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MATH 4010
Biographical Paper
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Sofia Kovalevskaya
1850 – 1891

The Beginning

Sofia Vasilievna (Sofia Kovalevskaya) was born to Vasily and Elizaveta Vasilievna on January 15, 1850. Vasily was a military man, a general in the Russian Army. Elizaveta was a well-educated woman who liked to be involved in high society rituals such as concerts, some of which she performed on the piano, and balls. Anna Vasilievna was the first of three surviving children born to the Vasilievnas. Anna, more commonly called Aniuta, was an attractive, healthy blonde female who could easily fit into the high society world frequented by Elizaveta. At some point the couple was said to have a son by the name of Vasily, it is assumed that he was the first-born son since he was given his father's name. Young Vasily died in his early years. Next came Sofia and lastly, their youngest son.

Vasily and Elizaveta were both extremely involved in their own lives. Vasily spent most of his time at work, not spending much time with his family. Although he could not find time for his family, Vasilly did find the time to feed his gambling needs. Vasily was not what most would call a successful gambler though. He was reported to have lost large sums of money on a regular basis, which led to the sale of sections of the family's estate to pay off his debts. Elizaveta was an accomplished pianist and spent most of her time rubbing elbows with high society. Neither parent wanted to be bothered with the burden of their children.

Since the Vasilievna parents were not raising their children, Aniuta, Sofia, and their brother were raised by a variety of people. The Vasilievich children were mostly raised by the family's nanny. Aniuta took up the majority of the nanny's time. In her early

years Aniuta was attracted to the high society life her mother led. Aniuta demanded a lot of attention while trying to become the socialite she dreamt of being. Sofia, six years younger than Aniuta, was thirsty for knowledge from the beginning. While Aniuta practiced her dancing with the nanny, Sofia taught herself to read. Sofia often felt the stress of being a middle child in a family where there was a beautiful well-liked daughter ahead of her in age and the son a father wishes for on the other side of her. The nanny actually preferred Sofia. It was not subtle that Sofia was the least liked by her parents. The nanny felt did not mind taken on the responsibility of making up for the lack of attention towards Sofia.

Along with her childhood nanny, Sofia became close and admired a couple of her uncles. The first is her mother's oldest brother, Fyodor Fyodorvich Shubert. Fyodor would tell Sofia stories. His stories were not of fairy tale princesses and happy endings, but of algae and other biological subjects. Although he only played a minor part in Sofia's life, she felt a special bond with him. The other uncle she became close with was a brother of Vasily, Pyotr Vasilievich. Pyotr was not the brightest or most educated man, but he had a passion for mathematics and would tell Sofia about squaring a circle and asymptotes, even before she was old enough to know what these words meant. Sofia did not lack for positive role models.

After years of working to prove their nobility, in 1858 the Vasilievich family was awarded the right to be called Korvin-Krukosky and was entered into genealogical register. At last the family was recorded as nobility.

That same year, 1858, General Krukosky, formally General Vasilievna, retired from the military and moved the family to Palibiino. Upon retirement Vasily began to spend more time with his family. He was appalled to find out that his daughters were grossly ignorant. Inn order to rectify this, he replaced the nanny with an English governess, Miss Margaret Smith and a Polish Tutor, Joseph Malevich.

The new educational staff at the Krukosky house began a new era for the girls. Sofia,

whose idol was the older and more lavish sister Aniuta. Miss Smith's created strict rules designed to assist Sofia in not becoming contaminated by her older sister. Miss Smith began watching Aniuta very closely. During this time, Aniuta turned a corner and gave up the fine clothing and balls she had become accustom to. She gave up the unnecessary materials to buy books and give lessons to peasant children. Aniuta's new serious attitude was contributed to by a couple of young men. The first was Mikhail Ivanovich Semevsky. Mikhail was a young officer and a former pupil of Malevich. He and Aniuta agreed to marry, but the union was forbidden by Vasily because Malevich was beneath Aniuta in the social hierarchy. Mikhail was forbidden to visit Aniuta anymore. Aniuta found support from a priest's son, who was also beneath Aniuta socially, and again Vasily was unhappy. This spawned conflict between Aniuta and her father that would not be resolved and eventually cause the resignation of Miss Smith.

Miss Smith's departure did not bring peace in the Krokosky household. Aniuta began her true struggle for independence. Among many topics, Aniuta and Vasily began to argue the merits of Dostoevsky, whose journal "The Epoch" came to the Kruskovsky home. Unbenounced to Vasily, Aniuta had sent her own short stories to Dostoevsky. They had continued a secret correspondence concerning Aniuta's stories, which Dostoevsky paid 300 rubles for. Vasily discovered a letter and although he was angry at first, Aniuta reasoned with her father and got permission for a visit from Dostoevsky. Dostoevsky's intentions did not seem to be completely business-related. When he came for the visit he asked Aniuta to marry him. Aniuta declined the proposal, as she felt she would not be free to act independently if she married Dostoevsky.

Aniuta's pull towards the literary field was quite the opposite of her younger sister Sofia. Sofia had felt a natural pull toward science since she was a little girl. She had been enthralled with the stories of her uncles and spent countless hours studying the wall of a room in the house papered with the lecture notes of a calculus course, which were there due to a lack of wallpaper. The makeshift wallpaper, at the very least, gave her an introduction to the symbols of calculus.

Aside from the fascination with the wallpaper, Sofia showed her talents after reading a book written by a family friend. Nokolai Nikanorovich Tyrtov, a family friend, brought a book by that made use of trigonometry. The unfamiliar subject did not stop Sofia. Since the sine function was not familiar to her tutor, Sofia was forced to make sense of it on her own. She guessed that the sine of a central angle in a circle is proportional to the chord subtended by the angle. In fact it is proportional to half the subtended chord of twice the angle, but for small angles the difference is negligible (Cooke, pg. 10). Indeed this is how sine was discovered historically. When Tyrtov came across Sofia's work, he was determined to convince Vasily to allow her to seek higher education.

In search of a higher education Sofia studied differential and integral calculus. However, both girls were getting older and the liberalizing movement of 1861 – 1862 in Russia was over. Like many other young women the sisters decided the wanted to go west. This would prove to be problematic, considering it was unacceptable for young women to travel alone without permission from their fathers. Not unlike most fathers, Vasily refused to give the girls permission to travel without an escort. Many women were not allowed to travel alone, so it became popular for these women to enter into a secret agreement with a more liberal man. Women would "marry" a liberal man that agreed to allow his "wife" to pursue her own interests. The fictitious marriage would be legal and binding, however, the two who entered into the agreement understand the reasoning behind it. As can be imagined, the demand for willing men far exceeded the supply.

The idea was for Aniuta's friend, Zhanna, to enter into a fictitious marriage and then the couple would chaperone the sisters and their friend Julie while traveling west. Zhanna proposed the idea to a young professor in Petersburg but was turned down. The group moved down their list to the next prospect. Eventually came Vladimir Onufrievich Kovalevsky, a young publisher.

Vladimir would eventually become Sofia's husband. Vladimir was born on August 14, 1842 to a family in the Vitebsk province. He was a lower social class than the girls and made his money translating books. Vladimir was known for his quick mind and leaning

toward liberal causes. After meeting Sofia, Vladimir expressed a desire to enter into a fictitious marriage with her. Like with many other boys brought to Vasily's home, Vladimir and his proposal were met with resistance. Sofia overcame this resistance by sending word out that she and her fiancé were busy making plans for their wedding. After Sofia's brilliant action Vasily had two choices. He could publicly admit his daughter's rebellion or simply approve of the marriage. He chose to approve of the marriage.

The newlywed couple had planned to chaperone the other three women in their travels. However, things did not go according to plans. The three single women had difficulty getting permission from their fathers to travel with the newlyweds. Vladimir and Sonya ended up staying in Petersburg for a few months while they worked to get permission for the girls. Eventually Aniuta was granted permission to go and the three of them set out to Vienna. From there Aniuta followed her ambition to Paris where she aimed to work with other politically active young adults, which she hid from her parents by sending letters to Sofia who, in turn, sent them to their parents. Vladimir and Sofia continued on to Heidelberg, where Sofia had dreamt of studying.

In Heidelberg Sofia was met with disapproval. She wished to study at the University, however, it was still cliché for women to go the University. After much effort from both her and Vladimir she was granted permission to study if she had the permission of the lecturer. She eventually had the opportunity to study with scientist such as Bunsen, Kirchhoff, and Helmholtz. Sofia took on a load of 22 credit hours, 16 of which were mathematics. While studying in Heidelberg, life took a stressful turn. She was not happy where she was anymore and it was time for a change.

Since it was time for a new look at things, Sofia decided to journey to Berlin. In the fall of 1870 she went to Berlin to seek out Professor Karl Weierstrass. Once found, Sofia discovered that Karl Weierstrass was not a liberal thinking man. At first he was skeptical of Sofia. He obliged her with a set of problems as a sort of test. When she completed the work Weierstrass was amazed at her talent. This warmed Weierstrass up to Sofia and he

began to meet with her twice a week for tutoring.

During her tutoring the world's event began to affect Sofia. Her sister was now fighting for as a member of the National Guard in Paris along with her common-law husband Victor Jaclard. The National Guard had not accepted the peace treaty, which the National Assembly had negotiated with the Prussians. Paris was surrounded by the Prussians and the French Army was soon going to invade the commune the National Guard had created. Sofia and Vladimir attempted to cross the border under the pretext that they were traveling to study fossils for Vladimir's dissertation. They were denied and forced to sneak across the border in a rowboat they found. For about a month they lived and worked the rebels. Sofia was acting nurse and Vladimir studied fossils. They left the Commune when news came that Paris had fallen to Theirs' forces. They knew that Aniuta and Victor were both in danger now. Victor was being actively hunted by Their and Aniuta had managed to escape to London where Karl Marx helped her find temporary lodging. Vasily and Elizaveta traveled to Paris out of concern for their eldest. Fortunately Vasily was able to use his connections to help Victor escape to Switzerland where him and Aniuta were married. This was the most eventful spring of Sofia's life.

In Berlin with things calming down Sofia went back to her studies. She began an extensive correspondence with Weierstrass. To start the letters were merely administrative materials and setting up appointments. At about the seventh letter, they began to contain more substantial information. In one letter Weierstrass sent notes about his development of the algebraic background for his lectures on Abelian integrals. As the letters continue the two mathematicians became friends and confidants. Though Weierstrass claimed Sofia to be his one real friend, his main concern was mathematics. He put Sofia to work on a dissertation. In the period of 18 months Sofia wrote three dissertations under Weierstrass' direction. From these dissertations Sofia will accomplish her goal of receiving a degree. Along with the aid from Weierstrass and her talents she received a PhD from the University of Gottingen.

The Later Years

After reconciliation in 1873 Sofia and Vladimir began to make plans for their future. Vladimir took the qualifying exam in order to teach in Russia, this time he failed, but he would eventually pass the exam in 1875. Sofia and Vladimir had a hard time finding jobs in Russia due the Populist movement. Many upper-class young people were taking menial jobs in the villages of Russia. Sofia and Vladimir decided to try out real estate with the hopes of becoming independently wealthy, which would allow them to pursue their studies. This was an elaborate project, which found little success. In 1875 General Krukovsky passed away leaving Sofia 50,000 rubles, minus 20,000 previously loaned to the couple to pay off the debt the publishing company had created.

Now without the worries of money, the couple settled into a busy social life. They spent time with many famous scholars and writers in Russia. In 1878 Sofia gave birth to a daughter, Sophia Vladimirovna Kovalevskaya, nicknamed Fufa. Soon after Fufa's birth Elizaveta died and the investments Sofia dn Vladimir had made previously failed. Vladimir did not take the hit well. He lost interest in the world and withdrew from society. Sofia took a different approach. After a difficult pregnancy and a severe illness, Sofia decided to make some changes. She took on the added responsibility of being a mother and proved yet again to be a strong and driven woman. She began writing for Weierstrass again and, although she didn't have much time for mathematics, she attended the Sixth Congress of Mathematics and Physicians in December 1880. Attending this event introduced her to Gosta Mittag-Leffler, which proved to be helpful in the future.

Mittag-Leffler was born in Stockholm in 1846. His father was an elementary teacher and his mother was a highly respected woman in Stockhom society. In 1872 he received his PhD from the University of Uppsala. After traveling on a stipend for a year he was offered a position at Berlin. He did accept a chair at the University of Helsingfors (Helsinki). Mittag-Leffler attempted to obtain a position for Sofia, but did not succeed. He was unsuccessful due to Sofia being Russian, not a woman ironically. It seems the world had moved into a more liberal view on women's opinions. Mittag-Leffler soon

resigned his position at Helsingfors and joined the new Stockholm Hogskola, which was founded in response to the conservative character of older Swedish universities. Mittag-Leffler initiated a dynamic career in mathematics at the new university. Mittag-Leffler founded the mathematical journal *Acta Mathematica,* which is still a top journal today. Sofia would have a section of the journal dedicated to her at one point.

Grateful for the attempted help, Sofia was forced to continue in her own way. She took a better that the constant failing business ventures of Vladimir. In 1880 Sofia applied to take the magisterial examination so she could teach at Russian institutions of higher learning. Sofia had to pull her application due to more unsuccessful ventures by Vladimir. When she finally officially put in her application, she was denied that chance to even apply.

Although Sofia could not teach, Vladimir was offered a position, though menial, at the University of Moscow. Before Vladimir took the job he was distracted by his involvement with the Ragozins. While Vladimir was away on a trip for the Ragozins, Sofia made a trip to Berlin to see Weierstrass. During this trip their friendship was renewed. When Sofia returned to Moscow she found out that Vladimir didn't show up for the position at the university. She further learned that he owed a large sum of money to the Ragozins. Vladimir finally returned about a month later, only for Tsar Alexander II to be assassinated. The family needed to leave the country due to their ties to the radicals. Sofia and Fufa went to Berlin, while Vladimir returned to Moscow.

When Sofia and Fufa were in Berlin alone was when Mittag-Leffler tried to get Sofia a position at the university and failed. However, Weierstrass gave Sofia a project to work on at the same time. Weierstrass was working on gaining a way back into the mathematical world for Sofia after her two-year absence. This project, although important, was not the end result of her work. While working on the project for Weierstrass, Sofia gained insight into a problem she had previously studied, the Euler equations. The Euler equations describe the motion of a rotating rigid body. The problem had been proposed to Sofia before, but she didn't make much progress on it,

however, during the summer of 1881 the ideas coming flooding to her. She needed to work on the other project Weierstrass had given her, so she simply worked on both.

To add to the stress of doing two projects at the same time, Sofia found out that Vladimir was in even more trouble in Russia. He had sold some of her mother's jewelry and this was just the tip of the iceberg. Throughout her marital troubles she continued to love her husband and would occasionally sent affectionate letters. One letter stated that she would move back if Vladimir would find suitable living for the family.

On the more positive side, Mittag-Leffler had not given up on trying to find Sofia a position at the university. He eventually succeeded in procuring a position for her privat docent, which is an unpaid position teaching at a university.

In 1883 Vladimir, still trying to figure out his finances, had too much debt to the Ragozins. He knew he would not be able to get out of the company, which is what he needed to do to save his job at the university. Almost positive that there was no way out of this predicament, Vladimir committed suicide on April 27th. Upon the news Sofia locked herself in a room and refused to eat. After five days she went into a coma from starvation. A doctor was able to feed her gradually and nurse her back to health. When she had completely recovered both mentally and physically, she was faced with a few considerable situations. She would need to finish her work on Lame's equations and financially secure her life so she could again take care of her daughter.

In the summer of 1883 she traveled to Berlin once again to visit her friend Weierstrass. Obviously a supportive friend, he helped her regain focus and finish her research. Sofia took Weierstrass' advise and wrote a letter to Mittag-Leffler stated that she was ready to take the position he had procured for her. She also attended another conference, where she shared her research on Lame's equations. After the conference she went to Stockholm to begin her work at the university.

Mittag-Leffler met Sofia when she arrived in Sotckhom and offered his place for her to

stay. She stayed with him and his wife for six weeks. She worked to adjust to speaking in German, her third language, and being in a new place without her daughter. On January 30, 1884 Sofia gave her first lecture (in German). She planned to lecture on linear differential equations, instead she lectured on partial differential equations. She was a successful lecturer despite her shyness. Like previously mentioned the university did not pay her a salary, instead she had to get it from her students. Her students toasted her at the end of the semester, which successfully completed her probationary period. She had hoped to get her daughter during the holiday, however her brother-in-law made the decision that it would not be the appropriate action for Fufa. Fufa ended up staying in Russia for two more years. In 1884 Sofia also became an editor for Mittag-Leffler's journal *Acta Mathematica.* Sofia also published her first paper on crystals during this year.

The year 1886 brought new challenges for Sofia. In the summer she went to visit Aniuta, who was extremely sick. When Victor returned from a trip, Sofia left Aniuta and Victor and went to pick up her daughter. When Sofia and Fufa returened to Stockhom, Sofia was presented with the tasks of teaching, keeping up with Fufa, worrying about Aniuta, and writing her memoirs.

In the spring of 1887, an old acquaintance, Maxim Kovalevsky came to Stockholm to deliver a course of lectures. He had just been fired from the University of Moscow due to his disapproval of the government's policies and including his opinions in his lectures. Including their political opinions, Sofia and Maxim had many things in common, including a like for one another. Their relationship turned into a scandalous affair. While Sofia was engaged in her work for the French Academy of Science's new competition for the Prix Bordin, Maxim asked her to marry him on the condition that she give up her work. To help Sofia from having to make a decision, Mittag-Leffler invited Maxim to his summer home for a vacation. Sofia finished her work and submitted it on time. Her paper was so good they increased the prize to 5,000 francs from 3,000 francs. She attended the award ceremony with Maxim and received a congratulatory speech from the President of the Academy of Sciences. To add to all of this excitement Aniuta passed

away in the spring of 1888.

Absolutely exhausted from the events of the past year, Sofia asked for a leave of absence for health reasons, she was granted this leave. She took a trip to Paris and decided it suited her better than Stockholm. Paris allowed Sofia to lead a more active social and intellectual life. When Weierstrass heard of her plan to leave Stockholm he was upset and let her know his feelings. Sofia never did leave Stockholm. She was an international celebrity now. She would eventually get everything she had wished for. She was made a full professor for life at the University of Stockholm, with the recommendation of Bjerknes, Hermite, and Beltrami. Upon her return from her absence Sofia didn't really have any new mathematics to show.

She continued to teach and said she was working on some papers, there is no evidence of this later work. After the fall term in 1890 she traveled to Genoa to spend the holiday with Maxim. A disorganized return from her trip caused her to not have any Danish money to tip the porter when she arrived in Copenhagen. As a result she had to carry her bags in through the rain, which resulted in her getting sick. When she returned to Stockholm, she felt well enough to teach her first class, which she did. The term had begun on February 6th. The next Monday Sofia described her plans for future work on the Euler equations to Mittag-Leffler. He claimed that this would be her best work yet. Unfortunately, on Tuesday, Febraury 10, 1891 Sofia died. Many people were saddened by her death. Sofia was buried in Stockholm with a white lily wreath dangling from her gravestone from her most cherished friend, Weierstrass.

On February 19, 1891, following Sofia's death speeches were made at the Moscow Mathematical Society. Sofia's works were reviewed in these speeches and she was praised by many of her peers. Sofia was the first woman to be accepted into the mathematics circle as an equal. Although mathematics was not the only world Sofia contributed to. She had a number of literary works published including, *Nihilist Girl,* a story about a young aristocrat that wishes to devote her life to a cause and the effect of a changing world on the patriarchal traditions of Russia. She also contributed greatly to the

scientific world, which named a lunar crater and a “minor planet” (asteroid) after her. Sofia Kovalevskaya contributed to many facets of the world and paved the way for future women scholars to succeed.

Sofia’s Work

The following boxes are extracts from and article by Kimberly A. Meares. This was the best way to show the work clearly.

Cauchy-Kovalevskaya Theorem

Sofia generalized a problem Cauchy previously worked on. Cauchy looked at the existence theorem for partial differential equations and Sofia generalized Cauchy’s results to systems of order r containing time derivatives of order r. Sofia was said to have simplified the proof and given the theorem its definitive form. The theorem is sometimes known as the Cauchy-Kovalevskaya Theorem.

The partial differential equation given in the form:

The Euler Equations

Sofia's paper completes a program implicit in the works of Euler and Lagrange - to solve in an analytic manner the equations of motion. To do so requires cases in which there are enough algebraic integrals to permit a reduction to quadratures, and then a transformation of variables suitable for allowing an application of theta functions. (7)

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