin Scholarship for needy students.

In December 1886 Borodin wrote, "I am dashing off this note in a great hurry, as I am up to my neck in stacks over all kinds of reports, notifications, memoranda, recommendations, decisions—a heap of utter rubbish. Lord! When will it end..."^{1,18}

Despite the lack of time, Borodin was always looking for an opportunity to help someone. He made notations on scraps of paper of the things he wanted to do. On one of these papers he wrote, "Go to B and ask him to admit A into a hospital. Write a prescription for K. Talk to B concerning D. Could not something be done for V?" If he succeeded in helping someone, he was very happy.²²

During 1886, Borodin worked on the Third Symphony, which remained unfinished because the year of 1886 was "a very hard one." First his mother-in-law was ill, and then his wife's tuberculosis grew worse and she was twice "literally on the point of death and saved only by a miracle." At the beginning of 1887, Borodin returned to *Prince Igor* and composed some parts, which he played to his friends but never wrote down except in fragmentary sketches (Fig. 5). *Prince Igor* was finished posthumously by his friends who were composers.

All this made no small demand on his time and was a great strain on his nerves. This period was apparently reflected in his opera *Prince Igor* by the words *Ni sna, ni ótdikha izmúchennoi dushé* (my tortured soul knows neither sleep nor rest). These words became almost idiomatic in modern Russian language and are often quoted jokingly.

On Feb. 10, 1887, Borodin did not feel well and apparently had a foreboding of impending death. His colleague, A. P. Dianin, found Borodin one day in the "room with open fire" throwing bundles of letters into the grate. When he was asked what on earth he was doing, Borodin declared, "Well, you see, my dear fellow, I am making quite sure that all this does not fall into the hands of some journalist after I die. I am afraid someone might have the bright idea of publishing all this." Because a large number of these letters survived, Borodin probably was diverted from the task of burning letters by some urgent piece of business.

On Feb. 14, 1887, "he thundered away for quite a long time playing the tremendous music... A few minutes later he came into the laboratory in a state of excitement and joy; there were tears in his eyes." "Well..., he said, 'I know that some of the things I have written are not bad. But this finale!... What a finale!'"²² Not a single bar of this finale has survived; he never got as far as writing it down. Borodin was very busy making arrangements for a fancy dress ball to be held next day.

Borodin wrote in his last letter that the ball was to be in grand style. Borodin asked his colleagues to dress up and wanted them to be as gay and informal as possible. Borodin begged professors to come and bring their wives to the party; he assured them that they would have an interesting time and

see things they would never see the likes of again.^{1,18}

In the evening of that day, Borodin wrote a letter to his wife, who was living in the drier climate of Moscow on account of her tuberculosis: "Tomorrow we shall have a dance. It is going to be a grand affair—a costume ball in the auditorium. I do not care to write to you about it since others will tell you about it later."

On the morning of Feb. 15, 1887, Borodin improvised at the piano some new material for the Third Symphony; in the evening of the same day he attended the ball organized by the professors of the Military Medical Academy for their families and friends at the lecture hall of the Academy.

He appeared at the ball dressed in Russian folk style with a dark red woolen shirt and dark blue baggy trousers and apparently enjoyed himself immensely. One of the witnesses gave the following description of the ball:

They were all there at the appointed time. There were not many people, but the place was packed. Everyone was in high spirits. Not long after the dancing began, Borodin had a waltz with someone, and then came over to me. We were standing there talking when Professor Pashutin arrived and came across to greet us. He had come from a dinner and was in evening dress. Borodin asked him why he was looking so smart. I remarked that of all male attire I liked evening dress the most; it seemed to suit everyone and always looked elegant. Borodin declared with his usual mock gallantry that if I was really so fond of evening dress, he would in future always wear his frock-coat whenever he came to me, so that I should never have any cause for displeasure.

These were his last words. He spoke them indistinctly as though his tongue had grown numb, and it seemed to me that he was swaying. I stared at him, and I shall never forget the look on his face: a helpless, pitiful, and frightened look. I hardly managed to cry 'What's the matter?' before he fell full length on the floor. Pashutin was standing right next to us but failed to break his fall...

My God! How terrible this was! And the cry that went up from everyone! They all rushed towards him and, without lifting him up from the floor, tried to bring him round. Every doctor and professor in the Academy was soon there. For almost a whole hour they tried everything possible to revive him, but it was no use. I shall never forget the despair of one of the doctors, who was sitting with his head in his hands saying again and again that he would never forgive himself for not applying bleeding treatment at the start.

And there he was, lying on the floor before us, and we all standing round him in our fool's costumes, afraid to admit to each other that this was the end.

I remember that the last to come was Professor Manassein, but all hope had been abandoned by that time. He leant over him and listened to his heart; with a wave of his hand he said, 'Lift him up.' And they lifted him up and carried him out. It was all over.^{1,18}

The autopsy was performed in the very same hall where his last dance had been held. It showed that the cause of death was rupture of a coronary artery aneurysm, with hemopericardium and cardiac tamponade. In falling, Borodin had struck his temple against the corner of the stove; this caused a minor brain hemorrhage.

An exceptionally large crowd of people of all professions and walks of life attended his funeral. Students from the Academy bore his coffin all the way from his home in the laboratory to the cemetery. Mikhail Shchiglev, his close friend with whom Borodin took his first piano lessons, was in tears as he conducted a student choir at the funeral. Borodin was buried in the cemetery of the Alexander Nevsky Monastery, next to the grave of Musorgsky.

Borodin's wife died a few months later of "dropsy," possibly right-side heart failure caused by progressive pulmonary fibrosis, and pulmonary hypertension, which may have been the result of amyloidosis caused by long-standing tuberculosis.⁷

In 1906 Sir Henry Hadow stated of Borodin that, "No musician has ever claimed immortality with so slender an offering. Yet, if there be, indeed, immortalities in music his claim is incontestable."³⁴

In 1936 Sarton wrote the following: "The chemical fame of Borodin is not comparable with that of Zinin—who was one of the most distinguished leaders of Russian science and who obtained international recognition. Borodin's fame is humbler, but none the less important... while the musician Borodin is a dear and old friend to thousands of people all over the world."³⁵

EPILOGUE

Ten years after Borodin's death, the income from *Prince Igor* alone amounted to 50,000 rubles. The essential sum was arranged soon to be donated to the St. Petersburg Conservatoire in the form of a Borodin Scholarship for young composers.

Borodin was the greatest musician and chemist of all surgeons. Although he did not make a great surgeon, he expressed himself equally well in his medical work and music of immortal beauty. More

than 100 years after his death, his music continues to capture and inspire audiences all over the world.

This article is dedicated to the 200th anniversary of the Military Medical Academy. I thank Professor V. O. Samoilov and Dr. Timothy Pansegrau for their valuable advice regarding the manuscript.

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