The Life of S.V. Kovalevskaya

By Roger Cooke

The following informal essay highlights some intriguing moments in the life of this distinguished woman. If it leads the reader to the excellent 1983 biography *A Convergence of Lives*, by Ann Hibner Koblitz, its purpose will have been more than fulfilled. To this end, I am including some trivial gossip that would have no place in a more scholarly publication, just because it illustrates some of the more colorful aspects of her personality. For Kovalevskaya was a very strong and determined person, though subject to periods of depression. When I wrote my analysis of her mathematical work in 1984, I thought I had finished writing about her, having said all that I could. I was wrong; the more I reflect on her life and consider the magnitude of her achievements set against the weight of the obstacles she had to overcome, the more I admire her. For me she has taken on a heroic stature achieved by very few other people in history. To venture, as she did, into academia, a world almost no woman had yet explored, and to be consequently the object of curious scrutiny, while a doubting society looked on, half-expecting her to fail, took tremendous courage and determination. To achieve, as she did, two results of lasting value to scholarship, is evidence of a considerable talent, developed through iron discipline. In this essay I hope to pay due respect to that courage, determination, talent, and discipline. The present rather gossipy sketch of her life will stand on my web page next to a more serious analysis of her mathematical work, aimed at a mathematically literate audience. This brief biography consists of four parts: Childhood (1850–1868), University Years (1869–1874), The Wilderness Years (1875–1883), and The Professional Years (1883–1891).

Childhood (1850–1868). Sof'ya Vasil'evna Kryukovskaya was born January 15, 1850 (January 3 on the Julian Calendar used in Russia at the time). The family was in Moscow because her father Vasilii Vasil'evich Kryukovskoi (1800–1874), an artillery officer, was stationed there. They were minor gentry, not at the time listed in the Russian equivalent of Burke's *Peerage,* despite having petitioned for such recognition for many years. Kovalevskaya's mother, Elizaveta Fyodorovna Shubert (1820–1879), was the great granddaughter of Johann Ernst Schubert, a Lutheran theologian driven from Braunschweig to Pomerania by the Seven Years' War (1757–1763). His sixth and last son, Theodor, Elizaveta's grandfather, emigrated to Russia, becoming a surveyor in what is now Estonia. In Russia he followed the practice of Russifying his name and using his father's name as his middle name (patronymic). Hence he became Fyodor Ivanovich (Theodor, son of Johann) Shubert. (The German Sch is represented by the single letter Ш in Russian, transliterated into English as Sh.) Fyodor Ivanovich Shubert became a competent mathematician and astronomer, and was eventually elected to the Petersburg Academy of Sciences. He corresponded with some of the great German scientists of his time, including C.F. Gauss and F.W. Bessel, and with the French astronomer/mathematician Pierre-Simon Laplace. His son Fyodor Fyodorovich, Elizaveta's father, was a distinguished geodesist, whose papers on map-making were read with interest by mathematicians, including one who was to play an important role in the life of our subject, Karl Weierstrass. In 1861, nine years before he ever met or heard of Sof'ya Vasil'evna Kovalevskaya, Weierstrass wrote a paper on geodesics on general ellipsoids, in which he cited findings of "the Russian general Schubert" on the actual shape of the earth. Elizaveta Fyodorovna Shubert was a talented woman, an excellent pianist, who responded to the confinement imposed on Russian women by organizing a home theater. Having nannies to look after her children, she took very little interest in their upbringing.

Vasilii Vasil'evich Kryukovskoi likewise entrusted the upbringing of his children to the servants, and in addition, neglected his wife. Having served in the army from the age of 17, he had risen to the rank of artillery colonel by 1848. After becoming commander of the Moscow Artillery Garrison, he spent a great deal of time gambling at the English Club. Following in the tradition of Tolstoy, he had to sell some of his estates to pay off his gambling debts.   He did, however, show a desire to become a proper country gentleman. To that end, he sought recognition as a member of the nobility. Although the exact details are murky, it appears the family was able to parlay its surname into a genealogical connection with the family Krukovskii and thereby trace a descent from a Hungarian king Matthew Corvus ("Raven"). In

1858 their claim was recognized, and they were granted the right to use the name Korvin-Krukovskii and a family crest with a raven. By this time Vasillii Vasil'evich had risen to the rank of lieutenant-general, and, because the emancipation of the serfs was imminent, decided to retire to his estate, named Palibino, near Vitebsk in Belarus. In Vitebsk he became Marshal of the Nobility (Предводитель Дворянства) in 1863.

Vasilii Vasil'evich Kryukovskoi and Elizaveta Fyodorovna Shubert were married in 1843. Within a year of their marriage their first daughter Anna was born. There was apparently another child in the 1840's, who did not survive. Then, in 1850, Sof'ya was born, followed by the only surviving male child, Fyodor, in 1855. Thus the first eight years of our subject's childhood was spent in Kaluga, south of Moscow, with a much older sister, joined when she was five by a younger brother. The main adult in her life was her nanny.   When their father retired in 1858, he discovered to his horror that his daughters were very ignorant. He replaced the nanny with an English governess, Margaret Smith, and hired a Polish tutor named Joseph Malevich.

The move to Palibino coincided with the beginning of the intellectual awakening of the eight-year-old Sof'ya. She later recalled that the walls in one room of the house had, for lack of proper wallpaper, been covered with the notes from a mathematics course her father had taken. (As he had taken calculus from the great mathematician Ostrogradskii, co-discoverer with Gauss of the divergence theorem, these haphazardly arranged notes may well have been from that course.) This room fascinated the 8-year-old. She also enjoyed listening her mother's brother tell her about the intricacies of infusoria and algae. Her father's brother told her, as she recalled, "about the quadrature of the circle, about the asymptotes toward which a curve continually approaches but never reaches, and many other things of that sort, whose meaning I of course could not yet understand, but which influenced my imagination, inculcating in me a reverence for mathematics as the highest and most mysterious science, which opens to its initiates a new and wondrous world that is inaccessible to ordinary mortals." This material is of course beyond the ken of a preadolescent, but it certainly piqued her interest, else she would not have remembered it all into adulthood. Her memories of this life were elegantly written up in an autobiographical book called *Memories of Childhood*, translated into English by B. Stillman and published as *A Russian Childhood,* (Springer-Verlag, 1978).

Here are some reminiscences of the time from those who were present:

> "…this way [the traditional education of girls] could never satisfy her fiery, receptive nature, [and she was obliged to wage a struggle for the freedom of her education]." (Fyodor Vasil'evich Krukovskii, on his sister's education.)

> "At my first meeting with my gifted pupil in October 1858 I saw an eight-year-old girl rather strongly built, of a pleasant and attractive appearance, whose brown eyes shone with a receptive intelligence and a heartfelt kindness. From the very beginning of her studies she exhibited a rare attentiveness and rapid assimilation of what was taught, a completely methodical approach, so to speak, a precise fulfillment of what was required and consistently good understanding of the lessons…Three or four years of entirely successful lessons passed without the occurrence of anything notable. But when our study of geometry reached the ratio of the circumference of a circle to its diameter…my pupil, when explaining this topic in the next lesson, astonished me by arriving at the same result in a completely different way using her own reasoning." (Joseph Malevich. He adds that when he pointed out that her approach was rather roundabout, she grew embarrassed and burst into tears.)

Three other influential people can be singled out as having recognized Sof'ya's talent and encouraged the young scholar to pursue her education. The first of these was a neighbor, the physicist N.P. Tyrtov, who brought Krukovskii a textbook of physics some time during the early 1860's. In 1864 he was astonished to learn that the 14-year-old Sof'ya had been reading the book. Not knowing trigonometry, she had been obliged to do her best to make sense of the sine function. Her guess was that the sine of an angle is

proportional to the chord in a circle subtended by a central angle. In fact it is proportional to the chord subtended by an inscribed angle, but for small angles the difference is negligible. Tyrtov called the attention of Krukovskii to his daughter's extraordinary abilities. Krukovskii thereby became the second beneficent influence by agreeing to find a more advanced tutor for her. The tutor eventually found, A.N. Strannolyubskii (1839–1903), was the third major influence. Strannolyubskii, an excellent teacher, and Sof'ya, an excellent pupil, were ideally matched. In three years of study during the family's winter stays in Saint Petersburg, they progressed through calculus and perhaps beyond.

Although these notes have been written so far with an emphasis on Sof'ya's education, we cannot ignore the most important influence of all, her older sister Anyuta, whom she called "my spiritual mother." Anyuta was not scientifically inclined. Her interests were literary and romantic. Her personality was much more flamboyant and outgoing than that of her morose younger sister, leading the nanny to encourage little Sof'ya in the belief that she was not loved as much as she deserved. Anyuta wrote short stories and communicated her enthusiasm for radical causes to her younger sister. A beautiful and talented 20-year-old, she sent some of her short stories to Dostoevsky in 1863, one of which he printed in his journal *Epoch*. Anyuta's father was outraged that Anyuta had had the effrontery to pursue a career without his consent. Nevertheless, Dostoevsky visited Anyuta, and even proposed marriage to her. Sof'ya, only 14 at the time, developed a crush on Dostoevsky, and was appalled that Anyuta refused him. Her adolescent pride was also wounded when she found Dostoevsky wooing Anyuta while she, Sof'ya was attempting to get his attention by playing his favorite music on the piano (Beethoven's *Sonate Pathétique*).

During the Polish uprising of 1863, both sisters sided with the Polish rebels, against the government of the tsar. Sof'ya even began to take lessons in Polish from Malevich. The rebellion had been brutally crushed, and the rebels who were not killed were either in exile in Siberia or had fled to the West. Among them was a young man named Bujnicki, who had shown some interest in her and had written in the personal album that she kept (as did all young women at the time) the following lines, in Polish of course:

> My child, if I never see thee again, I shall forever keep the bright memory of thee.
> How happy I had been, had it been granted me to see the flowering of thy bud, which is even now
> about to bloom.
> But fate will not grant me that happiness, and I can only salute thy beauty in farewell.

Sof'ya later wrote of these lines, "What could these verses mean? I was happy and proud that he had dedicated them to me, but at the same time my heart was oppressed with a sense of foreboding." Bujnicki disappeared a few days later.

It was in this frame of mind that Sof'ya approached an impending reception at the family estate in April 1865, to be attended (against the family's wishes) by one Colonel Yakovlev, who had helped to crush the rebellion. She began to fantasize, " Tomorrow, as soon as he sits down to table, I'll take a large knife and plunge it into his heart, crying 'That's for Poland!' Then they'll seize me, of course, clap me in irons, and send me to Siberia, where I'll meet Pan Bujnicki." Needless to say, the affair turned out differently. Yakovlev tried to show off his artistic talent and asked for an album in which to draw a picture. Sof'ya was ordered to produce her album, the one containing the verses quoted above. Reluctantly she did so; and as soon as Yakovlev had drawn his picture, she ripped it out, tore it into pieces, and stepped on it. She was duly punished for this impertinence, and the family explained to Yakovlev that she was jealous of his ability.

But childhood does come to an end. To continue her education and get that all-important seal of excellence, the university degree, was a problem for young women of her time, one that, in retrospect seems almost unsolvable. Absolutely every instant of socialization of young girls at the time was directed toward making them wives and mothers. If a girl somehow overcame her own natural inclination to fit

into her society and persisted in wanting an education, she most likely ran into such formidable opposition from her family that only the most heroic would continue the struggle. If by some happy circumstance her family could be persuaded to consent, the larger society itself made it essentially impossible to get any recognized degree by closing all the universities to women, confining them to what were called in Russia the Women's Higher Courses. These were, as one might expect, rather weak in science. How was the eighteen-year-old Sof'ya shown in the photograph below to continue the education she had begun so auspiciously?

It seems likely that Sof'ya hoped to persuade her father to support her enrollment in some institution,

perhaps even allowing her to travel abroad, if necessary. Although he was very old and of military and conventional background, she was his favorite child and she knew that she had considerable influence over him. However, her sister Anyuta was also to be considered, in her early 20's by 1868, and the two had girl friends who also wanted to pursue an education. One way of getting out was to find a politically conscious young man willing to enter into a formal marriage, while observing all the Victorian proprieties of behavior between people who were not actually married. In other words, the young man had to be a rebel willing to flout the conventions of society, yet enough of a traditional gentleman to treat a lady with the proper respect. Having a husband of this sort brought a measure of freedom and independence. It was, however, a drastic solution to the problem of women's emancipation, ironically well-described in the words of the English marriage ceremony: an estate not to be entered into lightly. That it was resorted to as often as it was shows the difficulties in the way of women's education at the time.

A young man more or less fitting the qualifications described above was Vladimir Onufrevich Kovalevskii (1842–1883), a radical publicist with an interest in biology. It may have been, as he stated, his desire to serve science that caused him to revoke his agreement to "marry" Anyuta and promise to "marry" Sof'ya, instead. He had begun a correspondence with Darwin in 1867, in connection with his Russian translation of the second volume of Darwin's work on domesticated animals. (Sof'ya helped to edit this translation.) Together they began to dream of an ascetic life devoted to the cause of science and the reform of society. This may be the appropriate place to mention the movement in Russia at the time known as nihilism. The nihilists, as originally depicted by Turgenev in the character Bazarov of his novel *Fathers and Sons*, were people who thought the current state of society was radically hopeless, and that it was necessary to start over *ex nihilo*, on a foundation of science and humanitarian values. By the 1860s this term was being used to describe the radical youth of the time. Kovalevskaya considered herself a nihilist, though she was less devoted to the cause than her older sister.

Sof'ya and Vladimir were married on 15/27 September 1868. They immediately set out for Petersburg, where both attended lectures on anatomy and physiology. (In Sof'ya's case, even though anyone could legally attend lectures, she entered in the company of her husband, her uncle, and another trustworthy man, so as to avoid attracting attention.) One brilliant opportunity was lost to her in Saint Petersburg. She made the acquaintance of the distinguished mathematician Pafnutii L'vovich Chebyshev (1821–1894). Chebyshev had grown wealthy by speculating in real estate, and he was by no means a reclusive academic. He held weekly open houses to which anyone could come and consult with him on mathematical problems. If only the university had been open to women, Sof'ya would undoubtedly have become his student. She became acquainted with him at this time, but as women could not take examinations or be granted degrees, there seemed to be no future in this direction. Nevertheless, this acquaintance was later to be of mutual benefit, as Chebyshev supported Sof'ya's eventual appointment as a corresponding member of the Petersburg Academy of Sciences, and she in turn helped him to put his students in touch with Western journals and mathematicians.

University Years (1869–1874). Sof'ya, Anyuta, and Vladimir left Petersburg for Vienna on 16/28 April 1869. The high cost of living and the search for a mathematician with whom Sof'ya could work, however, impelled them to move on to Heidelberg, where their requests for admission became something of a *cause célèbre*. In the end it was left to individual professors to grant women the right to attend their classes if they wished. Sof'ya was able to study with some very well-known professors: Helmholtz, Kirchhoff, Bunsen, Leo Königsberger, and Paul Du Bois-Reymond. Her efforts on behalf of another young woman, Yuliya Lermontova, with whom she became good friends, led to an amusing incident with Bunsen. The latter had sworn never to allow women into his laboratory, especially not Russian women. He not only didn't want to let Lermontova study with him, he didn't even want to hear about her. Sof'ya, however, asked him so tenderly that he changed his mind. Later he wrote to Sof'ya's professor Weierstrass that Sof'ya was a "dangerous woman." Well, if she did sometimes take advantage of the fact that men found her attractive, who can blame her?   This small asset was hardly sufficient to counterbalance the overwhelming weight of society against a woman's career in her day. In her work she was always earnest, and never wanted anything she hadn't honestly earned by her talent and effort. From Heidelberg Sof'ya and Vladimir frequently traveled to different parts of Europe, including England, where they visited Darwin and Thomas Huxley, and were once guests of the writer George Eliot. Eliot described Sof'ya as, "a pretty creature, with charming modest voice and speech, who is studying mathematics (by allowance, through the aid of Kirchhoff at Heidelberg)…." Kovalevskaya was herself a writer of considerable talent and later wrote an essay on her acquaintance with George Eliot.

Anyuta soon left Heidelberg for Paris. To keep her parents believing that she was still properly chaperoned by her married younger sister, she sent letters to her parents via Sof'ya, who repackaged them so as to make it appear that they came from Heidelberg. (Eventually their father learned of the deception and terminated Anyuta's allowance.) In the end, Heidelberg also proved unsuitable as a place to obtain a degree. It was clear that Sof'ya would need the support of some very influential people to achieve that end.   Such a person was Karl Weierstrass (1815–1897), one of the giants of nineteenth-century mathematics, a professor at the University of Berlin, and by good fortune the teacher of two of her teachers at Heidelberg. As it must have seemed to her in 1870, even if she couldn't obtain a university degree, the mere fact of having been a student of Weierstrass would establish her credentials in a very impressive way. It should be said that Vladimir had involved himself in her life more than she may have wanted or expected from a fictitious husband, and certainly more than Anyuta wanted. However, had he not appeared on the scene to vouch for her marital state, the university authorities might not have allowed her to attend classes at all. On the occasions when he visited Heidelberg, the two frequently quarreled. Therefore, when Kovalevskaya (as I shall henceforth refer to Sof'ya) set out for Berlin in the late summer of 1870, she was probably feeling a mixture of hope and relief. Anyuta, meanwhile, was still in Paris, where she had entered into a liaison with a French radical named Victor Jaclard.

World events sometimes break into the lives of ordinary people with momentous consequences. In 1870 the major event in Europe was the Franco-Prussian War, which began in August. Its first consequence for Kovalevskaya was that, when she knocked on Weierstrass' door, the 55-year-old confirmed bachelor, an opponent of admitting women to the universities, was favorably inclined to her for at least two reasons. First, her visit had been preceded by good letters of recommendation from her Heidelberg professors. Second, his auditory of 50 students the previous year had shrunk to 20 because of the war. Still, since she couldn't attend classes legally, he proposed private lessons. (I am trying hard not to make that proposal sound sinister. There is not the slightest reason to believe their relationship was anything but that of a friendly professor and student, despite some outrageous insinuations to the contrary in the book by E.T. Bell, in which Kovalevskaya, the only woman in a book appropriately named *Men of Mathematics*, is trivialized and depicted as a seductive playmate.)

Kovalevskaya proved to be very well prepared and was able to solve the test problems Weierstrass proposed to her. She began a correspondence with Weierstrass at this time, of which about 150 letters from Weierstrass to her have been preserved, but only fragments of one of her letters to Weierstrass.

(Weierstrass burned her letters when he learned of her death in 1891. The draft of the letter she wrote to him on her arrival in Stockholm in 1883 was only recently uncovered by Professor Reinhard Bölling.)

Like all her earlier tutorials, this one appears to have gone very well and fallen into a pleasant routine; but that routine underwent a hiatus in April of 1871 when the Franco-Prussian War irrupted into Kovalevskaya's life for the second time. The Prussians had essentially won the war, having surrounded Paris, but the National Guard defending Paris refused to recognize any peace with the Prussians. The defenders of Paris included Anyuta's husband Victor Jaclard, and of course Anyuta herself. Sof'ya and Vladimir managed to get through the German lines into Paris. They lived in the famous Paris Commune for most of its brief existence, Sof'ya serving as a nurse and Vladimir visiting the Paris museums to inspect the fossils. (He received the degree of doctor of philosophy from the University of Jena in 1872.) When they finally left Paris, it appeared that the Commune would hold out for a while, yet they had hardly departed when the news came that the Commune had fallen, Jaclard had been arrested, and was probably facing the death penalty. At this point it was necessary to appeal to their father. He came to Paris, arranged to have Jaclard spirited away from the line of convicts who were being marched to show trials, and saw to it that Victor and Anyuta were legally married in Switzerland.

Back in Berlin, Kovalevskaya began to suffer from overwork. Although Weierstrass and his two unmarried sisters, with whom he shared a house, were very cordial to Kovalevskaya, they were somewhat puzzled by her mysterious relationship with her husband. Kovalevskaya did not attempt to explain it, for the reason best expressed by another Russian woman who went abroad around this time, Elizaveta Litvinova: "You don't have to be a genius to understand that, but you do have to be a Russian." However, by October of 1872, quarrels with Vladimir had made Sof'ya so miserable that she made a full explanation to Weierstrass. Full of sympathy for her situation, he cast about for ways to help her. The result was the following letter of 26 October 1872:

> …I have been very preoccupied with you this night, and indeed, how could it have been otherwise? My thoughts have run in many different directions, but have always come back to the same point, which I must discuss with you today. Do not fear that I will mention things that we have agreed not to talk about, at least not yet. What I have to say to you is much more concerned with your scientific ambitions. However, I am not sure whether, given the endearing modesty with which you judge what you are now able to achieve, you will be inclined to agree with my plan…

Obviously Weierstrass intended to propose that Kovalevskaya write a dissertation. From this point on in his letters to her, he always uses the informal Du-form of address (as she does with him, in the fragment discovered by Prof. Bölling). Over the next 18 months Kovalevskaya, guided by Weierstrass, wrote a number of mathematical works, three of which Weierstrass cited in requesting a degree for her from the more liberal University of Göttingen. The emotional bond between them, though always tinged on Kovalevskaya's side by the respect due from a young scholar to a teacher 35 years her senior, became ever closer. It was poignantly expressed by Weierstrass in a letter of 25 April 1873:

> …That you, so long as you can learn something from me and wish to do so, will remain my student in the best sense of the word, I wouldn't even bother to mention if not for one place in your letter. You think that the student could be a burden (such is the ugly word you use), even if the friend could not. If I were malicious, I could interpret the fact that you have no such fear for the friend in a sense that you might vigorously protest, but in all seriousness, my dear, beloved Sonia, be assured that I shall never forget that it is the gratitude of my student to which I owe the possession of not my best but my only true friend…

Later that year, on 20 August, he wrote to her:

> I hope that by now you have escaped from the Zürich atmosphere and are breathing the pure mountain air. During my stay here [in Sassnitz] I have often thought of you and pictured to

myself how wonderful it would be if I could spend a few weeks with you, my soulmate [Herzensfreundin], in such a magnificent natural setting. How wonderful it would be for us here—you with your imaginative soul, I stimulated and refreshed by your enthusiasm—to dream and contemplate the many problems that remain for us to solve, on finite and infinite spaces, the stability of the solar system, and all the other great problems of the mathematics and physics of the future. However, I learned long ago to be reconciled to the fact that not every beautiful dream comes true.

It is impossible to doubt that Weierstrass was in love with Kovalevskaya, in a way that only a middle-aged bachelor can be, when an emotional bond that he has long ago renounced and believed impossible suddenly becomes a glorious reality. It is equally impossible to imagine the reticent and proper Weierstrass, a sincere Catholic, taking advantage of Kovalevskaya's gratitude in order to obtain sexual favors, if for no other reason than the realization on his part that such a step would destroy the whole relationship. (I say this despite the fact that Prof. Biermann's acute detective work has recently shown that Weierstrass may have fathered a child in 1882 by the widow of his good friend Borchardt.)

To return to less exciting matters, Weierstrass, as mentioned, persuaded the University of Göttingen to award the doctorate to Kovalevskaya in 1874, in absentia, and without the usual oral defense. (He wrote that neither her German nor her nerves were strong enough to display her true talents in such a setting.) She returned to Russia in September 1874, to be joined there by Yuliya Lermontova and Vladimir in a well-deserved celebration of three doctoral degrees earned.

The Wilderness Years (1875–1883). The barriers to a woman's career in the nineteenth century were multitudinous. Like a course of high hurdles, each barrier surmounted with great expenditure of energy was soon followed by another requiring an equal expenditure of effort. Having obtained a degree against all odds, Kovalevskaya now found no employment. Vladimir, who could have found academic employment, had the indiscretion to criticize the work of one of his examiners when taking the examination for certification to teach. As a result, he was not certified. Kovalevskaya's father died in 1874, leaving her a small legacy, which the couple invested in real estate, hoping by following the example of Chebyshev mentioned above, to become independently wealthy and free to pursue their scholarly interests. Unfortunately academic brilliance is not necessarily correlated with financial shrewdness. Their enterprise ultimately ended in bankruptcy. Meanwhile they took the momentous decision to end the charade of their fictitious marriage by consummating it. The unsurprising result of this decision was the birth of a daughter, Sof'ya Vladimirovna Kovalevskaya, in October of 1878, affectionately referred to as "Fufa." Difficult as it may be to remember at the end of the twentieth century, a century ago there were many people who believed women were so frail that they couldn't possibly withstand the rigors of university life. This belief was to some degree absorbed even by women who had obtained such an education. At the time of her daughter's birth, Kovalevskaya had been away from academic work for three years, and she actually took pride in that fact, remarking to Elizaveta Litvinova, "Thank heaven I did not completely waste my strength studying mathematics; now at least my little girl will inherit some intellectual ability." The pathos of that statement is, I believe, unmatched anywhere in literature.

Fufa's first year of life was not auspicious for the family, as Kovalevskaya's mother died in February 1879, and this heavy blow was soon followed by the bankruptcy just mentioned. Such stresses are notoriously bad for unstable marriages, and relations between Sof'ya and Vladimir were never again close. Vladimir, despite his generous liberal heart, could not overcome the feeling that he should be the protector of the family. He fell into a severe depression, and began to pick quarrels with Sof'ya. By 1879, Kovalevskaya began hesitantly to try to resume the mathematical career she had abandoned three years earlier. Even before the birth of Fufa she had renewed her correspondence with Weierstrass. At the end of 1879 she went to a scientific meeting in Saint Petersburg, where she gave a talk on one of the three papers she had submitted as a dissertation. (Only one of the three papers had been published; the paper she spoke on at this meeting was published in the mid 1880s and was later highly praised by the

great French mathematician Henri Poincaré.) This meeting was attended by another of Weierstrass' students, the Swedish mathematician Gösta Mittag-Leffler (1846–1927), then at the University of Helsingfors (Helsinki). He had met her in St. Petersburg on 10 February 1876. He described the earlier meeting in a 1923 quotation from his own diary (translated into French):

> What interested me most in Saint Petersburg was making the acquaintance of Madame Kovalevsky. I spent several hours with her today. She is a delightful woman. She is beautiful and when she talks her face lights up with an expression of feminine good will and superior intelligence that one cannot help being dazzled by. Her manners are simple and natural with no trace of pedantry or affectation. In short, a "high society woman" in all respects. As a scholar she is distinguished by a rare clarity and a precision of expression, as well as an extraordinarily quick perception. It is also easy to see the degree of profundity to which she has pursued her studies, and I understand perfectly why Weierstrass regards her as the most talented of his students.

From that time on Mittag-Leffler was determined to find an academic position for Kovalevskaya. Wisely, both Kovalevskaya and Mittag-Leffler allowed themselves to be guided by Weierstrass, who showed considerable shrewdness in regard to academic politics. Resented as a Swede among Finns, Mittag-Leffler was himself eventually forced out. He returned to his native Stockholm and became one of the founders of the institution that is now the University of Stockholm, a modern, progressive institution, contrasting with the more traditional universities of Uppsala and Lund. There he would eventually be able to arrange a position for her. Kovalevskaya, in turn, eagerly accepted Weierstrass' invitation to apply a mathematical technique he had developed to solve a problem in mathematical physics. Conditions for working on the problem were far from ideal, however. Her marriage was strained. She was in poverty, having had to take a loan of 65,000 rubles, guaranteed by her brother. And she had a baby daughter to look after (although she received so much help in that regard from her friend Yuliya Lermontova, Fufa's godmother, that she was sometimes accused of exploiting Yuliya's good nature.)

In October 1880 she went back to Berlin to consult with Weierstrass, leaving Fufa with Yuliya, for a two-month stay. Meanwhile Vladimir had decided to try his hand at making money again, with results that were even more disastrous than the real estate speculation. This time he would find himself set up by his unscrupulous business partners as the legally responsible person in a stock scandal, facing prosecution in addition to bankruptcy. However, this situation took several years to develop fully. In April 1881 Kovalevskaya returned to Berlin with Fufa and (despite her poverty!) a nursemaid to free her from the necessity of looking after her 2-year-old daughter. At this time Mittag-Leffler, still in Helsingfors, was exploring the possibility of a position there for Kovalevskaya. Once again, however, world events intervened, this time against Kovalevskaya's interests. The University of Helsingfors, though nominally under control of the Russian empire, enjoyed a great deal of autonomy. The assassination of the liberal Tsar Alexander II in March of 1881 was sure to provoke a crackdown on radicals, and Kovalevskaya was of course tainted in the eyes of the government by her nihilist associations. The University declined to take a chance on Kovalevskaya.

Kovalevskaya's life remained unsettled throughout 1881 and 1882. Vladimir's position became more and more precarious. In March of 1882 Kovalevskaya sent Fufa away from Paris, where she had moved in the fall of 1881, back to Russia with her nursemaid. For the next four years she would see Fufa only on occasional visits. After Fufa's departure she continued to work on the problem Weierstrass had set for her, but she also became involved in some radical political circles in Paris, making the acquaintance of the Polish revolutionary Maria Jankowska (recently released from the prison at Poznan), the German Social Democrat Georg Volmar, and a young Russian expatriate, a student of mathematics named Joseph Perott. An incident of great dramatic impact, though not a major event in Kovalevskaya's life, took place at this time. Considering it was such a trivial incident, it is surprisingly well documented, and I shall tell the story in documents. (Remember, I promised to include interesting gossip if it showed some aspect of Kovalevskaya's character, whether or not it was of intrinsic importance. The following is such a story.) The story begins with a reminiscence by Maria Jankowska.

Once, when she was visiting me I noticed a cloud on her brow. She was distracted and her nervousness was increasing. Our conversation, despite efforts from both sides, was constantly breaking off. Finally, unable to contain herself any longer, she burst out: "Excuse me, but I must involve you in a matter that has me completely absorbed at the moment. I would like to ask you to give me some advice as to how to proceed in this situation. One of my friends, a mathematician, has a 16-year-old sister who also wants to devote herself to science and study mathematics. Her parents won't hear of it. This is all taking place in Russia, where women are forbidden access to the universities, so that the girl can't even dream of achieving her goal. One might consider a fictitious marriage," she added, and a plaintive smile passed across her face, "but it's not easy to find a man willing to sacrifice his own freedom just to make the path to science and higher education easier for a young girl. That way out isn't available in this case. I have advised my friend to get the girl out secretly. But so that she couldn't be stopped on the road through a telegram from her parents I loaned her my passport. My friend was supposed to telegraph me as soon as they reached Prussia. By my calculations they should have been there by now, and I'm very worried that I haven't had any news."

In this whole affair Sof'ya's behavior is very typical. She had formed a plan in complete accord with her nature, impetuous and romantic.

"Have you considered how many unpleasant consequences your friend's impetuous action might involve? If the young lady is detained at the border, she will certainly be turned over to her parents. And if it becomes necessary for you to go to Russia, you will find yourself in trouble, not to mention that you might be accused of abetting the abduction of an underage girl…"

"All that may happen," the worried Sof'ya interrupted, "but I couldn't do otherwise. Just consider, how can one refuse to help a person who is thirsting for knowledge and unable to reach its source? After all, so many obstacles are piled up in a woman's way whenever she doesn't want to follow the well-trodden path to marriage! I myself have encountered many of them, and so I consider it my duty to remove as many as possible from the paths of others. The girl I'm talking about possesses, according to her brother, a remarkable talent for the exact sciences. Who can say whether a great scholar will emerge from this? I shall be proud if I am able to advance a young talent in the arena of science!"

The story continues with an undated newspaper clipping in Swedish:

Suspected nihilists. …Two travelers from the Kuopio district, one a young man, the other an even younger, barely full-grown woman, were detained by the Uleåborg police from the 8th to the 11th of October. The man had a passport for Mr. Josef Perott, and the girl had her school report card from Saint Petersburg.. But the police thought they saw signs of nihilism nevertheless, if only because the girl was very beautiful with dark hair and rosy cheeks. After an exchange of telegrams it was clear that a mistake had been made and the detainees were allowed to continue their interrupted journey….yet [it appears] that the travelers were, after all, fugitives of a kind, a pair of unlucky lovers, whose parents had refused consent to their marriage. As a result, they were forced to spend three days in the Uleåborg "guest house."

Those who lived through the late 1960s will recall how easy it seemed to identify young anarchistic rebels at the time, merely from the length of their hair. Again, it bears repeating that those inside the nihilist movement thought of themselves as reforming society, but the general public regarded them as violent anarchists. It appears from this story that the Prussian route was not the one chosen for escape. The Swedish route they chose was fortuitous (or perhaps advised by Kovalevskaya), since it brought them the assistance of Mittag-Leffler. The next relevant documents are a telegram and letter from Kovalevskaya to Mittag-Leffler, dated October 18, 1882. First the telegram:

Please do me the great favor of providing 100 francs to M. Perott on board the steamship Norra Sverige. Letter and money follow…

Next the letter:

I have taken the great liberty of sending you a telegram requesting the loan of 100 francs to one of my friends upon his arrival in Stockholm. The case was an extreme emergency, and I thought you would excuse me for appealing to your friendly feelings in this way. M. Perott, who is also a mathematician, was forced to leave Russia suddenly for very important reasons, which are, however, not of a political nature. I have received a telegram from him saying that he will arrive in Stockholm on the steamship "Norra Sverige" and asking me to send him money by telegraph. I could not do that, since the telegraph here does not accept money for Sweden, and no banker would agree to send such a small sum by telegraph. I had no choice but to resort to your aid, dear sir. I very much fear that you will think me impertinent and that this request will cause you some trouble.

Kovalevskaya need not have worried. Perott and Mittag-Leffler got along famously, and for the next few years the latter occasionally reminded Kovalevskaya to seek out papers by Perott that he could publish in his journal *Acta Mathematica*. A telegram from Perott to Kovalevskaya (in French) dated 28 October 1882, says simply, "Arrested twice, released twice. All going well now." To close out the story, we return to Maria Jankowska:

A week later Sof'ya appeared again at my door, but this time accompanied by a beautiful young girl with black curls and laughing eyes, full of life. She was in ecstasy at everything she had found in Paris and absolutely worshipped her new friend and mentor. To be sure, she would mention her love for knowledge and her intention of attending lectures at the Sorbonne, but her beauty and her laughing eyes told me clearly that Paris appealed to her more as a city full of diversions than as the cynosure of world enlightenment and the treasure trove of knowledge. Sof'ya was sharing an apartment with her and had already begun to teach her mathematics. These lessons did not last long: Mathematics turned out to be too difficult a subject, too dry for a girl not trained in mental labor. The young Zoya, beautiful and aware of her beauty, preferred having fun, getting dressed up, making the rounds of the Paris shops, and chatting with young professors and students, of whom there were many around Sof'ya Kovalevskaya. Sof'ya once confided to me that she was a little disappointed, and that science in general would not gain much from her young friend, and mathematics even less. As she said this, she gave a deep sigh and adopted a comically concerned expression. She was extremely pleasant whenever she returned to reality from her golden daydreams; she seemed to be laughing at herself, confessing that she didn't understand either the world or people. Nevertheless, she maintained cordial relations with Zoya, for which the girl loved her sincerely. Circumstances were soon to provide the young girl with an occasion to demonstrate her gratitude and devotion to her brother's friend.

We shall take up those circumstances shortly. However, at this point we should note a few points on which Jankowska was slightly misinformed. First, the girl was Zinaida (Zina), not Zoya, a common trick of memory, to which we are all subject. Second, Perott was Russian on his mother's side; only his father was Polish (although at the time the Tsar had imposed on Poles the necessity of communicating in Russian). Jankowska describes his relationship to Kovalevskaya as she had heard it from Kovalevskaya herself, saying that Kovalevskaya was fascinated with Poland and Poles and had been enchanted by Perott's ability to convey Polish culture and literature to her. As soon as she stopped looking at him as a representative of Polish culture, however, and saw him merely as a man, she lost all interest in him. She also says, by the way, that Kovalevskaya confessed to being unable to feel the excitement other women expressed when they were courted by handsome young men. Without speculating on what that may mean in the context of the late twentieth century, it should be noted that Kovalevskaya certainly tried to find out what it was about men that interested other women, and she became deeply infatuated with at least one man a few years later. In fact, she expressed herself in an entirely different way when talking to Mittag-Leffler, saying that she was annoyed by the fact that so many men wanted to marry her, when she would much prefer to be a mistress. Mittag-Leffler commented in his diary,

Unfortunately for her she is not such that a man would desire to get her as his mistress whereas many would want her for a wife. Men do require from a mistress primarily physical attraction,

which she lacks, but in a wife they can well accept the absence of these if compensated by other qualities, which she has in such eminent degree.

Jankowska's description of Zinaida as a frivolous party-goer seems to be borne out by at least one letter that the latter wrote to Kovalevskaya (in Russian) from Port-Navalo, France in 1885, full of utterly trivial gossip about her cousin Rudolph Becker from Kaunas who posed as her brother in order to visit her. She confirms that she and her actual brother posed as newlyweds during their journey from Saint Petersburg. I have found no trace of her after 1885. Probably she got married and settled down. Finally, let us finish with this rather pompous fellow Joseph Perott. He left for Port-Navalo, on the south coast of Brittany, almost immediately, leaving Zinaida in Kovalevskaya's care. He kept up a correspondence with Kovalevskaya and his sister for a brief time. The last letter from him that Kovalevskaya kept was an 1889 request for a set of mathematical notes. In this letter he expresses his extreme reluctance to write to her and refers to some unpleasantness between them, as he finishes his request by saying, "One word on any subject different from that which forms the object of this letter will be for me a sufficient motive to refuse to accept what I am asking, even if you should grant it." At the same time that he wrote this letter, he departed for America, where he studied briefly at Johns Hopkins University, then became a lecturer in mathematics at Clark University in Worcester, Massachusetts, from its third year of existence until his retirement in 1921. He died in 1924 and is buried in Worcester. The late R. C. Archibald, secretary of the Mathematical Association of America was once led to ask Mittag-Leffler if it was true, as Perott claimed, that he had had an intimate acquaintance with Kovalevskaya. As Archibald remarked, "I have met the man and can scarcely credit that even when he was much younger he could be at all attractive to such a brilliant woman."

The preceding "soap-opera" story is an example of the capriciousness of historical documents. The documents that survive do so in a seemingly random manner. It is both frustrating and ironic that so many documents related to this trivial incident were preserved, when so many other things one would like to know about the life and work of Kovalevskaya cannot be found.

To resume Kovalevskaya's life from early 1883, the furies finally cornered poor Vladimir. Faced with prosecution in the stock scandal mentioned above, on the night of 27 April 1883 he drank a bottle of chloroform, leaving behind a note imploring Sof'ya's forgiveness for the financial and emotional mess he had made of their lives, protesting his innocence of the charges he knew he would be facing, and asking Anyuta to look after Sof'ya and Fufa. Sof'ya, in Paris, was devastated by the news of his death. According to Jankowska, for five days she sat alone in her room with the curtains drawn, weeping and refusing all food. A doctor was called; she refused to see him. Finally, after she fell into a coma, the doctor opened her mouth and forced some liquid food into her stomach. Zinaida attended her faithfully, never leaving her side for a minute. On the sixth day, Zinaida greeted Jankowska with the news that Kovalevskaya was saved, saying, "This morning she woke up and, without saying a word, sat up in bed and began to trace some symbols on the blanket. Then she asked me for pencil and paper. She is engrossed in some mathematical problem."

The mathematical problem was most likely the one Weierstrass had wanted her to solve to re-establish her mathematical credentials preparatory to taking up a position in Stockholm. All summer she worked on that problem, getting no assistance from Weierstrass, a chronic hypochondriac who didn't feel well enough to write to her. She finished the problem in the fall, and sailed for Stockholm at the end of November, ready to go (boldly, but with great diffidence) where (almost) no woman had gone before.

The Professional Years (1883–1891).   Having devoted considerable space to the early part of Kovalevskaya's life, I find it is possible to describe her entire professional career—the last eight years of her too-short life—in many fewer words. She came to Stockholm to lecture at the newly opened university there. As a fallback position, to avoid compromising the cause of women's careers in case her lectures were not successful, Mittag-Leffler had caused it to be believed that these lectures were a one-time special occasion, the opportunity to hear the words of a distinguished woman scholar. His caution is

understandable, but fortunately was not necessary. Her lectures were well received. After she lectured for one semester in German, her Swedish was adequate for future semesters. She immediately began collaborating with Mittag-Leffler as an editor of *Acta Mathematica*, her Russian contacts being particularly valuable in procuring good papers to establish the reputation of this new journal. She soon brought Fufa to live with her in Stockholm and lived the life of a single mother with a career that was not very different from what such a life would be today. Looked at as a whole, her career cut an amazingly wide swath through the economic and social structure of her times. It is as if a pioneer went into an uncharted wilderness and built there a complete city with skyscrapers.

Nevertheless, she was continually forced to confront new gender-related issues. The first was unabashed prejudice. Kovalevskaya, as mentioned, had literary talent and collaborated on the writing of plays with Mittag-Leffler's sister Anne-Charlotte. Her presence in Stockholm was an irritant to the famous playwright and misogynist August Strindberg (1849–1912). In December of 1884 she wrote to Mittag-Leffler:

> As a Christmas present I have received from your sister an article by Strindberg in which he proves as clearly as two times two equals four how monstrous a phenomenon is a woman professor of mathematics, how pernicious, useless, and unpleasant. I think he is essentially correct; the only thing I object to is his assertion that there are many male mathematicians in Sweden who are better than I and that I have been invited here only out of a sense of chivalry.

The second gender issue she faced was the perennial family/career conflict that women are still dealing with today. On 19 August 1886 Mittag-Leffler wrote the following to Kovalevskaya, who had gone to Russia to be with her gravely ill sister Anyuta. (Anyuta died the following year.)

> You do me a great injustice if you think that only egotism leads me to fear the consequences if you should not return by the beginning of the semester. That is not at all the case, and I deeply share the feeling that leads you to remain with your sick sister. But in Sweden, as in the majority of other countries, leave of absence is never granted for personal reasons. A man may not request, and would never be granted, leave to care for a sick wife, child, or other relative. He can obtain a leave for his own medical treatment, but in that case it is granted because he is unable to work…If you request leave to care for your sister, it will provoke a storm, and will become an issue in the women's question…Be that as it may, I will do whatever I can in your interest.

Kovalevskaya returned to Sweden. The unfairness of the gender comparison reported by Mittag-Leffler, and his seeming unawareness of its injustice, strikes the modern reader as both sad and curious. Did he really not understand that the male professors he spoke of were expected to have female relatives to bear the burden of caring for the sick, a boon not enjoyed by Kovalevskaya? In fairness to Mittag-Leffler, however, it must be said that he remained Kovalevskaya's loyal friend and protector even in the face of what he regarded as callous ingratitude and betrayal on her part. She seemed to count for nothing the extraordinary efforts he had made in order to procure her a position and keep it in the face of powerful opposition. She was continually trying to find a more advantageous position for herself elsewhere, and would have left Stockholm at a moment's notice, leaving him to face the consequences, if only she could have arranged it.

Naturally one wonders if she was paid less than her male colleagues in comparable positions. The answer, unsurprisingly, seems to be, "Yes." According to excerpts from Mittag-Leffler's diary, recently published by L. Hörmander, Kovalevskaya had originally been willing to work in Stockholm without salary, and then declared that 2,000 kronor would suffice. Mittag-Leffler generously arranged for her to receive 4,000 kronor. In 1887 he arranged for her to teach an extra course in mechanics for a supplement of 3,000 kronor. After that she found she couldn't live on less. In order to get her 6,000 kronor for 1888 Mittag-Leffler paid 1,000 kronor out of his own pocket. Still she complained that it wasn't enough. According to Hörmander, Strindberg had written in his play *Getting Married*:

> When the University of Stockholm divided the salary of a male mathematics professor to give half of it to a woman, it was a crime–against justice. And the men rejoiced.

The editors of the 1982 edition of Strindberg's works comment that, "the salary was in no way divided, but Sonja Kovalevsky was paid far less than her male colleague."

Tragic though Vladimir's death had been, it was propitious for Sof'ya's career. She had the respectability of a married woman with a legitimate child, without the burden of a husband whose companion and support she would have been expected to be. She was as free as a woman could be at the time. One can therefore only conclude that it was a sincere emotional attachment that she developed to one Maksim Kovalevsky (1851–1916). It is not entirely a coincidence that her second great love in life had the same surname as the first. They met because the Swedish postal authorities mixed up their mail when he came to Stockholm in 1885 to deliver a series of lectures. He was a radical sociologist and legal scholar, and he spent a good deal of time outside Russia because of his radical views.

His entrance into her life came at an inconvenient time, but perhaps she was pleased to have the distraction from the concentrated effort she was expending at the time. She was writing a play jointly with Anne-Charlotte Leffler and, more importantly, was developing a mathematical discovery that she had made and was planning to submit to a prize competition at the Paris Academy in 1888. At Mittag-Leffler's request, Kovalevsky went away briefly to allow her to complete the work.

She apparently made this discovery in 1886 and communicated it to several prominent French mathematicians in June of that year. The acknowledged leader of French mathematics at the time was Charles Hermite (1822–1902), who routinely arranged competitions to obtain recognition for his protégés. He did this both for his son-in-law Emile Picard and for the greatest French mathematician of the time, Henri Poincaré. As Kovalevskaya wrote to Mittag-Leffler on 26 June 1886:

> Yesterday Hermite, Bertrand, Camille Jordan, and Darboux, who are all members of the committee [to choose the topic for the prize], discussed the project with me…and they seemed to find it so interesting that they believed it has a good chance of winning. The only disadvantage is that in that case I shall have to postpone publication until 1888. I shall have to submit it to the Academy, and the decision will be made in 1888. Only in that case it is impossible for me to communicate my work at Christiania [Oslo] this year. That would be much too risky…

As Darboux was a member of the jury for this competition, one might speculate that the competition itself was not entirely as objective and anonymous as the rules required. However, that impression would be misleading. This competition was exactly like many others. As Hermite described it in a letter to Thomas Jan Stieltjes a few years later, when he was proposing to render Stieltjes the same service,

> The problem proposed for the prize will be the one that you yourself indicate. You will choose among the problems you are currently studying, the one that suits you. You may trust me, that I am not going beyond my authority in asking you. I have the complete assurance that it will be accepted immediately and with dispatch by all the members of the committee charged with choosing a prize topic. Moreover, we are only following traditional usage, so that there is no question of any special favor being done for you.
>   The prize awarded to Mme. de Kowalewski and the prize won by M. Picard were given for problems that everyone knew had been investigated by M. Picard and Mme. de Kowalewski, whose work it was desired to reward with distinction.

The competition was, as everyone expected, won by Kovalevskaya, and Hermite arranged for an increase in the value of the prize (a gold medal) from 3,000 to 5,000 francs. The strain of preparing a long and difficult manuscript for the competition and revising it for publication were so great that she experienced a terrible depression immediately after the award ceremony, one that took her some time to recover from. The ceremony itself miffed Maksim Kovalevsky, who was not used to sitting on the sidelines and

cheering while others collected honors. Relations between the two of them were strained from that time on.

The competition was the certification that Mittag-Leffler needed to get Kovalevskaya tenure at Stockholm University. However, despite her gratitude to Sweden and Mittag-Leffler, she had already begun to dream of a more exciting place to live. She wanted to present her prize-winning paper as a dissertation to a French university so that she could become a naturalized French citizen and procure a position there. How much her desire to live with Maksim Kovalevsky influenced this project is impossible to establish. Certainly she had begun to express her boredom with Stockholm to her Swedish friends in the most tactless manner. She confided her plan in a letter to Weierstrass, who was appalled. He told her in no uncertain terms that it was an unforgivable insult to the University of Göttingen to seek a second doctorate in mathematics from another university and mentioned that if she did so, she might well find her degree revoked. She eventually abandoned the plan.

The rest of her life was comparatively uneventful. After the astounding achievement of becoming a full member of the mathematical community of her time, respected for her mathematical achievements and in no way patronized by male mathematicians as being "good, *for a woman,*" she was undoubtedly rather tired. She produced no more original papers, but in 1889 presented an old one dating to her unversity days. It had never been published and was not used in her dissertation, although Weierstrass had alluded to it in his letter to the University of Göttingen requesting a degree for her. She kept trying to make the relationship with Maksim Kovalevsky work out. (For her "working out" would have meant living together as lovers. According to Mittag-Leffler, she was adamant that she would not marry Maksim, fearing that if she did, he would begin to take her for granted and look for a mistress.) It never did. After they traveled to Genoa for the holidays at the end of 1890, they parted for the last time. On the way back to Stockholm, she took a route that avoided Copenhagen because of a current epidemic. Having no Danish money to tip a porter, she had to carry her own bags in a driving rain. She returned to Stockholm with a bad cold, which turned into pneumonia. She died on 10 February 1891 and is buried at the Norra Begravningsplats in Stockholm.

Weierstrass was so overcome with grief at the news of her death that his friends feared for his own life. Fufa was briefly cared for by the family of the Swedish astronomer Hugo Gyldén, who wished to adopt her. In the end she was adopted by Yuliya Lermontova, returned to Russia, and served with the Red Cross during World War I. She became a physician, never married, and had no children. She lived to help with the celebration of the centenary of her mother's birth in 1950, and died the following year.

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