Women in Mathematics: A Historical Account of Women's Experiences and Achievements

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Throughout history, women have been looked down upon and seen as insubordinate and incapable. Women were never viewed as equal to men until about the 1950s. It is quite uncommon to hear, see, or read about many women and their additions to the field. History will also tell us that men dominated the mathematical scene and have made the biggest contributions in that field, yet this does not seem to be the case. Women have had just as big an impact on math as men have, if not a bigger contribution. They still continue to change the mathematical world today. Various women such as Hypatia from the ancient Greeks, Maria Gaetana Agnesi from the Modern Enlightenment in Italy, Mary Fairfax Somerville from the Imperialist English, and Grace Chisholm Young from England at the turn of the century have all contributed in major ways to the mathematical community.

Hypatia of Alexandria (370 CE - 415 CE) was a female philosopher and mathematician, born in Alexandria, Egypt possibly in 370 CE. She was the daughter of the mathematician Theon, the last Professor at the University of Alexandria, who tutored her in math, astronomy, and the philosophy of the day which, in modern times, would be considered science (see, e.g., [1]).

Nothing is known of her mother and there is little information about her life. As the scholar Michael A. B. Deakin writes, "The most detailed accounts we have of Hypatia's life are the records of her death. We learn more about her death from the primary sources than we do about any other aspect of her life (see, e.g., [1])."

In a city which was becoming increasingly diverse religiously, Hypatia was a close friend of the Roman prefect Orestes and was blamed by Cyril, the Christian Archbishop of Alexandria, for keeping Orestes from accepting the "true faith." She was also seen as a "stumbling block" to those who would have accepted the "truth" of Christianity were it not for her charisma, charm, and excellence in making difficult mathematical and philosophical concepts understandable to her students, concepts which contradicted the teachings of the relatively new church (see, e.g., [1]).

By all accounts, Hypatia was an extraordinary woman not only for her time, but for any time, and she was a popular public speaker. Michael Deakin cites the ancient historian Damascius describing her public lectures: "Donning the tribon [the robe of a scholar, and thus an essentially masculine item of apparel], the lady made appearances around the center of the city, expounding in public to those willing to listen on Plato or Aristotle or some other philosopher…There was a great crush around the doors [of her house], a confusion of men and horses, of people coming and going and others standing about for Hypatia the philosopher was now going to address them and this was her house (see, e.g., [1])."

Her father, Theon, refused to impose upon his daughter the traditional role assigned to women and raised her as one would have raised a son in the Greek tradition, by teaching her his own trade. Scholar Wendy Slatkin writes, "Greek women of all classes were occupied with the same type of work, mostly centered around the domestic needs of the family. Women cared for young children, nursed the sick, and prepared food (see, e.g., [1]).”

Hypatia, on the other hand, led the life of a respected academic at Alexandria's university, a position to which only males were entitled previously. Deakin points out that she surpassed her well-respected father as evidenced by ancient testimonies to her brilliance. She never married and remained celibate throughout her life, devoting herself to learning and teaching. The ancient writers agreed that she was a woman of enormous intellectual power, even the Christian writers such as John of Nikiu who were hostile toward her. Deakin comments, “[t]he breadth of her interests is most impressive. Within mathematics, she wrote or lectured on astronomy (including its observational aspects - the astrolabe), geometry (and for its day advanced geometry at that) and algebra (again, for its time, difficult algebra), and made an advance in computational technique - all this as well as engaging in religious philosophy and aspiring to a good writing style. Her writings were, as best we can judge, an outgrowth of her teaching in the technical areas of mathematics. In effect, she was continuing a program initiated by her father: a conscious effort to preserve and to elucidate the great mathematical works of the Alexandrian heritage (see, e.g., [3]).”

Devastatingly, Hypatia was murdered in 415 CE by a Christian mob who attacked her on the streets of Alexandria. The primary sources, even those Christian writers who were hostile to her and claimed she was a witch, are generally sympathetic in recording her death as a tragedy. These accounts routinely depict Hypatia as a woman who was widely known for her generosity, love of learning, and expertise in teaching Neo-Platonism, mathematics, science, and philosophy (see, e.g., [3]).

Maria Agnesi (May 16, 1718 – January 9, 1799) was a female mathematician, born in Italy. Maria was the eldest of 21 children. Her father was Pietro Agnesi and because of his wealth he was able to afford her the best tutors in the land. He earned his wealth through silk, but many sources have also said he was a mathematician. Maria did many things, but her most notable accomplishment is known as "the witch of Agnesi (see, e.g., [4])."

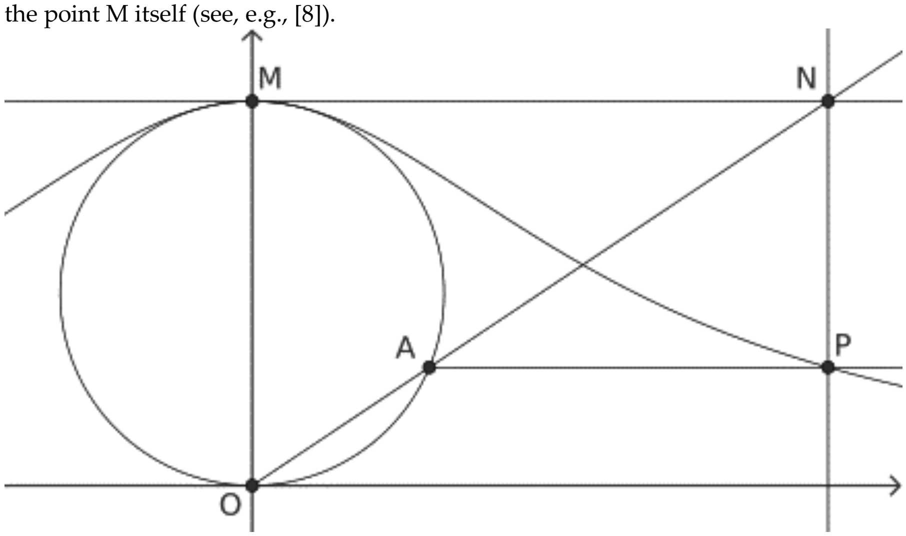
Maria Agnesi was known for being a child prodigy (called the "oracle of the seven tongues”); by the time she was nine years old she knew many different languages and would give performances on her knowledge in a special room of her father's home. She was very shy, but she wanted to please her father, so she continued to show her talent to many others. Due to the time and the fact that she was a female, higher education for women was not practiced, so at the age of nine she published a Latin discourse defending education for women. This was done with the help of one of her tutors (see, e.g., [4]).

When she was twenty, she published "Propositiones Philosophicae" which was a series of essays on philosophy and natural science. These essays would be a topic of discussion many times, and she would defend them with all her knowledge. Her free time was spent studying religious books and learning mathematics. She wrote a commentary that was never published on de L'Hopital's "Traite analytique des section coniques." Another book that she had published was "Instituzioni analitiche ad uso della gioventu italiana” (Analytic Institutions for the Use of Italian Youths). This book was written in Italian, published in her home and was meant to be used as a textbook for her brothers. Her next book, "Instituzioni analitiche ad uso della gioventu italiana," had two volumes and was published in 1748. This brought her much fame (see, e.g., [8]).

Pope Benedict XIV honored her by appointing her to be honorary reader at the University of Bologna; later she was asked to accept the chair of mathematics. No one knows with certainty if she accepted or not, but her name remained on the rolls for many years (see, e.g., [8]).

Another book she wrote "Institutzioni Analitiche" did not have original works from her, but it was full of examples. In this book Maria discussed a cubic curve now known as the "Witch of Agnesi." The name "witch" derives from a mistranslation of the term averisera ("versed sine curve," from the Latin vertere, "to turn") in the original work as avversiera ("witch" or "wife of the devil") in an 1801 translation of the work by Cambridge Lucasian Professor of Mathematics John Colson (see, e.g., [8]).

To construct this curve, start with any two points O and M, and draw a circle with OM as diameter. For any other point A on the circle, let N be the point of intersection of the secant line OA and the tangent line at M. Let P be the point of intersection of a line perpendicular to OM through A, and a line parallel to OM through N. Then P lies on the Witch of Agnesi. The curve consists of all the points P that can be constructed in this way from the same choice of O and M. It includes, as a limiting case, the point M itself (see, e.g., [8]).



Now suppose that point O is at the origin and point M lies on the positive y-axis, and that the circle with diameter OM has radius a. Then the curve constructed from O and M has the Cartesian equation $y = \frac{8a^3}{x^2+4a^2}$. This equation can be simplified, by choosing a = 1/2, to the form $y = \frac{1}{x^2+1}$. In its simplified form, this curve is the graph of the derivative of the arctangent function. The Witch of Agnesi can also be described by parametric equations whose parameter θ is the angle between OM and OA, measured clockwise: $x = 2a\tan\theta$ and $y = 2a\cos^2\theta$ (see, e.g., [8]).

The main properties of this curve can be derived from integral calculus. The area between the curve and its asymptotic line is four times the area of the fixed circle, $4\pi a^2$. The volume of revolution of the Witch of Agnesi about its asymptote is $4\pi^2 a^3$.

This is two times the volume of the torus formed by revolving the defining circle of the witch around the same line (see, e.g., [8]).

The curve has a unique vertex at the point of tangency with its defining circle. That is, this point is the only point where the curvature reaches a local minimum or local maximum. The defining circle of the curve is also its osculating circle at the vertex, the unique circle that "kisses" the curve at that point by sharing the same orientation and curvature. Because this is an osculating circle at the vertex of the curve, it has third-order contact with the curve (see, e.g., [8]).

The curve has two inflection points, at the points $(\frac{2\sqrt{3}a}{3}, \frac{3a}{2})$ and $(\frac{-2\sqrt{3}a}{3}, \frac{3a}{2})$ corresponding to the angles $\theta = 60°$ and $\theta = 120°$. When considered as a curve in the projective plane there is also a third infinite inflection point, at the point where the line at infinity is crossed by the asymptotic line. Because one of its inflection points is infinite, the witch has the minimum possible number of finite real inflection points of any non-singular cubic curve (see, e.g., [8]).

Lastly, the largest area of a rectangle that can be inscribed between the curve and its asymptote is $4a^2$, for a rectangle whose height is the radius of the defining circle and whose width is twice the diameter of the circle (see, e.g., [8]).

Maria's life was not a glorious one. She once asked her father to let her enter the convent, yet he denied her. During the remainder of his life, she did as he wished, but she lived in closed rooms of his house and helped old sick women. When he died, she turned her life over to helping ill and poor women, never wanting to talk of mathematics again. Later she became the director of a facility but turned all the earnings over to the facility. Maria later died in the poorhouse and is buried in a mass grave for the poor with fifteen other bodies (see, e.g., [4]).

Mary Fairfax Somerville (December 26, 1780 – November 29, 1872) was born Mary Fairfax in Jedburgh, Scotland, the fifth of seven children of Vice-Admiral Sir William George Fairfax and Margaret Charters Fairfax. Only two of her brothers survived to adulthood and her father was away at sea, so Mary spent her first years in the small town of Burntisland being home-schooled by her mother. When her father returned from the sea, he discovered 8 or 9 year-old Mary could neither read nor do simple sums. He sent her to an elite boarding school, Miss Primrose's School in Musselburgh (see, e.g., [5]).

Miss Primrose was not a good experience for Mary, and she was sent home in just a year. In addition, she took music and painting lessons and instructions in handwriting and arithmetic. She began to educate herself, learning to read French, Latin, and Greek largely on her own. At age 15, Mary noticed some algebraic formulas used as decoration in a fashion magazine, and on her own, she began to study algebra to make sense of them. She surreptitiously obtained a copy of Euclid's "Elements of Geometry" over her parents' opposition (see, e.g., [5]).

In 1804 Mary Fairfax married (under pressure from family) her cousin, Captain Samuel Greig, a Russian navy officer who lived in London. They had two sons, only one of whom survived to adulthood, future barrister Woronzow Greig. Samuel also opposed Mary's studying mathematics and science, but after his death in 1807 (followed by the death of their son) she found herself with the opportunity and financial resources to pursue her mathematical interests (see, e.g., [5]).

She returned to Scotland with Woronzow and began to study astronomy and mathematics seriously. On the advice of William Wallace, a mathematics teacher at a military college, she acquired a library of books on mathematics. She began solving math problems posed by a mathematics journal, and in 1811 won a medal for a solution she submitted (see, e.g., [6]).

She married Dr. William Somerville in 1812, another cousin. Somerville was the head of the army medical department in London and he warmly supported her study, writing, and contact with scientists (see, e.g., [6]).

Four years after marrying, Mary Somerville and her family moved to London. Their social circle included the leading scientific and literary lights of the day, including Ada Bryon and her mother Maria Edgeworth, George Airy, John and William Herschel, George Peacock, and Charles Babbage. Mary and William had three daughters (Margaret, 1813–1823; Martha, born 1815, and Mary Charlotte, born 1817), and a son who died in infancy. They also traveled extensively in Europe (see, e.g., [6]).

In 1826, Somerville began publishing papers on scientific subjects based on her own research. After 1831, she began writing about the ideas and work of other scientists as well. One book, "The Connection of the Physical Sciences," contained discussion of a hypothetical planet that might be affecting the orbit of Uranus. That prompted John Couch Adams to search for the planet Neptune, for which is he is credited as a co-discoverer, along with Somerville (see, e.g., [5]).

Mary Somerville's translation and expansion of Pierre Laplace's "Celestial Mechanics" in 1831 won her acclaim and success: that same year, British prime minister Robert Peel awarded her a civil pension of 200 pounds annually. In 1833, Somerville and Caroline Herschel were named honorary members of the Royal Astronomical Society, the first time women had earned that recognition. Prime Minister Melbourne increased her salary to 300 pounds in 1837. William Somerville's health deteriorated and in 1838 the couple moved to Naples, Italy. She stayed there for most of the remainder of her life, working and publishing (see, e.g., [5]).

William Somerville died in 1860. In 1869, Mary Somerville published yet another major work, was awarded a gold medal from the Royal Geographical Society, and was elected to the American Philosophical Society (see, e.g., [5]).

By 1871, Mary Somerville had outlived her husbands, a daughter, and all of her sons: she wrote: "Few of my early friends now remain—I am nearly left alone." Mary Somerville died in Naples on November 29, 1872, just before turning 92. She had been working on another mathematical article at the time and regularly read about higher algebra and solved problems each day (see, e.g., [5]).

Her daughter published "Personal Recollections of Mary Somerville" the next year, parts of a work which Mary Somerville had completed most of before her death (see, e.g., [6]).

Grace Chisholm Young (March 15, 1868 – March 29, 1944) was an English mathematician, born in Haslemere, England. She was educated at Girton College, Cambridge, England and continued her studies at Göttingen University in Germany, where in 1895 she became the first woman to receive a doctorate in any field in that country. Her early writings were published under the name of her husband, William Henry Young, and they collaborated on mathematical work throughout their lives (see, e.g., [7]).

For her work on calculus (1914–1916), she was awarded the Gamble Prize. She was the youngest of three surviving children. Grace and her sister were taught at home by their mother and a governess which was customary during that time. Her family encouraged her to become involved in social work by helping the poor in London. She had aspirations of studying medicine, but her family would not allow it. However, Chisholm wanted to continue her studies. She passed the senior examination for entrance into Cambridge University at the age of 17 (see, e.g., [7]).

Later in life Grace had a tutor by the name of William Young, whom she married the year after she received her Ph.D. at Göttingen. Grace and William spent the next 44 years together having six children together in a span of nine years. Chisholm entered Girton in 1889, four years after she passed the senior entrance examination. At the end of their first year, when the Mays list came out, she was top of the Second class right below Isabel Maddison. In 1893, Grace passed her final examinations and scored the equivalent of a first-class degree. She also took the exam for the Final Honours School in mathematics at the University of Oxford on which she out-performed all the Oxford students. However, women were not awarded formal degrees at that time and Chisholm remained at Cambridge for an additional year to complete Part II of the Mathematical Tripos, which was unusual for women at this time. Chisholm was still interested in continuing her studies and since women were not yet admitted to graduate schools in England, she went to the University of Göttingen in Germany to study with Felix Klein. This was one of the major mathematical centers in the world. The decision to admit her had to be approved by the Berlin Ministry of Culture (see, e.g., [7]).

In 1895, at the age of 27, Grace became the first woman to attain a doctorate in any field in Germany. Again, government approval had to be obtained to allow her to take the examination, which consisted of probing questions by several professors on sections such as geometry, differential equations, physics, astronomy, and abstract algebra, all in German. Along with her test, she was required to take courses showing broader knowledge as well as prepare a thesis which was entitled "Algebraisch-gruppentheoretische Untersuchungen zur sphärischen Trigonometrie" (Algebraic Groups of Spherical Trigonometry.) Grace and William had six children together in a span of nine years; most of their children went on to become mathematicians. In addition to her career as a pioneering woman in what was then a discipline with significant barriers against entry, Grace completed all the requirements for a medical degree except the internship (see, e.g., [7]).

She also learned six languages and taught each of her children a musical instrument. With the approach of World War II, Grace left Switzerland in 1940 to take two of her grandchildren to England. Grace was to return immediately, but because of the fall of France, she could not. In 1944, Grace passed away. Of their six children, three continued on to study mathematics, one daughter became a physician, and one son pursued a career in finance and business. One of Grace's fourteen grandchildren, Sylvia Wiegand, is a mathematician at the University of Nebraska and is a past president of the Association for Women in Mathematics (see, e.g., [7]).

In 1991 the Mathematical Association of America published a book titled *Winning Women Into Mathematics*. The beginning of the book starts off with a list of goals for the 1990s set by the Committee of Participation of Women. It is interesting to look at the goals set up in the 1990s and compare them with the progress that has been made since then. The goals were listed as follows (see, e.g., [2]):

- Increase public appreciation of the role of women in mathematics, their achievements and problems
- Increase public awareness, especially among parents, teachers, and counselors, of the advantages of mathematics-related careers for women
- Increase the national commitment to supporting mathematical education for girls and women
- Increase the number, not just the percentage, of American women earning a Ph.D. in the mathematical sciences, and of those Women in Mathematics [increase those] achieving advanced academic ranks and other high-prestige positions
- Increase the number of women mathematical professionals of all types
- Increase the percentage of women among MAA members, officers, editors, authors, committee members, and presenters of both invited talks and contributed papers
- Increase support services for minority women and others with special needs
- Decrease both macro- and micro-inequities that women experience
- Investigate the special challenges women face and explore their solutions
- Make more information available for those wanting to help women fulfill their potential in mathematics.

Along with the incredible work provided by Hypatia, Maria, Mary and Grace, there have been incredible strides taken when it comes to the conditions for women in the mathematics field. However, while all of the goals listed by the Committee of Participation of Women have been addressed at some point, none of them have been completely achieved. This list of goals is still very pertinent to the situation for women in the mathematics field today. Whether it has to do with having children or just simply empowering women to rise above the stereotypes, all the articles and books that have been read agree that although much progress has been made, there is still a long way to go to reach equality for women in the field of mathematics.

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Bibliography

[1] Dzielska, M., & Lyra, F. (1996). *Hypatia of Alexandria (Revealing Antiquity)* (Reprint ed.).
Harvard University Press.

[2] Kenschaft, Patricia C., and Sandra Z. Keith, eds. (1991). *Winning Women Into Mathematics*.
Washington, D.C.: Mathematical Association of America.

[3] Koch, Laura C. (1998). Hypatia. *Notable Women in Mathematics: A Biographical Dictionary*. Ed. Charlene Morrow and Teri Perl. Westport, CT: Greenwood. 94-97.

[4] Morrow, C., & Perl, T. (1998). *Notable Women in Mathematics: A Biographical Dictionary*.
Greenwood.

[5] Neeley, K. A. (2001). *Mary Somerville: Science, Illumination, and the Female Mind (Cambridge Science Biographies)* (1st Edition). Cambridge University Press.

[6] Patterson, E. C. (1876). Personal recollections, from early life to old age, of Mary Somerville. With selections from her correspondence. By her daughter, Martha Somerville. by Michigan Historical Reprint Series (2005-12-21). Scholarly Publishing Office, University of Michigan Library.

[7] Slatkin, W. (2000). *Women Artists in History: From Antiquity to the Present* (4th ed.). Pearson.

[8] Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype Threat and Women's Math
Performance. *Journal of Experimental Social Psychology*, 35(1), 4–28.