The Pioneering Women Mathematicians*

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The first creative and professional woman mathematician was Sof'ya Vasil'yevna Kovalevskaya (1850–1891), [11] and [20], but six women are known to have achieved some distinction in mathematics before her (cf. the very title of [17]). The lives of those six pioneers were extraordinary in the strict sense of the word, since no ordinary woman could possibly have succeeded in an intellectual activity in which only a tiny minority of men had worked seriously.

Hypatia

The earliest woman known to have worked in mathematics was the celebrated Hypatia, who was born in Alexandria about the year 370. Her father was Theon, a distinguished mathematical editor and commentator, who educated her in the philosophy and mathematics of Greece. She is thought to have assisted her father to write his Commentary on the *Syntaxis* (or, *Almagest*) of Ptolemy and his revised text of Euclid's *Elements*, which has been the basis of almost all subsequent editions of Euclid. She is said to have written commentaries on Apollonius' *Conic Sections*, Ptolemy's *Syntaxis* and Diophantus' *Arithmetica*, but those works have not survived ([10], v.6, pp. 615–616). She lectured at the Museum of Alexandria on the Neoplatonic doctrines of Plotinus and Iamblichus, and about the year 400 she became the head of the Neoplatonic school in Alexandria, which was fiercely opposed by the Christians. Many eminent people attended her lectures and supported her doctrines. She was renowned also for her beauty, and for the fact that she had declined proposals from many distinguished suitors, preferring to dedicate herself to philosophy and mathematics.

The philosopher Synesius of Cyrene had become Bishop of Ptolemais (even though he traced his descent from the gods of Olympus!) and we have several of his letters to her, full of chivalrous admiration and reverence. In one letter he asked her how to construct an astrolabe and a hydroscope, and she appears to have invented a form of planisphere.

The government of Alexandria was disputed between the Roman praefect Orestes and the Patriarch of Alexandria, the infamous Saint Cyril ([9], Ch.47). The contemporary Christian historian Socrates Scholasticus wrote of Hypatia ([18], Bk.7, Ch.15): "Such was her self-possession and ease of manner, arising from the refinement and cultivation of her mind, that she not infrequently appeared in public in the pres-

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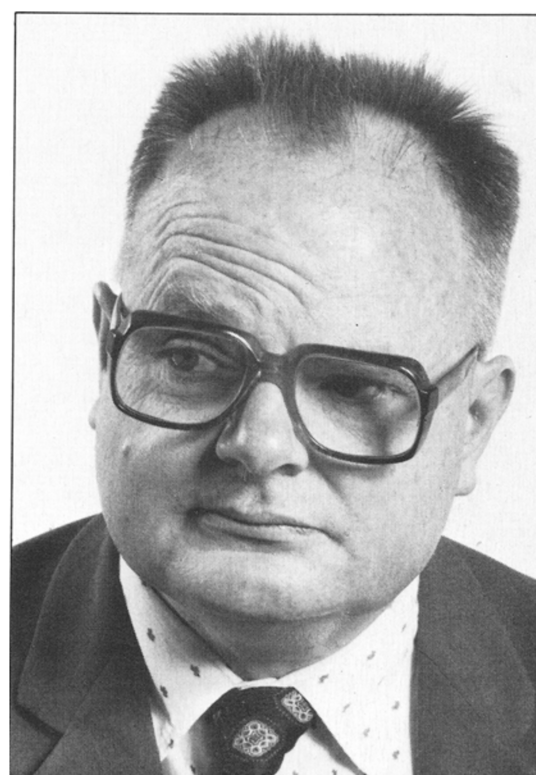

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ence of the magistrates, without ever losing in an assembly of men that dignified modesty of deportment for which she was conspicuous, and which gained for her universal respect and admiration. Yet even she fell a victim to the political jealousy which at that time prevailed. For as she had frequent interviews with Orestes, it was calumniously reported among the Christian populace, that it was by her influence that he was prevented from being reconciled to Cyril.

"Some of them therefore, whose ringleader was a man named Peter, hurried away by a fierce and bigoted zeal, entered into a conspiracy against her; and observing her as she returned home in her carriage, they dragged her from it, and carried her to the church called Caesareum, where they completely stripped her, and then murdered her with shells. After tearing her body in pieces, they took her mangled limbs to a place called Cinaron, and there burnt them."

The long and glorious tradition of Alexandrian mathematics died with Hypatia, in the year 415.

Gabrielle-Émilie Le Tonnelier de Breteuil, Marquise du Châtelet

In the 12th century the Indian mathematician Bhāskara 2nd ([10], v.2, pp. 115–120) dedicated his great treatise on mathematics to his daughter Līlāvatī, but otherwise there is no record of any significant female mathematician between Hypatia and the 18th century.

The Marquise du Châtelet, who became known throughout Europe as Voltaire's love Émilie, was born on 17th December 1706 as Gabrielle-Émilie Le Tonnelier de Breteuil ([10], v.3, pp. 215–216; [12]; [22]). Her father was a rich and powerful civil servant, one of the effective rulers of France. He recognized his daughter's intellect and had her trained in many languages, and also in mathematics, which became her major interest. When she was 19 she married the Marquis du Châtelet (then aged 30), a bluff and amiable regimental colonel whose only interest was in the army, and who spent most of his time away from his wife. She led a gay life in the frivolous high society of Paris, but after the birth of her third child she settled down, at the age of 27, to the serious study of mathematics.

Her principal lover at that period was the mathematician Maupertuis (1698–1759), who was an important supporter of the physics of Newton against that of Descartes, which was still fashionable in France. But, in 1733 she met Voltaire (1694–1778), then aged 39. They quickly announced their love, and Émilie declared that she was planning to spend the rest of her life with him, which she did (although she still continued ardently to pursue Maupertuis). The Marquis was well-satisfied to have such a uniquely distinguished man as his wife's official lover, and when he visited Émilie he was happy to dine with her children

Émilie, Marquise du Châtelet (1706–1749). Anonymous portrait, reproduced by courtesy of le Marquis Henri François de Breteuil and M. Michel de Breteuil.

whilst she and Voltaire continued their philosophical discussions over dinner.

She was handsome rather than beautiful, and richly dressed rather than elegant, but Voltaire compared her mind with that of Newton, the master of his thought. His *Memoires* begin by reporting their meeting, which he regarded as the turning-point of his life. In order to get away from the frivolous distractions of Parisian society, and also to be safer from the police who frequently sought to arrest Voltaire for his writings, Émilie and Voltaire moved in 1734 to her husband's isolated estate of Cirey, in the province of Champagne. Voltaire rebuilt the decayed mansion, and they lived there for most of the rest of her life, with occasional periods in Paris, Versailles, Brussels and Lunéville. Their philosophical retreat at Cirey became one of the important intellectual centres of Europe, admired greatly by their few visitors, and the target of much malicious gossip.

They studied intensely and wrote prodigiously [22]. She wrote a lengthy sceptical commentary on the Bible (unpublishable at that time), and she published several essays on philosophy and science. Voltaire had made her an ardent Anglophile (they frequently conversed

Maria Gaetana Agnesi (1718–1799). Portrait by M. Longhi, from Luísa Anzoletti, *Maria Gaetana Agnesi,* L. F. Cogliatti, Milan, 1900.

in English) and a Newtonian, but in 1740 she dismayed him by publishing a Leibnizian book *The Institutions of Physics.* She had written it for the education of her son, and it was acclaimed as an extraordinarily lucid exposition of Leibniz's physics ([12], p. 145; [22]), and it was reprinted three times. But Voltaire considered that she had wasted her time by expounding Leibniz's ideas rather than Newton's, even though she had given a careful and detailed historical and philosophical account of physics. She engaged in an extensive debate with many of the leading mathematicians of Europe about Leibniz's concept of *vis viva* ($=2 \times$ kinetic energy), and that debate contributed substantially to the clarification of the concept of kinetic energy. However, she then returned to Newtonian physics, and from 1745 her major efforts were devoted to translating Newton's *Principia Mathematica* from Latin into French, with extensive and valuable commentaries and supplements, in which she was assisted by the physicist Clairaut.

But in 1748 Émilie acquired a new young lover, and she became pregnant at the age of 42. Both she and her lover agreed ruefully with Voltaire's remark that their child would have to be listed under her "Miscellaneous Works" ([12], p. 257). She dedicated herself to completing her edition of Newton, and made arrangements for it to be published if she would not live. Her daughter was born on 2nd September 1749, while she was sitting at her desk and writing on Newtonian theory ([12], p. 269). She appeared to be making excellent progress, but on the 10th September 1749 she died very suddenly. Voltaire, her lover and her husband were all heartbroken by the unexpected tragedy.

Her edition of Newton was finally published in 1759, with an eulogistic Preface by Voltaire. The book has been reprinted in modern times, and it remains the only French translation of the *Principia Mathematica.*

Maria Gaetana Agnesi

A marked contrast to the flamboyant life of the Marquise du Châtelet is provided by her near-contemporary Maria Gaetana Agnesi, who was born in Milan on 16th May 1718 ([10], v.1, pp. 75–77, [21]). Her father was professor of mathematics at the University of Bologna, and he carefully planned her education. By the age of 9 she was fluent in Latin, Greek, Hebrew and several modern languages, and she had delivered a Latin dissertation (which was published) defending higher education for women.

Her teenage years were devoted to private study and the tutoring of her many younger brothers—there is no record that she tutored any of her many younger sisters. She studied the mathematics of Fermat, Descartes, Newton, Leibniz, Euler and the Bernoullis. Many distinguished intellectuals attended the salons arranged by her father, at which she acted hostess. She engaged in discussions on many scientific and philosophical topics, usually speaking in Latin for her cosmopolitan audience; but when any foreigner addressed her she would usually reply in his own language.

At the age of 20 she published a Latin book of *Philosophical Propositions,* based on those domestic seminars, in which she reiterated her support for the higher education of women. She was very shy and retiring by nature, and at the age of 20 she persuaded her father to cease displaying her as an intellectual prodigy, but she was unable to persuade him to let her enter a convent.

For the next 10 years she worked on her magnum opus, the *Analytical Institutions for the Use of Italian Youth,* which was published in 1748 as two huge quarto volumes, containing over 1000 pages. This text (written in Italian) was the first text-book for teaching the differential and integral calculus, a subject which had been mastered only by the leading mathematicians of Europe. Volume 1 dealt with algebra, theory of equations and coordinate geometry, and Volume 2 dealt with the differential and integral calculus, infinite series and differential equations. She combined the ideas of many mathematicians into a clear and systematic text-book, which contains also much of her original work. It is ironic that she should be remembered mainly for the minor detail of a cubic curve, which has become known as the "witch of Agnesi."

A committee of the French Academy of Sciences reported in 1749 that: "This work is characterized by its careful organization, its clarity and its precision. There is no other book, in any language, which would enable a reader to penetrate as deeply, or as rapidly, into the fundamental concepts of analysis. We consider that treatise the most complete and best written work of its kind" ([10], v. 1, p. 76). Accordingly, the 2nd volume was translated into French and published in 1750. A deputy of that Academy wrote to her that "I do not know of any work of this kind that is clearer, more methodical or more comprehensive. . . . There is none in methematical sciences. I admire particularly the art with which you bring under uniform methods the diverse conclusions scattered among the works of geometers and reached by methods entirely different" [4]. Nonetheless the French Academy did not admit Maria, although the Bologna Academy of Sciences did elect her to membership.

Her book remained the standard introductory text on calculus for many years. As late as 1801 an English translation was published by John Colson, the Lucasian Professor of Mathematics at Cambridge. His editor explained that Colson "found her work to be so excellent that he was at the pains of learning the Italian language at an advanced age for the sole purpose of translating her book into English, that the British youth might have the benefit of it as well as the youth of Italy" [1]. And indeed, Charles Babbage benefited from his study of the book ([2], p 26). However, since Babbage had yet to accomplish "the triumph of 'The Principles of pure D-ism in opposition to the Dot-age of the University' " ([2], p. 79), Colson replaced Agnesi's Leibnizian d-notation by a botched version of Newton's dots.

In 1748 the reigning Pope was that genial liberal Benedict XIV. Indeed, the French ambassador hinted to him that the award of a papal medal to Voltaire would be welcomed by the French King Louis XV—Voltaire had briefly become almost respectable, but he soon recovered. However, the Pope replied that he had already given Voltaire a gold medal, and "I couldn't give him a larger one if he were St. Peter himself!" ([12], pp. 205–206). In 1749 that broad-minded Pope sent to Agnesi a congratulatory note on the publication of her book, with a gold medal and a gold wreath adorned with precious stones. On 2nd September 1750 he appointed her to the chair of mathematics and natural philosophy at the University of Bologna. However, she never taught there, and after her father died in 1752 she ceased to do any scientific work.

Sophie Germain (1776–1831). Medallion portrait, reproduced from *Grand Larousse Encyclopédique* (1962), by courtesy of Librairie Larousse.

In 1762 the University of Turin asked her for her opinion of some papers on the calculus of variations by the young Lagrange, but she replied that she was no longer concerned with such interests. She devoted her time to caring for the sick and poor of her parish. The records of an institution for the ill and infirm call her "an angel of consolation to the sick and dying women until her death at the age of eighty-one years on January 9, 1799" ([21], p. 216). She shares a common grave with 15 inmates of that institution.

Scholarships for girls have been founded in her honour, streets in Milan, Monza and Masciago have been named for her, and a normal school in Milan bears her name.

Sophie Germain

Sophie Germain was born to wealthy parents in Paris on 1st April 1776 ([10], v. 5, pp. 375–376; [5], Ch. 14). At the age of 13, with the French Revolution beginning, she began to spend much time in her father's ample library, where she read of Archimedes being killed by a Roman soldier. That episode inspired her to study mathematics, which resolution was fiercely opposed by her parents, who removed lighting and heating from her bedroom and confiscated her clothes after she had gone to bed. Undeterred by this, she wrapped herself in quilts, lit some candles which she had concealed, and studied mathematics all night. Eventually her parents conceded defeat, and gave her free access to the mathematical books in her father's library.

In 1794 the Polytechnic School opened in Paris. Sophie could not attend, but she collected the lecture notes for some courses given there. She submitted a paper on analysis to Lagrange using the name of M. le Blanc, one of his students. Lagrange was profoundly impressed by that paper, and when he discovered the identity of its author he went to her home and praised her as a promising young analyst. He became her sponsor and mathematical counsellor.

Gauss had published his profound work *Disquisitiones Arithmeticae* in 1801, and Sophie studied it in detail. In 1804 she began corresponding with Gauss, who admired the mathematical ability of his correspondent M. le Blanc. In 1807 Napoleon's troops were fighting near Gauss's city of Brunswick. Remembering the fate of Archimedes, Sophie became concerned for Gauss's safety, and she interceded on his behalf with the local French general, who was a family friend. The general obliged by sending an envoy to ensure that Gauss was safe, but Gauss was confused by the envoy's mention of a Mlle. Germain, since he knew her only as M. le Blanc. When he understood what had happened, he wrote a remarkable letter to his protectress: "But how to describe to you my admiration and astonishment at seeing my esteemed correspondent M. le Blanc metamorphose himself into this illustrious personage, who gives such a brilliant example of what I would find difficult to believe. A taste for the abstract sciences in general and above all the mysteries of numbers is excessively rare; one is astonished at it; the enchanting charms of this sublime science reveal themselves only to those who have the courage to go deeply into it. But when a person of the sex which, according to our customs and prejudices, must encounter infinitely more difficulties than men to familiarize herself with the thorny researches, succeeds nevertheless in surmounting these obstacles and penetrating the most obscure parts of them, then without doubt she must have the noblest courage, quite extraordinary talents and a superior genius. Indeed, nothing could prove to me in so flattering and less equivocal manner that the attractions of this science, which has enriched my life with so many joys, are not chimerical, as the predilection with which you have honoured it. . . . Brunswick, 30th April 1807, my birthday" ([5], p. 262). Gauss also spoke highly of her work in a letter to Olbers.

Sophie continued to work in number theory, and when Legendre published the 2nd edition of his work on number theory he included many of her discoveries. She made a major advance in the study of Fermat's Last Theorem, by showing that if x,y,z and n are co-prime positive integers with n greater than 2 and

$$x^n + y^n = z^n,$$

then n must be greater than 100.

In 1808 the physicist Chladni demonstrated in Paris the vibrations of plates, a topic far beyond the range of existing mathematics. The French Academy of Sciences offered a prize in 1811 for an essay on elastic surfaces, including comparison with experimental results (especially Chladni's). No prize was awarded in 1811, but on the basis of the essay which she had submitted Lagrange was able to construct the 4th-order partial differential equation for the vibration of a uniform plane elastic plate. A second contest was held in 1813, when Sophie's new entry received honourable mention. A third contest was held in 1816, and her formulation of the partial differential equation for the vibration of a uniform curved elastic plate gained her the prize, although later investigators have criticised some aspects of her solution. Sophie was then welcomed into the group of brilliant French mathematicians, including Cauchy, Ampère, Legendre, Fourier, Poisson and Navier. She extended her work on plates to deal with the vibrations of curved non-uniform elastic plates. She also studied chemistry, physics, geography and history, and she published 2 volumes of philosophical works.

Gauss persuaded the University of Göttingen to award Sophie an honorary doctorate, but she died of cancer on 26th June 1831, before it could be awarded. In 1874 the University of Göttingen awarded the degree of Ph.D. in mathematics to Sophie Kovalevskaya ([11], p. 19; [20], p. 127). In December 1888 the French Academy of Sciences awarded a prize to Kovalevskaya for her essay on the motion of a rigid body around a fixed point, and she became the toast of Paris. In the following year, the French engineer Eiffel built his superb tower as a demonstration of the triumphs of modern engineering, in which the mathematical theory of elasticity played an essential role. The names of 72 *savants* were inscribed on that structure to celebrate their contributions to scientific engineering.

That list did not include the name of Sophie Germain.

Mary Fairfax Greig Somerville

Mary Fairfax was born in Jedburgh, Scotland on the 26th December 1780 ([10], v. 12, pp. 521–525; [16]; [17]; [19]).

Her father was a vice-admiral, and accordingly he was away from home for long periods. Her mother taught her to read but otherwise she had no education until the age of 10, when her father was shocked to find that she had grown into an un-taught "savage" ([19], p. 20). He sent her to a fashionable girls' school in Musselburgh, and the one year of misery, boredom and futility which she spent there was the only regular

Mary Somerville (1780–1872), aged 55. Detail of a portrait from life by Thomas Phillips, R.A; one of the series of "Eminent Personages" commissioned by her publisher John Murray. Reproduced by permission of the Scottish National Portrait Gallery.

schooling which she ever received. A few years later she gained an introduction to arithmetic, but her family were opposed to any further education for her. An aunt scolded Mary fiercely, saying: "I wonder you let Mary waste her time in reading; she never *shews* (sews) more than if she were a man!" ([19], p. 28).

One day at a tea-party she looked idly through a fashion magazine. "At the end of the magazine, I read what appeared to me to be simply an arithmetical question, but on turning the page I was surprised to see strange-looking lines mixed with letters, chiefly Xs and Ys, and asked, "What is that?"

"Oh", said Miss Ogilvie, "it is a kind of arithmetic; they call it Algebra; but I can tell you nothing about it." And we talked about other things; but on going home I thought I would look if any of our books could tell me what was meant by Algebra." But none of the books at home could ([19], p. 47).

By chance she heard that Euclid's *Elements* was a book important for perspective and mechanics, and she then had the problem of finding a copy—it simply would not do for a young lady to go into a shop and ask for it. Eventually her younger brother's tutor learned of her interest in Euclid, and he gave her what very little help he could in studying the *Elements*. Her mother was scandalized by such improper behaviour by her daughter, and as with Sophie Germain, the candles were removed from Mary's bedroom to stop her from studying. But Mary had by then studied the first 6 books of the *Elements*, and "I was now thrown on my memory, which I exercised by beginning at the first book and demonstrating in my mind until I could go through the whole. My father came home for a short time, and somehow or other finding out what I was about, said to my mother, "Peg, we must put a stop to this, or we shall have Mary in a strait-jacket one of these days" ([19], p. 54).

At the age of 24 she married her cousin Samuel Greig who died 3 years later, leaving her with a son and with enough money to study as she pleased. She won a prize problem in a popular mathematical journal, and was awarded a silver medal cast with her name. At the age of 32 she married another cousin, Dr. William Somerville, who encouraged and supported her studies. The couple lived in London and visited Paris, meeting many scientists. She published some papers on experimental physics which were much admired, and her supporters cited approvingly the fact that she combined her scientific studies with being an admirable wife and mother.

Her scientific friends persuaded her to translate Laplace's formidable treatise *Mécanique céleste*, and her version was published as *The Mechanism of the Heavens* in 1831, when she was nearly 51 years old. Unexpectedly the book became very popular—it was reprinted many times and it was used as a text-book of mathematical astronomy for nearly a century ([16], p. 321). She clarified and explained Laplace's notoriously obscure text and revealed herself to be one of the most accomplished of scientific expositors. Her mathematical preface to the translation was re-published separately as *A Preliminary Dissertation on the Mechanism of the Heavens*, which likewise remained popular for nearly a century. Many scientific societies elected her as a member, and the Royal Society commissioned a portrait bust of her which was displayed in its Hall. However, she could not see it, since women were not admitted to the premises of the Royal Society!

For the rest of her long life, spent mostly in Italy, she continued to write scientific expositions of a very high level. Her treatise on *The Connection of the Physical Sciences*, first published in 1834, appeared in 9 revised editions, and was much esteemed by James Clerk Maxwell. Her discussion of the hypothetical planet perturbing Uranus led John Couch Adams to compute the location of Neptune; and since the Astronomer Royal G. B. Airy made such a public fool of himself over Adams's discovery he became a life-long enemy of Mary Somerville. On two occasions her books were criticized by parliamentarians, and her text on *Physical Geography* was attacked from the pulpit of York Cathedral since she supported the geologists rather than the theologians, but it likewise appeared in many editions. Her large book on *Molecular and Microscopic Science* was published in 1869 when she was 89 years old, and she proceeded to prepare a second edition of that work. She was a friend of Darwin, but she insisted that there was to be "no Darwinism" in her books ([16], p. 336). In her later years she composed her fascinating memoirs [19] (published after her death), she revised the manuscript of her treatise on *Finite Differences* (begun 40 years previously); and she was studying a memoir on quaternions on the day that she died; 29th November 1872, a month before her 92nd birthday ([19], p. 376).

Her many scientific friends petitioned for her to be buried in Westminster Abbey, but the petition was vetoed by the Astronomer Royal Airy, still bitter and unforgiving ([16], p. 323, n. 73). Later, Somerville College at Oxford was named in her honour. An indication of her renown is given by the fact that when a Russian exile published a pamphlet about Kovalevskaya in 1899, he entitled it *Sofia Kovalevskaya, the Russian Mary Somerville* [17].

Augusta Ada, Countess of Lovelace

On January 2nd 1815, the poet Lord Byron married Anna Isabella Milbanke, a formidably pious and virtuous heiress, well-educated in mathematics and astronomy, and called by Byron his "Princess of Parallelograms." Their daughter Augusta Ada was born on 10th December 1815 [13]. On January 15th 1816, Lady Byron separated from her husband in a smoky blaze of publicity, and her industrious scandal-mongering soon drove Byron out of Great Britain, never to return. When Ada was less than a year old, Byron published Canto the Third of his automythological epic, *Childe Harold's Pilgrimage*, beginning with the striking lines [8]:

Is thy face like thy mother's, my fair child!
ADA! sole daughter of my house and heart?
When last I saw thy young blue eyes they smiled,
And then we parted,—not as now we part,
But with a hope.

Throughout Byron's 8 years of exile he kept a close interest in Ada, writing frequently to his wife and relatives to enquire about her, and when he died in Greece his last words consisted of a struggle to say something concerning her ([13], pp. 18–23).

Lady Byron developed into an aristocratic moral monstrosity, cultivating assiduously her reputation for sanctity while she left a trail of wrecked lives in her wake. Ada was tyrannized over by her dreadful mother, but she was educated by the best tutors available. Her health was precarious, and at the age of 14 her legs became paralysed—for some years afterwards she used crutches and then a walking stick. Later, she became an ardent rider of horses.

Augusta Ada, Countess of Lovelace (1815–1852), aged 19. Portrait by Margaret Carpenter, formerly in the British Embassy at Athens, now in the National Physical Laboratory at Teddington. Crown Copyright.

In 1833 Ada (then aged 17) met Charles Babbage (then aged 41), and she was much impressed by his scientific ideas. He demonstrated his small Difference Engine to Ada and her mother, telling them of his ideas for generalizing it to an Analytical Engine (or, general computer). Ada was already convinced that she would become a famous scientist, a remarkable ambition for any woman at that time. She was inspired by the example of her friend Mary Somerville, who advised her to study mathematics ([19], p. 154).

When Ada was aged 19, she met and soon married the Hon. William King, later 8th Lord King and 1st Earl of Lovelace. He was an amiable but weak man, proud of his wife's intellect, but dominated completely by her mother. The births of 3 children in quick succession caused Ada to fear that she might never have time to continue her scientific studies. When her 3rd child was a few months old she wrote to Babbage asking him to assist her in finding a man to train her scientific mind. Eventually he accepted her as his own disciple, and he became a close friend of the family.

Her mother entangled her in a prolonged and exceptionally squalid family episode—when she had dragged herself clear she wrote to her husband that: "my scientific and literary pursuits must ever be the main thing evidently, for myself" ([13], p. 146.) However, she also devoted much time to singing and to playing several musical instruments.

In 1842 the Italian military engineer L. F. Menabrea published (in French) a report of Babbage's ideas concerning his proposed Analytical Engine. Babbage wrote in his memoirs ([2], p. 136), in his only mention of Ada in that book, that "the late Countess of Lovelace informed me that she had translated the memoir of Manabrea. I asked her why she had not herself written an original paper on a subject with which she was so intimately acquainted? To this Lady Lovelace replied that the thought had not occurred to her. I then suggested that she should add some notes to Menabrea's memoir; an idea which was immediately adopted.

"We discussed together various illustrations that might be introduced. I suggested several, but the selection was entirely her own. So also was the algebraic working out of the different problems, except indeed, that relating to the numbers of Bernouilli (*sic*!) which I had offered to do to save Lady Lovelace the trouble. This she sent back to me for an amendment, having detected a grave mistake which I had made in the process.

"The notes of the Countess of Lovelace extend to about three times the length of the original memoir. Their author has entered fully into almost all the very difficult and abstract questions connected with the subject.

These two memoirs taken together furnish, to those who are capable of understanding the reasoning, a complete demonstration—*That the whole of the developments and operations of analysis are now capable of being executed by machinery.*"

After this scientific triumph by Ada at the age of 27 (with only her initials appearing with her paper in *Taylor's Scientific Memoirs* in 1843) her health deteriorated markedly, and she can hardly have benefited from her medical treatment. In accordance with standard medical practice of that period, leeches were frequently applied to suck her blood and she was dosed alternately with opium and morphine, counteracted by massive quantities of brandy ([13], p. 214). She had previously been rather arrogant in her letters to Babbage, but her subsequent letters and actions were hardly those of a sane person. She gambled on horses on an ever-increasing scale, and somehow she persuaded her husband to write a letter to some bookmakers authorising her betting.

In 1851 her doctors discovered that she was in an advanced stage of cancer, and by January 1852 she was being given opiates to reduce the pain. Her mother, however, regarded pain as being an expression of God's will, and she insisted on replacing the opiates by the ministrations of mesmerists, who proved to be ineffectual. Ada's calmness in settling her worldly affairs and in maintaining an active interest in scientific matters evoked the admiration of her friends. However, by August 23rd 1852 she was suffering such pain that her doctor wrote to her mother that the most that Ada could hope for was "euthanasia" ([13], p. 323). Thereupon, Lady Byron descended upon the Lovelaces, and her assiduous nursing kept Ada alive through months of terrible agony. Ada lost all of her composure in her suffering: she was forced to confess that she was being blackmailed by teams of bookmakers, and Lady Byron had to redeem the Lovelace family diamonds from pawn—twice! Ada's husband was deeply shaken by the confessions wrought from her by her mother. After many hideous months, Ada died very peacefully on 23rd November, 1852, at the age of 36.

Lady Byron wrote that "the greatest of all mercies shown her has been her disease—weaning her from temptation, and turning her thoughts to higher and better things" ([13], p. 312). A companion who assisted Lady Byron to nurse Ada wrote of her own satisfaction "that God in his mercy would not permit such a being to quit this world in darkness, so that bodily agony was protracted after all in *His* wonderful Providence to work for good" ([13], p. 326).

In the aftermath of Ada's death the bookmakers and the blackmailers were bought off, many letters were burnt and Lady Byron suppressed firmly all evidence of the life of her scandalous daughter. Babbage attempted to publish a memoir of Ada, but even he was defeated by Lady Byron's lawyers. Babbage died in 1871, embittered by his failure to build his Analytical Engine, and commonly regarded as a tiresome crank. Ada's memoir was re-printed in a book [3] about Babbage's engines in 1889, but thereafter both Babbage and Ada were forgotten almost completely until computers were re-invented during World War 2.

Dr. B. V. Bowden, an English pioneer in computing, re-discovered Ada's paper, and he has given a most revealing account [7] of the remarkable circumstances in which Ada's grand-daughter permitted him to examine her papers. A hundred and one years after the death of Ada he re-printed her paper, with a sketch of her life and a memorable portrait of her (looking like a Jane Austen heroine) [6], and Ada's 1843 paper has also been re-printed in a Dover book about Babbage [14]. These publications resulted in her present renown as the patron saint of computer programming, but no full biography of her was published until 1977 [13].

As Ada herself had insisted, her body had been laid alongside that of the father whom she had never known. As he had written [8]:

Diagram for the computation by the Engine of the Numbers of Bernoulli.

Number of Operation.	Nature of Operation.	Variables acted upon.	Variables receiving results.	Indication of change in the value on any Variable.	Statement of Results.	Data.			Working Variables.										Result Variables.			
						$^1V_1$ 0 0 0 1 [1]	$^1V_2$ 0 0 0 2 [2]	$^1V_3$ 0 0 0 4 [n]	$^0V_4$ 0 0 0 0	$^0V_5$ 0 0 0 0	$^0V_6$ 0 0 0 0	$^0V_7$ 0 0 0 0	$^0V_8$ 0 0 0 0	$^0V_9$ 0 0 0 0	$^0V_{10}$ 0 0 0 0	$^0V_{11}$ 0 0 0	$^0V_{12}$ 0 0 0	$^0V_{13}$ 0 0 0	$^1V_{21}$ B_1 in a decimal fraction. [B_1]	$^1V_{22}$ B_3 in a decimal fraction. [B_3]	$^1V_{23}$ B_5 in a decimal fraction. [B_5]	$^0V_{24}$... 0 0 0 [B_7]
1	×	$^1V_2 \times {}^1V_3$	$^1V_4, {}^1V_5, {}^1V_6$	$\{^1V_2 = {}^1V_2;\ ^1V_3 = {}^1V_3\}$	$= 2n$	...	2	n	$2n$	$2n$	$2n$											
2	−	$^1V_4 - {}^1V_1$	$^2V_4$	$\{^1V_4 = {}^2V_4;\ ^1V_1 = {}^1V_1\}$	$= 2n - 1$	1	...	...	$2n-1$													
3	+	$^1V_5 + {}^1V_1$	$^2V_5$	$\{^1V_5 = {}^2V_5;\ ^1V_1 = {}^1V_1\}$	$= 2n + 1$	1	...	...	...	$2n+1$												
4	÷	$^2V_5 \div {}^2V_4$	$^1V_{11}$	$\{^2V_5 = {}^0V_5;\ ^2V_4 = {}^0V_4\}$	$= \frac{2n-1}{2n+1}$	...	...	...	0	0	...	...	...	...	...	$\frac{2n-1}{2n+1}$						
5	÷	$^1V_{11} \div {}^1V_2$	$^2V_{11}$	$\{^1V_{11} = {}^2V_{11};\ ^1V_2 = {}^1V_2\}$	$= \frac{1}{2} \cdot \frac{2n-1}{2n+1}$	...	2	...	...	...	...	...	...	...	...	$\frac{1}{2} \cdot \frac{2n-1}{2n+1}$						
6	−	$^0V_{13} - {}^2V_{11}$	$^1V_{13}$	$\{^2V_{11} = {}^0V_{11};\ ^0V_{13} = {}^1V_{13}\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$	...	...	...	...	...	...	...	...	...	...	0	....	$-\frac{1}{2} \cdot \frac{2n-1}{2n+1} = A_0$				
7	−	$^1V_3 - {}^1V_1$	$^1V_{10}$	$\{^1V_3 = {}^1V_3;\ ^1V_1 = {}^1V_1\}$	$= n - 1\ (= 3)$	1	...	n	...	...	...	...	...	...	$n-1$							
8	+	$^1V_2 + {}^0V_7$	$^1V_7$	$\{^1V_2 = {}^1V_2;\ ^0V_7 = {}^1V_7\}$	$= 2 + 0 = 2$	...	2	...	...	...	...	2										
9	÷	$^1V_6 \div {}^1V_7$	$^3V_{11}$	$\{^1V_6 = {}^1V_6;\ ^0V_{11} = {}^3V_{11}\}$	$= \frac{2n}{2} = A_1$	...	...	...	...	...	$2n$	2	...	...	...	$\frac{2n}{2} = A_1$						
10	×	$^1V_{21} \times {}^3V_{11}$	$^1V_{12}$	$\{^1V_{21} = {}^1V_{21};\ ^3V_{11} = {}^3V_{11}\}$	$= B_1 \cdot \frac{2n}{2} = B_1 A_1$	...	...	...	...	...	...	...	...	...	...	$\frac{2n}{2} = A_1$	$B_1 \cdot \frac{2n}{2} = B_1 A_1$	....	B_1			
11	+	$^1V_{12} + {}^1V_{13}$	$^2V_{13}$	$\{^1V_{12} = {}^0V_{12};\ ^1V_{13} = {}^2V_{13}\}$	$= -\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}$	...	...	...	...	...	...	...	...	...	...	....	0	$\left\{-\frac{1}{2} \cdot \frac{2n-1}{2n+1} + B_1 \cdot \frac{2n}{2}\right\}$				
12	−	$^1V_{10} - {}^1V_1$	$^2V_{10}$	$\{^1V_{10} = {}^2V_{10};\ ^1V_1 = {}^1V_1\}$	$= n - 2\ (= 2)$	1	...	...	...	...	...	...	...	...	$n-2$							
13	−	$^1V_6 - {}^1V_1$	$^2V_6$	$\{^1V_6 = {}^2V_6;\ ^1V_1 = {}^1V_1\}$	$= 2n - 1$	1	...	...	...	...	$2n-1$											
14	+	$^1V_1 + {}^1V_7$	$^2V_7$	$\{^1V_1 = {}^1V_1;\ ^1V_7 = {}^2V_7\}$	$= 2 + 1 = 3$	1	...	...	...	...	...	3										
15	÷	$^2V_6 \div {}^2V_7$	$^1V_8$	$\{^2V_6 = {}^2V_6;\ ^2V_7 = {}^2V_7\}$	$= \frac{2n-1}{3}$	...	...	...	...	...	$2n-1$	3	$\frac{2n-1}{3}$									
16	×	$^1V_8 \times {}^3V_{11}$	$^4V_{11}$	$\{^1V_8 = {}^0V_8;\ ^3V_{11} = {}^4V_{11}\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3}$	...	...	...	...	...	...	...	0	...	...	$\frac{2n}{2} \cdot \frac{2n-1}{3}$						
17	−	$^2V_6 - {}^1V_1$	$^3V_6$	$\{^2V_6 = {}^3V_6;\ ^1V_1 = {}^1V_1\}$	$= 2n - 2$	1	...	...	...	...	$2n-2$											
18	+	$^1V_1 + {}^2V_7$	$^3V_7$	$\{^2V_7 = {}^3V_7;\ ^1V_1 = {}^1V_1\}$	$= 3 + 1 = 4$	1	...	...	...	...	...	4										
19	÷	$^3V_6 \div {}^3V_7$	$^1V_9$	$\{^3V_6 = {}^3V_6;\ ^3V_7 = {}^3V_7\}$	$= \frac{2n-2}{4}$	...	...	...	...	...	$2n-2$	4	...	$\frac{2n-2}{4}$	...	$\left\{\frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = A_3\right\}$						
20	×	$^1V_9 \times {}^4V_{11}$	$^5V_{11}$	$\{^1V_9 = {}^0V_9;\ ^4V_{11} = {}^5V_{11}\}$	$= \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{4} = A_3$	...	...	...	...	...	...	...	...	0								
21	×	$^1V_{22} \times {}^5V_{11}$	$^0V_{12}$	$\{^1V_{22} = {}^1V_{22};\ ^0V_{12} = {}^2V_{12}\}$	$= B_3 \cdot \frac{2n}{2} \cdot \frac{2n-1}{3} \cdot \frac{2n-2}{3} = B_3 A_3$	...	...	...	...	...	...	...	...	...	...	0	$B_3 A_3$	....	......	B_3		
22	+	$^2V_{12} + {}^2V_{13}$	$^3V_{13}$	$\{^2V_{12} = {}^0V_{12};\ ^2V_{13} = {}^3V_{13}\}$	$= A_0 + B_1 A_1 + B_3 A_3$	...	...	...	...	...	...	...	...	...	...	....	0	$\{A_3 + B_1 A_1 + B_3 A_3\}$				
23	−	$^2V_{10} - {}^1V_1$	$^3V_{10}$	$\{^2V_{10} = {}^3V_{10};\ ^1V_1 = {}^1V_1\}$	$= n - 3\ (= 1)$	1	...	...	...	...	...	...	...	...	$n-3$							
Here follows a repetition of Operations thirteen to twenty-three.																						
24	+	$^4V_{13} + {}^0V_{24}$	$^1V_{24}$	$\{^4V_{13} = {}^0V_{13};\ ^0V_{24} = {}^1V_{24}\}$	$= B_7$	...	...	...	...	...	...	...	...	...	...	....	....	....	......	......	......	B
25	+	$^1V_1 + {}^1V_3$	$^1V_3$	$\{^1V_1 = {}^1V_1;\ ^1V_3 = {}^1V_3;\ ^5V_6 = {}^0V_6;\ ^5V_7 = {}^0V_7\}$	$= n + 1 = 4 + 1 = 5$; by a Variable-card. by a Variable-card.	1	...	$n+1$	...	...	0	0										

My daughter! with thy name this song begun;
My daughter! with thy name thus much shall end;
I see thee not, I hear thee not, but none
Can be so wrapt in thee; thou art the friend
To whom the shadows of far years extend;
Albeit my brow thou never shouldst behold,
My voice shall with thy future visions blend,
And reach into thy heart, when mine is cold,
A token and a tone, even from thy father's mould.

(*Childe Harold's Pilgrimage*, Canto the third, verse 115).

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