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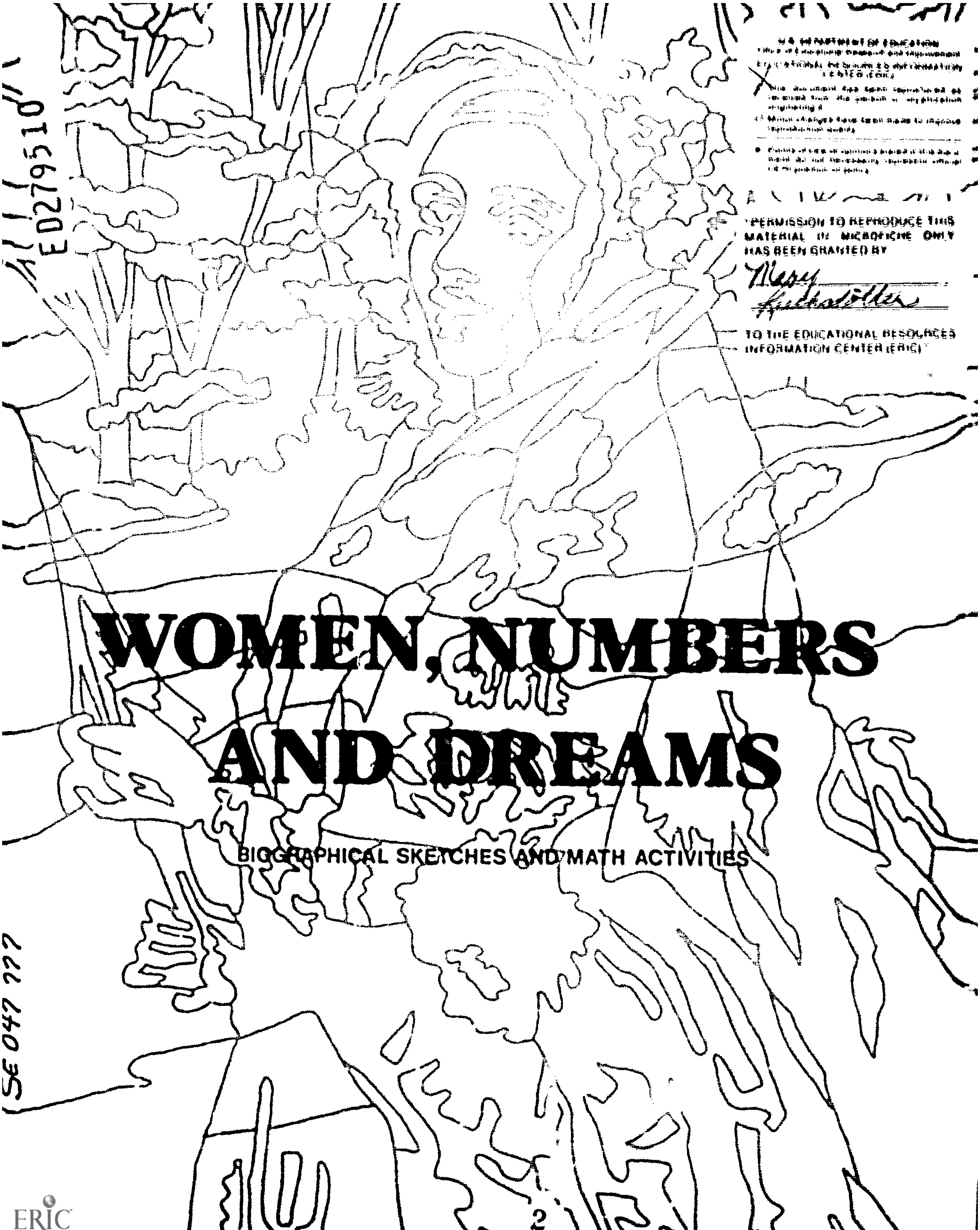
ABSTRACT

This booklet was written to provide role models for young people. Included are stories of 13 interesting women who have worked in careers that require substantial training in mathematics, with the hope of encouraging students to aspire to careers in fields using mathematics. Both contemporary and noncontemporary women are included to provide contrast between situations faced by women today and in the past. Mathematics activities are included to show that mathematics is far more than the arithmetic learned in elementary schools. Elementary number theory concepts such as prime numbers, triangular numbers, and common multiples are reinforced in mathematics shade-ins, where a picture is tied to the story. Role play is also incorporated. Biographical stories are given for Mary Somerville, Ada Lovelace, Sonya Kovalevskaya, Mary Boole, Emmy Noether, Lenore Blum, Evelyn Boyd Granville, Fanya Montalvo, Edna Paisano, Grace Yang, and three computer consultants from Wisconsin. (MNS)



WOMEN, NUMBERS AND DREAMS

BIOGRAPHICAL SKETCHES AND MATH ACTIVITIES

WOMEN, NUMBERS AND DREAMS

BIOGRAPHICAL SKETCHES AND MATH ACTIVITIES

Teri Hoch Perl   Joan M. Manning

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The reader is permitted and encouraged to make photocopies of the math activities.

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Women, Numbers and Dreams

Preface

This is the last quarter of the twentieth century, and most women expect to work the greater part of their adult lives. We want to share the stories of a group of women whose work has been very important to them. Some of these women lived long before you were born. Like you, they are from different backgrounds.

To all of them, their work has been rewarding in many ways. They work on interesting problems. They are proud of the results of their work. Among the contemporary women, good salaries allow them independence. These women are the lucky ones.

In the last chapter, you will read about a conference to inspire young women to join these lucky ones. It is a true story, as are all the other stories in this book.

Young women growing up now can become whatever their talents and dreams allow. Become one of the lucky ones. Dream big and keep your options wide open.

MARY SOMERVILLE

SHADE ALL MULTIPLES OF 9

All multiples of 9 have a digital sum of 9. See page 55 for details on how to find the digital sum of any number.

MARY SOMERVILLE
1780-1872

Mary Somerville was born in Burntisland, a small village on the northern seacoast of Scotland. As a child she loved to roam out-of-doors. She had only to step through an opening at the end of her garden and she was on the shore.

"When the tide was out," she wrote, "I spent hours on the sands, looking at the star-fish and sea-urchins, or watching the children digging for sand-eels, cockels, and the spouting razorfish. . . I knew the eggs of many birds, and made a collection of them. I never robbed a nest, but bought strings of eggs, which were sold by boys. . . I also watched the crabs, live shells, jellyfish, and various marine animals, all of which were objects of curiosity and amusement to me in my lonely life."

Mary's father was an Admiral in the English Navy. When Mary was about ten years old he came home after a long voyage. He noticed how wild Mary had become from her constant outdoor explorations and insisted she be sent off to a boarding school. Mary spent one year at Miss Primrose's boarding school.

Miss Primrose's School

Away from the wild Scottish coast, Mary was desperately unhappy. She was befriended by some older girls who flushed her eyes with water in order to hide the tears that were almost constantly running down her face.

At school she learned reading, writing, French and English grammar. The method of teaching was mostly memorizing: for instance, Mary had to memorize an entire page of Samuel Johnson's famous dictionary, giving the spelling, pronunciation and definition of each word in order. Poor Mary! She had no memory for subjects which did not interest her.

Add to this the costume she had to wear during her lessons, a steel busk or framework fitted around her chest under her gown. Another steel piece attached to this busk fitted over her shoulders, drawing them back so far her shoulder blades touched in back. A third metal piece fitted in a semicircle under her chin. In this suit of armor she had to learn her lessons, as did all the younger girls in the school. This was supposed to keep them from slouching!

Mary never did adjust to life at the school, and at the year's end she returned home still writing and spelling poorly. She wrote to her older brother who was at school at Edinburgh and asked him to buy her something with the "bank-knot" she sent.

Later, when Mary was thirteen, she lived for a winter in Edinburgh which was a nearby large city. There she went to a day school to study writing and arithmetic. Finally she learned to write "a fair hand" and found that she liked arithmetic.

Home Life

Learning something new always interested her. But before she could follow the studies she grew to love she had some hard times at home. Whenever she gave her opinion on a subject she was "instantly silenced, although (she wrote) I often knew, and could have proved, that I was in the right." Mary was timid and hesitated to speak up. These shy feelings never left her though they were much less strong when she was old and famous.

Her relatives disapproved of her when she was a teenager because she read so much. Her father said, "We must put a stop to this, or we shall have Mary in a strait jacket one of these days. There was X., (another girl) who went raving mad about the longitude!"

It was commonly believed that girls and women could go mad if they exercised their minds too much. It was also believed, even by doctors, that too much study would affect the ability of women to bear children.

That was one area, though, in which Mary was "determined and inflexible"--the pursuit of her studies. Bit by bit she learned French, Latin and Greek. The subjects that fascinated her most were the ones that grew out of her love of nature. She had always had a keen eye for observing fish, birds, plants and the night sky.

Using a small globe that showed the constellations, Mary studied the skies from north- and south-facing windows in her attic bedroom. Later, from reading a book on navigation, she learned that astronomy was not just star-gazing, and that to make progress she would need to know higher mathematics to chart the constellations.

Puzzles and Clues

One day a friend of Mary's showed her a needlework pattern in a "ladies magazine." As the friend leafed through the pages, Mary's eyes were drawn to a number puzzle, but included with the numbers were the letters x and y.

Mary said to her friend, "What do these letters mean?"

Her friend replied, "Oh, it is a kind of arithmetic. They call it Algebra, but I can tell you nothing about it."

Her friend had no information but Mary had at least the name of the mysterious subject—algebra. Later, when she was taking lessons in landscape painting (painting and needlework were considered acceptable subjects for girls to study), she heard her teacher talking to some of her classmates. He said, "You should study Euclid's *Elements of Geometry*, the foundation not only of perspective, but of astronomy and all mechanical science."

Another clue! Now she knew what books to ask for: books on algebra and geometry. About that time a tutor was hired for Mary's younger brother. This kind person agreed to buy the books Mary so desperately wanted and he did it on his very next trip to Edinburgh.

"Now," said Mary, "I had got what I had so long and earnestly desired.

"Before I began to read algebra I found it necessary to study arithmetic again, having forgotten much of it. I never was expert at addition, for, in summing up a long column of pounds, shillings, and pence in the family account book, it seldom came out twice the same way."

Reading Euclid's work on geometry was consigned to the nighttime, after the rest of the family and servants went to bed. The servants discovered that the candle supply was practically used up by Mary's nightly reading habit. Mary's mother told them to take away all her candles at bedtime.

Mary wrote, "I had, however, already gone through the first six books of Euclid, and now I was thrown on my memory which I exercised by beginning at the first book and demonstrating in my mind a certain number of problems every night, till I could nearly go through the whole."

Accomplishments

Studying mathematics was not the only thing Mary did. She spent hours every day at household chores and made and mended all her clothes, even her ball gowns.

About this time Mary and her mother went to Edinburgh to spend the winters. Here Mary paid many social calls and went to dances, where everybody danced reels and other country dances. Young ladies were somewhat free at that time in Edinburgh and it was the custom for gentlemen to carry them to dances in sedan chairs. Mary was permitted to be transported by gentlemen her mother knew. Mary loved dancing and was never without partners. She often came home from a dance in bright daylight.

Mary had a small and delicate face and figure and wore becoming and fashionable gowns. She was very fresh looking and was called "The Rose of Jedburgh," Jedburgh being the name of the town where Mary stayed with relatives.

As always Mary loved to read, so much so that one day Mary's aunt, who lived with the family, said to her mother, "I wonder you let Mary waste her time in reading. She never sews more than if she were a man."

Mary disagreed. She wrote, "I was annoyed that my turn for reading was so much disapproved of, and thought it unjust that women should have been given a desire for knowledge if it were wrong to acquire it."

Mary loved music too and practiced the piano hours each day. However, when her family obliged her to perform in front of company, her shyness returned and she played badly. Mary hated to do poorly.

As a landscape painter she was accomplished and her work was passed around to friends of the family who encouraged her. Though Mary did not seriously consider a career as a painter she was, she wrote, "intensely ambitious to excel in something, for I felt in my own breast that women were capable of taking a higher place in creation than that assigned to them in my early days, which was very low."

Marriage

When Mary was twenty-four she married. Her husband was a distant cousin of hers named Samuel Greig and he was Consul to Russia. Before consenting to the marriage, Mary's father insisted upon knowing that Mary would never have to live in Russia. There, stormy politics made life for foreigners dangerous, for in this year, 1804, Napoleon had declared himself Emperor and was leading his troops to battle with the Austrians and Russians.

Mary, who had grown up in a small Scottish village on the northern seacoast, moved with her husband to London where the Russian consulate was located.

Her husband did not forbid Mary to study but he had no good words for her occupation. Like most other people, he thought that educating women and girls was foolish and useless.

During the next three years, two sons were born to the couple. Then, suddenly, Samuel Greig died. In those days illness often carried off people very suddenly. There were no drugs or innoculations against diseases such as cholera, pneumonia or influenza.

Widowhood

Mary moved with her babies back to her parents' house. At twenty-seven she was a widow. There was one thing she could do--throw herself into her beloved studies.

For the first time in her life she did not have to meet with anyone's approval, for she was now independent. She resumed her old schedule of early morning and late evening study. She devoted the days to her children.

A Career

At this time there were "ladies magazines" that contained sewing and needlework patterns and recipes just as the "Ladies Home Journal" and "Woman's Day" do today. "The Ladies' Diary," for instance, was a magazine that was published for well over 100 years in England during Mary's lifetime.

Magazines and journals then had one major difference. They contained problems and puzzles in mathematics. Mathematics was something new to ordinary people who were not educated, and women were interested in the subject equally with men. It was not thought that mathematics was "over the head" of women.

Mary began to work on problems given in one such journal. She sent her solutions to the editor, Mr. Wallace. He was impressed with them and he sent back his own solutions.

"Mine were sometimes right and sometimes wrong," she wrote, "and it occasionally happened that we solved the same problem by different methods."

Finally Mary solved a problem in algebra and won a prize. It was a silver medal with her name on it. She was very pleased.

This same Mr. Wallace became Professor of Mathematics at the University of Edinburgh. Mary told him she wanted to learn "the highest branches of mathematical and astronomical science" and he gave her a list of books which were written in French, Latin, and English. The list included books on algebra, physics, calculus, geometry, astronomy, logorithms and probability theory.

"I was thirty-three years of age when I bought this excellent little library," she said of herself. "I could hardly believe that I possessed such a treasure when I looked back on the day that I first saw the mysterious word 'Algebra', and the long course of years in which I had persevered almost without hope. It taught me never to despair."

A Proposal

Mary received several offers of marriage. One offer, sent in writing as was the custom, listed the duties of a wife in such a narrow-minded way that Mary tossed it right away. She was no longer a child and she knew what she wanted.

After a time a cousin named William Somerville proposed marriage and Mary gladly accepted. He and Mary were married for sixty years and they were very happy together.

William, whom Mary always called "Somerville" in her writings, was very proud of Mary's growing skill as a mathematician. He searched out books at libraries for her. Since he was very interested in the correct use of language, he re-copied her manuscripts before they were sent to the printer in order to correct any errors in spelling, punctuation and grammar. He was not jealous of her fame or her mental brilliance. He was, Mary wrote many years later, one in ten thousand.

The First Book

Lord Henry Brougham, a publisher, realized that an English translation was needed of a new and important work on astronomy, written in French. He asked Mary to do the work. Because she had never studied at a university and had taught herself, she doubted her own ability.

She told her husband and Lord Brougham, "You must be aware that the work in question never can be popularized, since the student must at least know something of the differential and integral calculi, and as a preliminary step I should have to prove various problems in physical mechanics and astronomy. Besides, La Place (the author) never gives diagrams or figures, because they are not necessary to persons versed in the Calculus, but they would be indispensable in a work such as you wish me to write. I am afraid I am incapable of such a task, but as you both wish it so much, I shall do my very best upon condition of secrecy, and that if I fail the manuscript shall be put into the fire."

She did not fail and her first book, *The Mechanism of the Heavens*, was published in 1831. In the work Mary published her own solutions to difficult problems set by La Place. She gave clear accounts of experiments and gave examples. She wrote an introduction which was suitable for the ordinary reader.

The book was an instant success. It was used as a textbook for students at Cambridge University which was the center for the study of mathematics in England.

Professor Peacock, a mathematician from Cambridge, wrote to Mary, "I consider it to be a work of the greatest value and importance . . . which will contribute greatly to . . . the knowledge of physical astronomy."

After this she published three more books: *The Connection of the Physical Sciences*, *Physical Geography* and *Molecular and Microscopic Science*. Mary had discovered her niche--spreading knowledge about her beloved subjects. Her books were used by mathematicians, scientists and students. They sold well and were important in popularizing science.

This was a time when science was becoming a great influence upon the lives of ordinary people and many people were excited and curious about it.

Fame

Mary received many honors, honorary degrees, and medals. A statue of her was placed in the Hall of the Royal Society in London. In 1834, The Royal Astronomical Society named her and Caroline Herschel as its first honorary female members. A new sailing ship was called the "Mary Somerville" and a copy of her statue was placed on the ship's prow as a figurehead.

Because Mary was a woman working in a field where almost no women were to be found, she was especially famous. Since she successfully combined marriage, family, femininity and a scientific career, she helped the cause of other women interested in mathematics and science. She accomplished this at a time when women were not even admitted to universities.

As she grew older she continued to be very energetic. She packed every day with activity. As long as she lived she rose early, studied until early afternoon, then put her books away. From then on she took care of her household and went out to visit friends. Of course she, like everyone of her social class, had servants to make this schedule possible.

Family Life

She and William became interested in minerals. They invested their money in gems such as rubies, sapphires, topaz and amethysts. In the evenings they liked to take their collection out of the cabinet and arrange the gems or just admire them.

Mary had three daughters. The oldest, a child of unusual talent, died and Mary grieved for a long time. The two surviving daughters, Mary and Martha, never married but stayed in their parents' household.

In the 1840's when Mary was in her sixties the family moved to Italy. William was ill and the doctors advised a warmer climate. Woronzow Greig, Mary's son by her first marriage, continued to live in England with his own family. Mary and Woronzow were very close; they often visited and wrote letters back and forth. Woronzow handled Mary's legal and publishing affairs.

As her career progressed, Mary turned from mathematics to science. She later regretted this decision since she believed her greatest gifts were in mathematics.

A Pet

All her life Mary loved birds, especially songbirds. A mountain sparrow was her pet for eight years and when Mary sat in bed in the morning, writing and reading, the bird would fly in and perch on her arm.

She had a horror of killing animals, either by hunting or by vivisection--even for scientific experiment. After she grew up she petitioned the lawmakers of England and Italy to outlaw these practices, which she believed were cruel. When Mary was a very old woman she wrote that she believed that God, in his great mercy, would provide an everlasting home for the helpless animals, as well as for human souls.

Old Age

Mary Somerville lived to be 92 years of age. By that time few of her friends remained alive.

"I am nearly left alone," she wrote. Indeed, her beloved husband and son had died before her.

Her daughter Martha published her memoirs a couple of years after her death. Martha wrote that Mary worked up to the very day she died. She was quite deaf but her eyes were good until the end--so good that she could pick out the threads of her needlework canvas without using glasses.

Mary's great happiness was that she never lost the power of her mind nor her memory. Even in her nineties, she could work difficult problems in algebra with the same joy and determination she knew as a young girl.

MULTIPLES OF 3 AND 5

Numbers that are common multiples of 3 and 5 are numbers that are multiples of 3, and at the same time are multiples of 5.

The last digit of all numbers that are multiples of 5 is either five or zero. Any number that ends in anything but five or zero fails that test.

All numbers that are multiples of 3 leave no remainder when divided by 3, and have a digital sum that is 3 or 6 or 9. The digital sum test is easy to do.

See page 95 for details.

All numbers that pass both tests are common multiples of 3 and 5.

Shade these common multiples and you will see Mary on her way to the Ball.

Mary's System

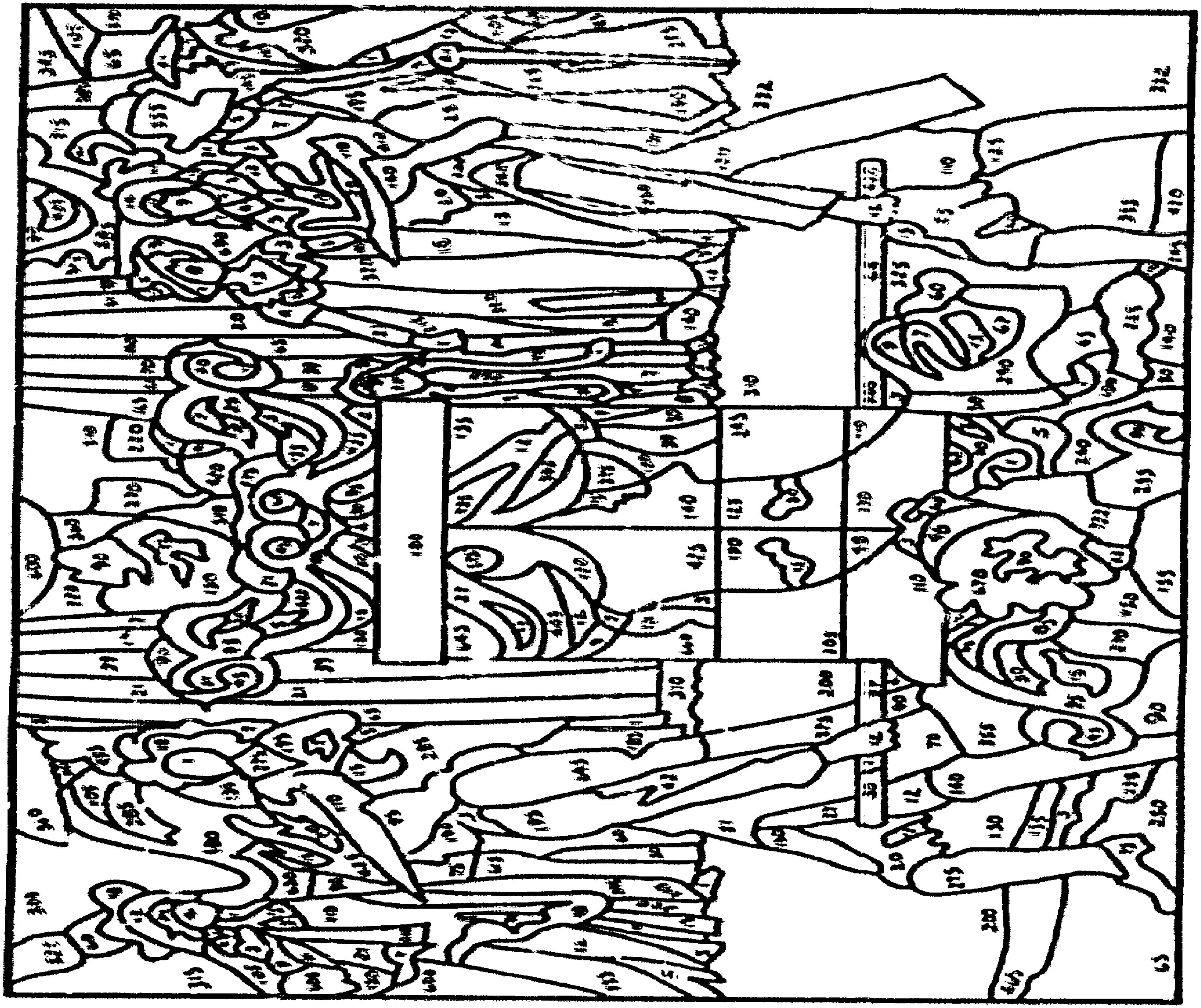
Mary Somerville used a system in her work that would be useful today. If she couldn't find the key to unlock a difficult problem she stopped working and turned instead to the piano, her needlework, or a walk out-of-doors. Afterward, she returned to the problem with her mind refreshed and could find the solution.

If she could not understand a passage in her reading, she would read on for several pages. Then, going back, she could often understand what was meant in the part which before had been confusing.

When she was trying to master geometry she worked out problems mentally at night in bed, beginning with the simplest problems and proceeding to more complex ones.

Her success as a mathematician may have depended in part upon these basic habits.

'ON THE WAY TO THE BALL'--SHADE ALL COMMON MULTIPLES OF 3 AND 5



Ada Lovelace **Shade all Triangular Numbers**

ADA LOVELACE
1815-1852

Pussy cat, pussy cat, where have you been?
I've been to London to look at the queen.
Pussy cat, pussy cat, what did you there?
I frightened a little mouse under her chair . . .

Whether timid as a little mouse or courageous as a lion, only Ada, in her 17-year-old heart knew, for she had learned to keep the feelings in her heart secret. Her mother called her "the young Lioness" when she was presented to the queen in the London season of 1833.

Ada was on the brink of entering the grown-up world, for she was meeting King William IV and Queen Adelaide at the Court of St. James. Her full name was Augusta Ada Byron, and she was thrilled with the splendor of the company and of the Palace itself. She had attended few parties in the past but in the winter of 1833, she went to many balls and dinners. This was her "coming out" season.

At these gatherings, for the first time in her life, she met many important and famous people. Many of them were not only famous, but they were intelligent, accomplished and witty. Ada yearned to be part of their group.

Lord Byron, Her Father

In a way you could say that Ada had been born into such a group. Her father, George Gordon, Lord Byron, was a poet who was known and loved throughout the world.

Lord Byron had come to London when he was a young man. He became known in society quickly because of his poetry, which made fun of the great literature and writers of his day. He was also talked about in social gatherings because he was a handsome man, and because he had affairs with many rich and beautiful women.

Besides being a playboy, Byron wrote biting criticisms of the weaknesses of English society. He attacked corrupt politicians and their lies. He stood up for factory workers when they rioted because of terrible working conditions.

Byron flirted, threw away his money, traveled all over the Continent and had many adventures. Finally, one day, home from his travels and attending still another party, he met an attractive, very proper young English woman named Annabella Milbanke.

This young woman had been brought up in a comfortable upperclass English country home. She believed in values such as duty, obedience and good works. She was a gifted student of mathematics and literature and she had read Byron's poems.

Unlikely as it seems, these two people fell in love. They married, but they did not "settle down." They moved about from place to place. Lord Byron treated Annabella very cruelly at times and made it clear that he was sorry he had married her. She, in turn, prayed for his soul, and pointed out his problems in long-winded speeches.

One year was all the marriage lasted. A week after the birth of their daughter, Ada, husband and wife separated forever.

Lady Annabella went to her parents' home with Ada; Lord Byron stormed away to Italy.

Ada! sole daughter of my house and heart?
When last I saw thy young blue eyes they smiled
. . . when we parted,--not as now we part
But with a hope . . .

Byron wrote this poem about Ada when she was one year old. It expressed his longing to see her but his wish was never fulfilled. Byron died in Greece, fighting in a war for Greek freedom from the Turks.

"The Separation," as everyone in English society called it, was gossipped about for many years. Lady Byron kept most of the gossip from reaching Ada's ears as Ada grew up. But though everything was "hush-hush," the young girl felt something. When the news of her father's death reached the family, when Ada was eight years old, she cried.

Ada was caught between the two extreme types of her parents' personalities. This conflict took its toll. Although as a child she had been described as cheerful and robust, she suffered a kind of nervous attack when she was eight years old--perhaps migraine--which is brought on by stress. Again, in her mid-teens, an attack had frightening consequences. Her legs became paralyzed, and it was nearly a year before she could move about normally.

Ambition

Ada overcame these illnesses and actually went on to became active in gymnastics, dancing and her great love--horseback riding. Her letters show her to be a high-spirited person despite being constantly surrounded by her mother's advisors, who were all given to preaching at the teenage girl about almost everything.

Ada had outstanding mental gifts. She loved music and was a promising and versatile musician: she played harp, violin and piano. She enjoyed mathematics and loved mechanical things. When she was eight and nine years old, she constructed and played with toy ships and boats.

Her mathematical interests persisted. When she was seventeen and studying algebra and astronomy, which she had mostly taught herself, she wrote playfully to a friend, "So this you see is commencement of 'A Sentimental Mathematical Correspondence between two Young Ladies of Rank' to be hereinafter published no doubt for the edification of womankind . . . Ever Yours Mathematically."

During her "coming out" season in London, Ada was looking for others to share her great love for mathematics, music, and riding, and anything else that was interesting and new. Most of all, she wished to meet the famous Mrs. Somerville. Mary Somerville was at this time living in London. She had just published *The Mechanism of the Heavens* on mathematical astronomy. This book was being read with fascination by the educated people of the day. Ada dreamed of becoming a famous mathematician like Mrs. Somerville.

Babbage and the Difference Engine

One of the brightest stars of the London scene was Charles Babbage, an inventor who had studied at Cambridge University. Babbage traveled widely and involved himself in many scientific projects. He loved to see and be seen at the best parties and balls. At one of these, Ada was introduced to him. She was delighted. He invited Ada along with her mother to see his pet project, an early computer.

This computer project, in fact, obsessed him. He called it the Difference Engine and it had many moving parts. This machine would be able to produce, with awesome speed and accuracy, tables for astronomers and navigators to use. Up to this point, these tables could only be computed tediously by people who multiplied and divided huge amounts of numbers. Their accuracy, of course, was limited. The Difference Engine added numbers instead of multiplying them, and the most powerful thing about the machine was that it could add heaps of numbers extremely quickly and accurately. The tables which were computed by the Difference Engine were badly needed, because shipping was England's leading industry. So Babbage received two grants of money from the government to build his machine.

Although Babbage was a genius, he was not a very good manager. When the money ran out the workmen whose skills he needed to produce all the Engine's precision parts quit for lack of wages. The project was never completed.

When Ada saw the Difference Engine she was enthralled. The evening after Babbage's demonstration to her and her mother, Ada went to the Queen's Ball and again conversed with Babbage. Thus began a professional tie and a friendship which lasted throughout her life.

Ada wanted to work with Babbage and began studying differential equations so that, as she wrote to him, "at some future time . . . my head may be made by you subservient to some of your purposes and plans." But it was to be some time before she would begin working with Babbage.

Meanwhile, Ada wrote about her work to another well-known mathematician, Augustus DeMorgan. DeMorgan was a kind of tutor to her.

One time he wrote to Ada's mother, Lady Byron:

> *I feel bound to tell you that . . . (Ada's) power of thinking on these matters . . . has been something so utterly out of the common way for any beginner, man or woman (that) . . . Had any young beginner, about to go to Cambridge, shown the same power, I should have prophesied (that he would become) . . . an original mathematical investigator, perhaps of first-rate eminence.*

Romance

Finally, Ada was able to meet her heroine, Mrs. Somerville. The older woman became very fond of Ada. Ada was invited to attend concerts and plays and even to stay overnight with the Somervilles. Woronzow Greig, Mrs. Somerville's son by her first marriage, and her two daughters, Martha and Mary, made up their group.

One day a Cambridge friend of Woronzow's, whose name was Lord William King, came to call.

At this time Ada was a lively young woman who looked like her handsome father. She had "large, expressive eyes and dark curling hair."

Lord King fell in love with Ada and she with him. They became engaged to be married. Eleven years older than Ada, and of a serious nature, he wrote love letters that were full of tender feeling. Long engagements were not in style and the two were quickly married. Ada was nineteen years old and her husband was thirty.

Home and Family

Their first child, Byron, was born a year later. The following year a daughter, Annabelle, was born, and soon after, a third child, Ralph, came into the world. From then on, Ada's health was never good for long. The symptoms of mystifying illness that she had shown as a young girl--symptoms that were beyond the skill and understanding of the doctors of her day--now showed up again. She had digestive trouble and developed kidney disease as well as heart t[illegible]uble and asthma. Between these attacks, however, Ada felt optimistic and contin[illegible] search for ways to pursue her mathematics career.

As a home mana[illegible] [illegible]da was not successful. She loved her children, but hated the interruptions they caused in her work. Although she and her husband were aristocrats, and much of the time they kept servants, tutors, and governesses, they were not wealthy, and sometimes day-to-day duties fell to Ada. So eager was she to rid herself of these domestic chores and make time for her mathematical work that she begged her mother, who was always ready to take over, to take the children off her hands.

Three years after their marriage, Lord King inherited another title. He became Earl of Lovelace and Ada became the Countess of Lovelace. Although this title brought them no more money, Lord Lovelace was given a place in the House of Lords in Parliament.

The Analytical Engine

Babbage was working on plans for a far more complex machine which he called the Analytical Engine. Indeed, the large-scale electronic digital computers of our own century copy the logical structure of Babbage's Analytical Engine, which he thought up in the 1830's.

Ada's enthusiasm for this computer matched Babbage's. Another admirer of Babbage's, L. F. Menabrea, wrote an article in French describing the Analytical Engine and its principles of operation. Since Babbage had not written about his machine, this work filled a real need. Ada translated Menabrea's article into English and, in the process, expanded the contents in important ways. Her notes, three times the length of the original article, set down in concrete terms the powers and limitations of the machine.

A Published Work

The work was published, and Babbage proudly distributed copies to the leading scientists of the time. He was tremendously impressed with Ada's paper, and asked her why she had not written a separate original article on the subject. She replied that the thought had not occurred to her. To do such a thing seemed out of the question. In fact, even signing her own work brought her great anxiety.

Although her paper was clearly the work of an expert, it was also the work of a woman and a woman of rank at that. For such a woman to publish a scientific article was highly unusual. It was even more unusual when the area in question was such an "unfeminine" one as mathematical computation. After much indecision, Ada signed her paper "A.A.L.", using her initials only. It was many years before the author's identity was commonly known.

Babbage proposed using punched cards for putting data into the Analytical Engine. This was similar to the clever method invented by J. M. Jacquard, who used punched cards to control the sequence of threads in a loom in order to weave fabulous fabric designs.

Ada saw an equal beauty in the Analytical Engine, and she wrote: "We may see most aptly that the Analytical Engine weaves algebraical patterns just as the Jacquard loom weaves flowers and leaves."

Ada's paper provided the public with the best account of the machine, an account which Babbage saw was far clearer than he himself could possibly have done. As it turned out, this paper was the summit of Ada's career. No one knew why she never went on. Her health was bad, and somehow she could not focus her attention on intellectual problems.

Musical Ambitions

She wrote to Woronzow Greig: "I am not dropping the thread of science, Mathematics, etc. These may still be my ultimate vocation... Although it is likely to have a formidable rival ... musical composition."

Ada was a promising musician. In her paper on the Analytical Engine, she suggested that the computer might be used to compose music, "if," she wrote, "the fundamental relations of pitched sounds in the science of harmony and musical composition were susceptible of sufficiently precise formulation."

Ada predicted computer music a whole century before it was actually produced!

Health and Money Troubles

But she was really not well enough to work at either music or mathematics. She wrote to Woronzow:

There is in my nervous system such a want of all ballast and steadiness. . . And I am just the person to drop off some fin· day when nobody . . . expects it. . . Do not fancy me ill. I am apparently very well at present. But there are seeds of destruction within me. This I know.

Ada swung between feelings of doom and exuberant joy and optimism. Her husband was different. The life of this ordinary mortal was wrapped up in the management of his estates. Developing and maintaining them was an expensive matter, and Lord Lovelace was not generous with money for other things.

He gave Ada 300 pounds yearly (or what would today be $840). This amount was part of her marriage settlement, a substantial 16,000 pounds (about $45,000). The entire sum was placed in a trust for her and would come into her hands only upon the death of her mother, Lady Byron. A much larger fortune, the bulk of her mother's large estate, would go directly to her husband, Lord Lovelace, according to the inheritance laws of the time.

As the only child of a very rich woman, Ada resented the small amount she was expected to live on. Her husband, she pointed out, would receive 7000 pounds per year--a sum, she wrote, "he is to enjoy to my exclusion!" Ada, it turned out, had reason to be concerned about money.

Playing the Horses

Perhaps Ada's greatest love was horses. When she was seventeen, she tried to avoid going on a vacation to Brighton resort because she had just got a new horse named "Sylph," and she so much wanted to ride instead. Lord King was an excellent rider, and the two of them loved to ride together.

Ada's passion for horses was now combined with another passion--gambling. Ada was a compulsive gambler; she could not quit once she started. She began to bet larger and larger amounts of money on horse races. She lost heavily. Part of the problem was her pride in her mathematical genius. She kept working on new formulas to help her figure the odds and pick a winner. It was common gossip that she and Babbage were fellow conspirators in choosing horses to bet on.

Since Ada had no control over the family purse strings and her husband did not approve of her large-scale gambling, Ada turned to "shady" money lenders to help meet her debts. These people blackmailed her, probably with the threat of telling her mother--her do-good, sin-hating mother.

Desperate for money, Ada pawned the family diamonds--not once but twice. Yet the debts kept piling up.

Tragedy's Path

Bad luck seemed to attract more bad luck, and Ada's illnesses returned with renewed force. She began to bleed internally. A tumor was found in her uterus. Cancer! And the doctors of the day knew of no cure.

Ada was crushed though she did not give up hope. Between bouts of intense pain, her spirit showed itself again and again. She had her bed moved near her beloved piano, and each day she played. Sometimes she played duets with Annabelle, her daughter, who was now fifteen years old.

Ada's mother moved into the Lovelace home, and from that time onward, visitors were not permitted to see Ada. Now, Ada could not leave her bed. Babbage in particular was kept away. Ada's mother felt bitter that it was his maid who had carried Ada's bets to the bookmakers.

Ada herself never lost her affection for Babbage. Lord Lovelace wrote in his journal eleven months before her death: "Babbage was a constant intellectual companion and she ever found in him a match for her powerful understanding, their constant philosophical discussions begetting only an increased esteem and mutual liking."

The Final Resolution

Now, of course, Lady Byron knew all. Ada's gambling losses could no longer be kept secret. Lady Byron paid out 5000 pounds ($14,000) to cover her daughter's losses.

Daily, Lord Lovelace struggled with his grief and with Ada's creditors, who came for their money--to the house where she lay dying. Ada's agony stretched out for nearly four months while her helpless family waited. Finally, two weeks before her 37th birthday, Ada died.

"By her own wish," a descendant wrote, "they carried her to the old Newstead country, and laid her by the father whom she had never known."

Ada's Influence

In the short years she lived, Ada Lovelace distinguished herself as a mathematician, and has even been called the inventor of computer programming. She used her gifts against tremendous obstacles and showed a spirit that would not be crushed.

As to Babbage and the influence of his Analytical Engine, his biographers wrote, "The Analytical Engine was never built, though Charles Babbage lived nearly another two decades. . . The Menabrea/Lovelace paper remains as the sole witness of the power and scope of the ideas of Babbage's Analytical Engine . . . these ideas . . . lay dormant for another century."

In a similar way, the Lovelace paper remains the sole witness of the power and scope of Ada Lovelace's special genius. Now, a century later, we marvel at her early contribution to the machines of our own day.

TRIANGULAR NUMBERS

The **triangular numbers** are the sums of the counting numbers 1, 2, 3, 4, . . . (See page 111, **Pascal Triangle**, for more about these numbers.)

Complete the first 20 triangular numbers listed below.

To calculate the numbers, use the information that $T_2 = N + T_1$, where T_2 = next triangular number; N = first (1), second (2), third (3), etc. counting number; T_1 = previous triangular number.

Triangular Numbers

N +	T_1 =	T_2
1	0	1
2	1	3
3	3	6
4	6	10
5	10	15
6	15	—
7	—	—
8	—	—
9	—	—
10	—	—
11	—	—
12	—	—
13	—	—
14	—	—
15	—	—

Use this list of triangular numbers (T_2) to complete the portrait of Ada Lovelace on page 20

A BIT OF BASIC

Many people consider Ada Lovelace to be the first person to describe what is now known as computer programming. A new programming language has been named after her. The language is called ADA. It was developed by the United States Department of Defense (DOD). The DOD hopes ADA will be adopted as a universal programming language. They hope it will replace the babble of languages now being used, and will make sharing programs much simpler.

BASIC is a language that is very popular now. Most microcomputers understand a version of BASIC. However, even this simple language is slightly different from computer to computer.

The following activity explores a few simple statements in BASIC. To do this activity, you need to have access to one of four popular microcomputers: APPLE, TRS-80 (Radio Shack), ATARI or PET (Commodore). This activity will introduce a program that works on each of these machines.

You need to learn three commands: NEW, LIST, RUN.
These commands speak directly to the computer.
You need to know three statements, or words: PRINT, GOTO, END.
These statements are part of the program and require line numbers.

First turn on the machine.

APPLE: Switch in back, left. (If you have a disk drive connected to your Apple you may need to press RESET to get the disc drive to stop whirring)
TRS-80: Switch in back, right.
ATARI: Switch on right side.
PET: Switch in back, left.

NEW and LIST

Type NEW and then hit RETURN. NEW tells the computer to clear its memory. Hitting RETURN is very important to remember, and often hard for the new user to remember. Hitting **RETURN** tells the computer you have completed your part, and it is the computer's turn to do its part.

Next, type **LIST** (and hit **RETURN**). **LIST** tells the computer to show what is in memory. If the new command worked properly, the **LIST** command will now show a blank screen.

PRINT, GOTO, and END

You are now ready to write a program.

To write a program you will need to write **LINE NUMBERS**. Any numbers will do, as long as they are in sequence. However, it is good practice to leave gaps between numbers in case more lines need to be added later.

For example, line numbers could be 10, 20, 30, ... or 100, 200, 300, ... or 110, 120, 130, ...

It would be a poor idea to number lines 10, 11, 12 ... or 101, 102, 103, etc.

The **PRINT** statement will cause any string of letters, enclosed by quotation marks, to be printed on the screen.

The **PRINT** statement can end with no punctuation mark, a comma, or a semi-colon. Later, we will see the different ways the screen will look when you use any of these.

The **GOTO** statement does what you have probably guessed it does. It is always followed by a line number, and it tells the program to jump to that line number and perform the statement at that number.

The **END** statement tells the computer that the program has ended.

Type the following program exactly as you see it.
Don't forget the quotation marks.
Don't forget the semi-colon.
Don't forget the line numbers.
Don't forget to hit **RETURN** at the end of each line.

```
10 PRINT "TEASE"; (hit RETURN)
20 GOTO 10
30 END
```

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When you have completed the typing, type **LIST** (and hit **RETURN**).
Does the screen echo what you have typed?
If you see a mistake, retype the line, including the number.

STOP: CTRL C and BREAK

Before you type **RUN** to execute the program you had better know how to **STOP** the program. To **STOP** the program:

APPLE: type **CTRL C**. (Hold down the control key as you type C. This button works like the shift key on the typewriter.)
TRS-80: Hit **BREAK**
ATARI: Hit **BREAK**
PET: Hit **RUN/STOP** key

RUN

Now type **RUN** and watch the screen fill. Wow!!!
Stop the program.
Type **LIST**.
Retype Line 10. This time leave out the semi-colon.
Run the program again. How does the screen look now?

STOP the program. Type **LIST**.
Retype Line 10 again. This time put a comma at the end of Line 10.
Run the program. How does it look now?
STOP the program. Type **LIST**.
Retype Line 10 again. This time put the semi-colon at the end of the line again.
Run the program.

You can fill the screen with attractive designs using the **PRINT** command, as you did in this program.

When you use the semi-colon in your **PRINT** statement, sometimes your message is printed in neat columns, sometimes it is printed in diagonals that set the entire screen in motion.

Can you predict when columns will appear; when diagonals will appear? Here is a hint! Each computer has room for a different number of symbols across its screen.

APPLE:	40 columns wide
TRS-80:	64 columns wide (Model 1 or 3)
ATARI:	36 columns wide
PET:	40 columns wide

When the number of letters and spaces inside the quotes of the PRINT statement is a multiple of the number of symbols across the screen, the screen will fill with columns. When the number is not a multiple, the screen will fill with moving diagonals.

For example, Apple's display is 40 columns wide. Print "CANDY" will fill the screen with 8 columns of CANDYs since CANDY had 5 letters and 5 times 8 is 40. If one or two spaces are added after CANDY, the screen will fill with a moving diagonal display since 6 and 7 are not multiples of 40. Try it and see.

Try running your program again using different lines 10. (Remember to copy them exactly as you see them. Do you remember how to RUN and STOP your program?)

```
10 PRINT "TEASE";
10 PRINT "*TEASE";
10 PRINT "*TEASE*";
```

Add an extra line; for example 15 PRINT "POP*";
See how the program runs now.

Change the punctuation.
Try your name.
Try your friend's name.
Print any patterns of letters or words or symbols between the quotes.

The GOTO statement explained on page 32 makes the computer run the PRINT statement continuously, or until the program is stopped from outside. When a statement makes a program go round and round in this way, we say the program is in an **infinite loop**.

Are you ready to try a program that is slightly more complicated? Here is a program like the one you have just done, but here you tell the computer exactly how many times you want it to run the PRINT statement.

FOR/NEXT LOOPS

The FOR/NEXT statement controls the number of times the PRINT statement will be run.

The FOR/NEXT statement is 2 lines long and is "sandwiched" around the statement or statements that are to be repeated.

```
10 FOR N = 1 TO 100
20 PRINT "TEASE*";
30 NEXT N
40 END
```

Run the program.

Lines 10 and 30 are the "bread." Line 20 is the "filling."

Line 10 tells how many times the "filling" will be repeated.

Line 20 is the "filling."

Line 30 moves the counter in line 10 along from 1 to 100.

When the counter shows the PRINT statement has been run 100 times, the program drops to Line 40, and ENDs.

Play around with this program.

N can be any letter. Try it.

Change the letter and the number in line 10 to ... FOR N = 1 to 100 ...

Try a different message in Line 20.

Try the message with and without a comma; with and without a semi-colon.

Remember to hit RETURN after you complete a line or when you type a command to the computer.

Play around with these commands.

Go to a book store or a computer store and find a book you like that will teach you more about BASIC.

Ada Lovelace would be proud of you!

SONYA KOVALEVSKAYA
1850-1891

Sonya Kovalevskaya was born in Russia at Palibino, a large estate in Vitebsk. In winter, wolves howled around the estate, and deep snow buried the road to St. Petersburg, the nearest large city. Pine forests protected the large house from the winds that blew over miles of plain.

Indoors, the family lived in a private world. Head of the household was General Krukovsky, Sonya's father. Her mother was much younger than the General; she liked to read novels, to paint and play the piano. Aniuta, Sonya's sister, was six years older, and Fedya, her brother, was three years younger.

A Strict Schooling

From the time Sonya was five years old until she was twelve, she had only one teacher, an English governess. This woman did not understand Sonya's passionate Russian nature. She tried to press Sonya into a mold labeled "proper English miss"--a mold that would produce a young woman who played the piano, had perfect manners in company, and was neat, tidy and prompt. She would not let Sonya read romantic novels and poetry as she loved to do, and she urged long winter walks on her, to improve circulation! Sonya escaped this torture only when the temperature fell below 10 degrees.

The governess held total power over young Sonya's life. Her father felt it was not his place to make decisions about Sonya's education, and her mother was not strong enough to go against the governess' rules. Sonya felt her parents did not really care about her.

More and more, the person to whom she showed her affectionate heart was her teenage sister, Aniuta. Because Aniuta and the governess despised one another, Sonya had to sneak when she wanted to see her sister.

The Krukovsky house was quite large, and each section was occupied by a part of the family. Sonya's father lived in the tower, her mother and sister lived upstairs in the main apartments, Fedya and his tutor lived in a separate upstairs wing, and Sonya and her governess lived on the ground floor.

Studying the Wallpaper

All of the rooms were decorated with fancy imported wallpaper. Only one was left unfinished. In this room the imported wallpaper ran out, and old papers were used to cover the walls. These papers were lecture notes which the General used in his student days. The subject was differential and integral calculus. Sonya was alone a great deal, and she amused herself by staring at the squiggles on the papers. Years later, she studied calculus in St. Petersburg. She caught on so quickly her teacher remarked that she must have known the subject all her life. In a way she had.

Sonya was a brilliant student. After her governess left, she taught herself physics. But in order to do this, she found she would need to learn trigonometry. So she taught herself!

A friend of the family was a physicist. One time, visiting the Krokovskys, he questioned Sonya about her studies. When he learned what she was achieving, he went to the General and convinced him that Sonya must be allowed to study mathematics in St. Petersburg. The General finally consented.

The World Outside

Sonya was growing up at a time of great social and political upheaval in Russia. In 1861, Czar Alexander II gave the serfs their freedom. Ideas about equality for all spread even to the country--to the estate at Palibino.

A young man from the nearest village struck up a friendship with Aniuta. He had been living in St. Petersburg and learned the new political ideas. He brought magazines and journals that told of the struggle for freedom from hunger, poverty and harsh rule all over Europe. They told of the serfs' desire for equality, of women's desire for higher education, and the people's desire for political power.

Many sons and daughters of the aristocracy, like Sonya and Aniuta, criticized the old-fashioned ideas of their parents. They were just beginning to understand that they could not continue their comfortable traditions--marrying early and settling into their role as upperclass landowners.

A Wild Plan

Aniuta, Sonya's sister, was now a grown-up young woman, longing to be free of her father's strict rules. Yet she was stuck at Palibino. She asked her father if she could study at the University of St. Petersburg and her father said no.

At this point, around 1860, the University had just opened classes to women, although women could not earn degrees. A couple of years later, when students protested in order to gain more liberties, the University closed. When it reopened, women were no longer permitted to attend classes there, nor anywhere else in Russia.

Sonya, like Aniuta, wanted to leave home. She wanted to study science at a university. Wherever Aniuta went, Sonya decided, she would follow.

Together with Sonya and a friend, Aniuta devised a wild plan. The young women would ask a young man who shared their political beliefs to marry one of them! Such a marriage would set them free. Once they were married, the couple, plus their friends, would set off to study at a university in Germany or Switzerland. In these countries, women had a better chance of being admitted to universities.

Such a marriage, it was understood, would be in name only. After their arrival in the foreign city the husband and wife would live apart.

The first young man they tried to interest in their plan turned them down. But one more "no" did not discourage these three. Next, they tried a promising student of geology. His name was Vladimir Kovalevsky. This young man said "yes."

There was one problem: he wished to marry Sonya, the youngest. He wrote to his brother, "Despite her eighteen years the Sparrow (Sonya's nickname) is extremely well-educated. She speaks foreign languages as fluently as her own. She studies mainly mathematics, is now tackling spheric(al) trigonometry and integrals. She is as busy as a bee from morning till night and still is lively, sweet, and very pretty."

To this bold marriage proposal the General said, "No"! It was unheard of that a younger sister marry before the older. But Sonya had seen her chance to escape and follow her dream of getting a higher education.

Sheer desperation gave her the courage to do what she did next. She, who was never allowed outside her home unchaperoned, slipped away to join Vladimir in his apartment in the nearby village. According to the rules of the society in which they lived, such behavior was equal to eloping. She left a note for her father, telling him where she was going and why. He followed her there. As she had hoped, her father now allowed their engagement.

Sonya and Vladimir were married with her family's blessing, and within six months, the couple was living in Germany.

Higher Education

During the two years spent at Heidelberg, Germany, Sonya's closest friend was Julia Lermontov, a student of chemistry. Lermontov later wrote about Sonya during these years: "She was just eighteen but looked much younger. Small, slender, with a round face and short curly chestnut hair, she had very mobile features. Her eyes, especially, were exceedingly expressive--sometimes bright and dancing, sometimes dreamy and full of melancholy . . . a mixture of childish innocence and deep thought . . . She took no pains about her personal appearance or dress . . . a trait which remained with her to the last."

According to plan, Sonya became a student in mathematics at the university, and began her climb to fame and honor and, along the way, to tragedy and heartbreak.

Sonya was a daring idealist who was concerned with bettering human life. She also loved society and its honors. In the other side of her life, she was a lonely scholar living for her work, avoiding other people who would bring desires and disappointments.

Sonya always felt a hunger for love. Her own life, she believed, was terribly lacking when she observed the lives of her friends. As in her childhood, she now felt she was somehow outside circles of love.

Sonya moved to Berlin in order to work under the famous mathe'ma'ti'cian, Karl Weierstrasse. Here she spent four years, finally receiving her degree in mathematics from the University of Gottingen in 1874.

She worked during this period in almost absolute solitude, often sitting for hours in her room trying to solve problems. When she succeeded, she would rise from her desk and pace the floor talking to herself, walking faster and faster, laughing and finally breaking into a run!

The calm satisfaction of a Mary Somerville she did not have. Rather, Sonya was nervous and withdrawn. She saw no one for days. She went neither to parties nor dinners.

Vladimir, her husband, also lived in Berlin during this period. When he visited Sonya, they would go for long walks. This was her only recreation.

Sonya frequently went back to Russia. From there she once wrote, "I feel released from the prison in which my best thoughts were in bondage. You cannot think what suffering it is to have to speak always foreign languages to your friends. You might as well wear a mask on your face."

Married Life

After five years of a marriage that was a mere business arrangement, Sonya and Vladimir became lovers. True to her passionate temperament, Sonya threw herself into married life, hoping the marriage would succeed as a love match. She also hoped it would produce the happy family life she longed for.

A daughter was born who was also named Sonya. But she was known by her nickname, Fouzi. Sonya put aside all of her studies to care for little Fouzi and to promote her husband's scientific work. She yearned to be a typical wife and mother. But she was not typical. When Vladimir, a lecturer in geology at the University of Moscow, began to lose interest in science, Sonya wrote his lectures for him. Instead of attending to his job, Vladimir plunged into business schemes. They failed, one after another.

Sonya believed she had the power to see the future. One night, she had a nightmare that a grinning monster was stamping Vladimir beneath its feet. She was terribly frightened. Later, she realized that the dream monster was Vladimir's business partner. This man cheated Vladimir out of a large sum of money. Through his persuasion all the family money, including Sonya's small inheritance from her father, was invested in Russian oil refineries. The refining company was later accused of fraud, and Vladimir was threatened with a lawsuit. While this was happening, the partner convinced Sonya that Vladimir was in love with another woman.

Sonya felt rejected. She left Russia with her daughter and returned to Berlin. There, in a hopeless state of mind, she threw herself once again into mathematics.

Vladimir committed suicide. Sonya was just thirty-two years old, and already a widow. The death of her husband was a great blow. She never stopped feeling somehow responsible for his sad end.

Professor Sonya

In the next ten years, Sonya came into her own. She became a respected mathematician. Her teacher, Weierstrasse, introduced her to Gosta Mittag-Leffler, a Swede, who took up her cause. Mittag-Leffler got her a job as mathematics professor at the University of Stockholm in Sweden. This was a tremendous step forward for Sonya, and for women of science!

The first year, many parties and balls were given in her honor. Swedish girl babies were named "Sonya" after her. After all, she was the only woman professor in the country!

But Sonya had enemies as well as admirers. A famous Swedish writer, August Strindberg, wrote a scornful article about her appointment.

Sonya repeated what he wrote in a letter to a friend. "She proves, as decidedly as that two and two make four, what a monstrosity a woman professor of mathematics is, and how unnecessary, injurious and out of place she is."

Nevertheless her career went so well that she was given a five-year contract in 1884 and asked to become a professor of mechanics, a branch of physics. When she accepted this second job, she joked, "Now I have become a professor squared!"

Mittag-Leffler's sister, Anna Carlotta, a well-known writer, became good friends with Sonya. Sonya now began a second career as a writer. Her themes were mainly about her childhood in Russia.

Both women were feminists and held high hopes for the future of women in the world. The "woman issue," as it was called in Sweden, was a subject of hot debate at that time.

The two women began to work on a drama in two parts, called "The Struggle for Happiness: How It Was, How It Might Have Been." Sonya was so excited about this work that she gave up mathematics for a time. She and Anna Carlotta dreamed about traveling to Germany and France to meet literary and theatrical stars and prepare for their coming fame.

They promised to write each other's biographies. With that in mind, they both began saving letters and documents.

It wasn't long, however, before Stockholm began to seem like a boring country town to Sonya, and one that was desperately cold in winter to boot. Sonya longed to live in a dazzling world capital like Paris. But she needed a job, and women mathematicians were not wanted in many universities--in almost none in fact. Rarely were women allowed to be students, much less paid teachers. Sweden was the only country in Europe, except for Italy, where there were women professors in any subject.

Sonya tried again to find work in Russia. After years of being ignored in her native country, she was made an Associate of the Russian National Academy of Sciences. So, with hopes high, she visited her homeland.

There, she heard of a job teaching mathematics in a girls' high school. When she inquired about it, the Minister of Education told her the position was too inferior for someone of her importance. More likely, she was turned down for two other reasons: the first, because she was a woman; second, because as a teenager she had worked with Aniuta and other students who wished to upset the Czar's government. Back to Stockholm Sonya went.

Now, almost as soon as one disappointment occurred, another followed--too fast to lessen the shock. Sonya was carried along, from grief to despair to death.

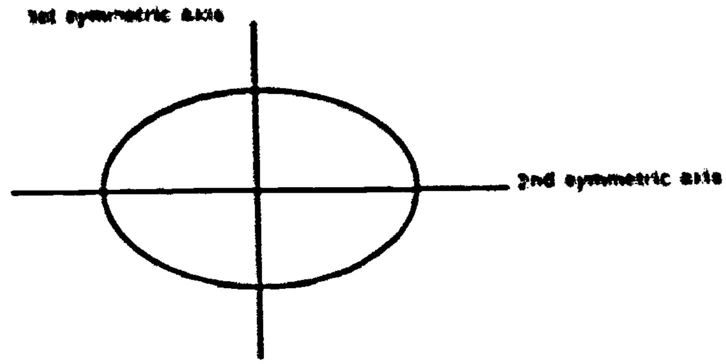
Her book, *Struggle for Happiness*, failed in Sweden. Her beloved sister Aniuta, whom she had called her "spiritual mother," died after a long and painful illness. Sonya buried herself once more in mathematics.

Prix Bordin

Sonya decided to compete for the greatest mathematics prize of the time, the Prix Bordin, offered by the Paris Academy of Sciences. All during the summer of 1888, Sonya worked on the problem she had set herself, staying up all night many times. The title of her research was "The Problem of the Rotation of a Solid Body About a Fixed Point." The subject was the form of Saturn's rings.

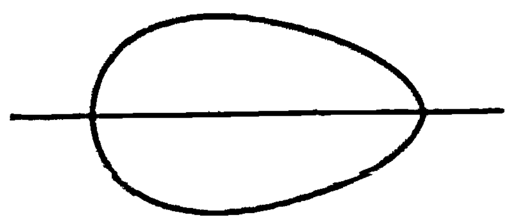
Mathematicians try to write equations that will describe certain situations that occur in nature, such as the rotation of the earth around the sun. Some of Sonya's most important work involved the study of the shape and behavior of Saturn's rings. This is particularly timely today, for at this very time scientists and non-scientists alike are holding their breath with excitement as Voyager I rushes past Saturn. Photographs are being broadcast which will confirm Sonya's research or add new puzzles.

Before Sonya's work scientists had considered the shape of Saturn's rings to form an ellipse. An ellipse is a special oval shape that has two axes of symmetry.



An axis of symmetry is a line across which you can imagine folding an object and fitting it perfectly on the opposite side.

Sonya proved that the cross-section of the Saturn ring must be egg-shaped. Such a shape, like a lengthwise slice of egg, is symmetric along only one axis instead of two.



Notice that if you fold the figure horizontally, the two parts are exactly the same. But if you try to fold the figure on a vertical axis, the two parts won't fit.

Sonya's conclusions about Saturn's rings may or may not be confirmed by the pictures sent back from Voyager I. But the work she did still stands.

A Great Prize

After putting out tremendous energy on her research on Saturn's rings, Sonya submitted her work to the Paris Academy of Sciences. On Christmas Eve, 1888, she was named the winner of the great prize! Along with it, she received 5000 francs, an increase of 2000 francs over the usual amount, because her work had solved a problem that was so important to the mathematics of that time.

A Love Affair

During this same year, 1888, Sonya fell in love. The man's name was Maxim Kovalevsky. She called him "Fat Maxim" in tones of proud affection.

Maxim was a Russian lawyer who was fired from the University of Moscow in Russia because he criticized Russian constitutional law. This was like criticizing the Czar himself. Neither he nor Sonya could go back to Russia and make a living.

Sonya and Maxim had many fights. She was jealous and possessive, and she went from love to anger, and back again, over and over. Maxim taught at universities mainly in France and often he left Sonya. When they were apart, Sonya felt utterly abandoned. Maxim turned up faithfully when she received the Prix Bordin in Paris.

Even while she was being honored in Paris, she was very unhappy because of her love troubles.

She wrote a friend, "Letters of congratulation are pouring in from all sides, but . . . I am as miserable as a dog. No; I hope, for their sake, that dogs cannot be as unhappy as human creatures, especially as women."

A couple of years passed, and again it was the middle of a long, harsh winter. For the Christmas vacation, Sonya went with Maxim to Naples. There, escaping from her bleak life in Stockholm, she spent many happy weeks with Maxim in the sunny atmosphere of Italy. She wrote to her daughter that the view from their veranda showed a garden "Blooming with roses, camellias and violets, and oranges ripening on the trees."

At the end of the vacation, the couple separated and Sonya was alone on the trains going north. The weather was cold and rainy and she caught cold.

The end was swift: from cold to inflammation of the lungs to pneumonia. In three days, she was dead. She was only forty-one years old. The evening before she died she said, "I feel as if a great change has come over me." Face to face with death, she was suddenly at peace.

The brother of Gosta Mittag-Leffler wrote a poem about Sonya. He called her the "Muse of the Heavens." He wrote:

While Saturn's rings still shine,
While mortals breathe,
The world will ever remember your name.

We do indeed remember her name today.

PRIME NUMBERS

Shade all prime numbers to complete the picture of Sonya Kovalevskaya on page 38.

For this activity it is convenient to have a list of prime numbers handy. If you don't have such a list, try the following activity. It is called the Sieve of Erosthenes, after the Greek mathematician who supposedly made up the idea.

Make the following modifications to the number grid on page 49

- Draw a square around [1]. Then remember that 1 is not a prime number.
- Draw a circle around (2). Two is the first prime number. Two is also the only even prime number.
- Now draw a horizontal line (—) through all multiples of 2. This will be all the other even numbers.
- Draw a circle around (3), the next number that has not already been crossed out.
- Now draw a vertical line (|) through all multiples of 3.

Notice the numbers crossed out with both vertical and horizontal lines. These are the common multiples of 2 and 3. These are also the multiples of 6.

- Draw a circle around (5), the next number that has not yet been crossed out. Now draw a diagonal line (/) through all multiples of 5.
- Next draw a circle around (7), the next number that has not previously been crossed out.
- Draw a diagonal line going the other way (\ ) through all multiples of 7. (You are just about done.)
- Go through the grid and draw a circle around every number that has not yet been crossed out.

These circled numbers are all the prime numbers between 0 and 100. Keep this page handy. All the prime numbers you will need to shade are circled here.

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

MARY EVERETT BOOLE
1832-1916

The two children crouched down in the soft morning rain. The girl poked under a leaf with a stick. The boy, smaller than she, pushed aside some wild grass.

"Regardez!" the boy exclaimed, "un papillon." (Look! A butterfly.)

Its wing was torn. The girl carefully carried the creature inside the house. Taking turns, they blew on it to warm it.

Mary and her brother George often nursed insects that had been hurt by the frost or rain. Then they kept them for "pets." These and an occasional lost dog were the only pets the children were allowed to have.

Their father, Thomas Everest, a minister, was seriously ill. He was under the care of a famous doctor named Samuel Hahnemann. Though Mary and George had been born in England, they moved to the small village of Poissy in France when Mary was five and George was two years old.

Dr. Everest's cure took six years. Life was lonely for the children in Poissy. They belonged to an English minister's household while everyone else in the town was a French Catholic. Also, the Everests did not approve of French politics of that time. The laws of the French monarchy were harsh toward the people. Their father's illness worried both of their parents. Servants looked after Mary and George, but the two children were mostly on their own.

The Leaves and the Root

Mary was a bright child, outgoing and talkative. "You were the roots and I the leaves of the plant," she wrote to George when both were old.

Little George was his sister's fan. When Mary was nine, she wrote a play, and George, who acted in it, boasted, "C'est ma soeur qui a invente cela." (My sister made that up!)

Homeopathy

Their father was a great believer in homeopathy, a medical system promoting health and preventing disease. Dr. Hahnemann was the founder of homeopathy, and Mary's father was devoted to his system. Followers of homeopathy practiced some extreme customs, and in the Everest household, Mary and her brother George had to practice them too.

They took long walks before breakfast in freezing weather and baths in ice water to help them resist disease. Some thought the cure was worse than the disease. But Mary was loyal to her father and submitted to whatever experiments he dreamed up without complaining. An ill person himself, he was determined that Mary and George would grow up to be h

Mt. Everest and Uncle George

Mary's family name was made famous by her uncle George Everest. George was a surveyor who spent twenty years in India. Because he led a survey team up the great mountain, Mount Everest was named for him.

Uncle George did not often visit his brother's family, but when he did, he brought tales of adventure in far-off places. Mary was a great favorite of this uncle, and he wanted to adopt her. But she was too attached to her parents to agree. Mary was very close to her father, and for as long as he lived, she was his devoted assistant.

Mary and her brother George were always being scolded for quarreling. George spent every French "sou" he got while Mary was a "pinchpenny." Their father saw to it that they didn't quarrel over money by giving them a joint allowance. Somehow, because of their common piggy bank, George became more cautious about spending, and Mary became more generous.

A Crush

Mary had a tutor from the village. Monsieur Deplace taught Mary every morning from 6:00 to 8:00. No lying abed for an Everest child!

From the first day, Monsieur Deplace made arithmetic clear to Mary. When her mother had tried to teach her long division, it was a mess! With Monsieur Deplace, learning was easy. He asked her a series of questions. Then he told her to write down the answers. When she read them aloud to him, she realized she was reading certain orderly steps that would solve her problem. Mary never forgot this wonderful way of learning.

Mary had a crush on Monsieur Deplace. Although he was pleasant, he never showed her affection. Still, she felt she was someone special to him, and she remembered him all her life.

The Rector's Assistant

When Mary was eleven, her father regained his health at last, and the family went back to England. Her father became rector of a church at Wickwar, at the foot of the Cotswold Hills. Mary was taken out of school and became her father's assistant in his parish work. Her duties were visiting old people, teaching children in Sunday School and helping her father prepare sermons.

The Differential Calculus

For mathematically-minded Mary, leaving school did not mean an end to study. She taught herself calculus from books she found in her father's library. While she was teaching herself differential calculus, she became stuck and she looked around for some help.

"I soon found in the library an old book of Fluxions into which I plunged with delight," she wrote . . . "After I had been revelling in my prize for a week, my father found me with the book and took it away, telling me that the Fluxion notation was old-fashioned and inconvenient, and quite given up now at Cambridge." (Since women students were not admitted to Cambridge, Mary had no way of discovering this for herself.) "I went back to my differential book, and found, to my great delight, that it was now perfectly clear to me."

How could that be? This was a puzzle.

Mathematics, Friendship and Love

Two years later, when Mary was eighteen, she had a chance to solve the puzzle. She visited the home of her aunt and uncle who lived in Cork, in Western Ireland. Her Uncle John was Professor of Classics at the University of Cork.

One day, a young professor, a good friend of her uncle's, came to call and Mary was introduced to him.

George Boole was already a well-known mathematician. Mary told George about the differential calculus puzzle and how the old-fashioned method of learning calculus had helped her. George said the book of fluxions helped her by setting up certain orderly steps for her to follow, just as Monsieur Deplace had done so long ago. Using these steps, Mary was able to solve the problems in the regular calculus textbook.

Mary liked George Boole very much. He was a kind and understanding man, as well as being a mathematical wizard. Students and children loved him. After her return to England, she wrote to him. She sent him examples of her work in mathematics. Two years later George came to Mary's home in England and began to teach her a serious course in mathematics.

At this time, George was writing a book called *Laws of Thought*. When it was published two years later, it became a sensation among mathematicians and other serious thinkers. In it, he investigated the laws that govern the part of the mind which reasons about things. These laws were expressed in an algebra of zeros and ones. This algebra even today is called "Boolean Algebra."

Later, when George revised his *Laws of Thought*, Mary, with the help of George's students, read the manuscript. When he wrote something that was not clear, they told him so in no uncertain terms. Once, when he was composing a section on differential equations, Mary sent the manuscript back five times for re-writing! On the sixth time around, it was clear. George had passed inspection.

A Boolean Family

A few years later Mary's father died. In her grief, she turned to George for comfort and friendship. A year later, the two were married. Mary was twenty-three years old and George was forty.

"Into the next nine years," wrote a biographer, "were crowded a lifetime of events. Five daughters were born to them: Mary, Margaret, Alicia, Lucy and Ethel. It was a very happy marriage, and Mrs. Boole was able by her understanding care to safeguard her husband's health and protect him to a great extent from the effects of his constant and strenuous work."

Safeguarding her husband's health, as she had spent her youth safeguarding her father's health, seemed quite natural to Mary. Like most women of her time, she was devoted to her family, and raised her five daughters. But her life did not follow a set formula. Rather than moving along a straight line, Mary's destiny was to wind, bend and curve back and forth throughout her life.

Mary and George read many books together. They enjoyed the great English poet Milton and other poets and philosophers. The two talked about new ways to educate the young, taking what was best from Monsieur Deplace, from their experience with George's students, from Mary's own study, and from other thinkers. But they laid no plans for educating their own children.

Suddenly, George caught pneumonia and died. Mary's youngest child was six months old, and she herself was only thirty-two and a grieving widow. She had to go on alone.

What did she do? She went out and got a job!

The Wide, Wide World

In those days, this was a heroic task. Mary had no job experience except sermon writing and parish teaching and working with George's students. But there was the key--writing and teaching.

While Mary tackled her personal problems, turmoil was also stirring up the wider world. Revolutions had swept through Europe in 1848 and America was now on the verge of Civil War. It was 1864, and educational and political questions were boiling in England. The young widow's mind bubbled with them.

Mary had never lost the love of learning that led her to pursue her studies alone and seek out scholars like George Boole. George had been interested in the ideas of a man named Frederick Denison Maurice and wanted to invite Maurice to join their discussion circle. But George's illness and death prevented this plan.

After George died, Mary pledged herself to further George's work. When the opportunity arose (she had a problem on which she needed advice) she made an appointment to meet Maurice. Maurice was a lecturer at Queens College.

Queens College In Harley Street

Queens College in Harley Street, London, was founded in 1847. It was the first women's college in England. Its patron was Queen Victoria. Its purpose was to train young women to become governesses. Neither women nor Jews at this time were granted college degrees anywhere in England, but at least here women could study on a college level.

But Queens College wasn't giving anything away to women. Women could not receive degrees and no women could be appointed to the teaching faculty. The only jobs available were so-called "staff assistants." There was no direct teaching of students in these jobs.

When Maurice met Mary, the first thing he asked was if she would take a position as librarian at the College. Mary accepted and went to work.

Now she was in her element! Although she could not teach, she became a friend and advisor to the students. She organized what came to be called "Sunday Night Conversations."

Mary and the students discussed Boole's mathematics, Darwin's natural history, and psychology, and how each subject affected the others. They held logic-practice talks. Mary presided over the meetings. They were a smashing success.

"I thought we were being amused, not taught," a graduate wrote to her later. "But after I left, I found you have given us a power. We can think for ourselves, and find out what we want to know."

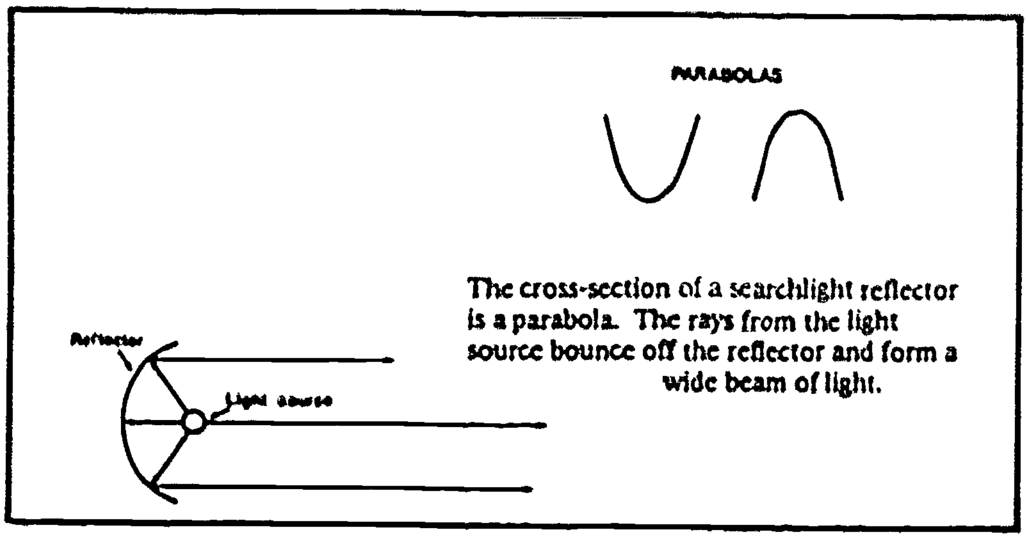
Mathematics As Fun

Mary began to teach children, using her own theories. She was most interested in showing how ordinary everyday activities prepared children to learn mathematics and science.

" . . . Children do things such as drawing or sewing, counting in tens . . . sharing an apple or painting a pattern on a wall. And in the unconscious (usually not to come into consciousness for years) is growing . . . (an understanding of) zero and infinity, adding or multiplying minus . . . and many other fundamental mathematical . . . (ideas)."

Natural materials and imagination: *that* was the magic combination to create excitement in mathematics class. Girls in her classes used needles, thread, and cardboard to form curves with long straight stitches. Boys used their penknives to cut twigs from hedges. They took elastic from hats and slats from cigar boxes to build three-dimensional figures.

One day the Head of the London Board of Education came to Mary's class. An eleven-year-old student demonstrated a toy the class had made together. It showed a parabola in the act of changing its rate of curvature. The official was "staggered" at the cleverness of the students.



The cross-section of a searchlight reflector is a parabola. The rays from the light source bounce off the reflector and form a wide beam of light.

Children, Mary believed, should "have the opportunity of watching . . . how one geometrical type-form grows out of, or flows into, another. A common night-light placed in the bottom of a deep round jar in a dark room throws on a sheet of cardboard held over it patterns of conic sections, which pass into each other as you change the position of the cardboard." Children love to watch the shadows change and it is good training for geometry, she advised.

Mary threw all these ideas together into a pot and out came a rich stew--a book called *The Preparation of the Child for Science* (which included mathematics).

Curve Stitching

Mary invented cards marked for the purpose of curve stitching. They were known as "Boole cards" in England. Mary happened upon curve stitching, or what today we call string geometry, by chance, and saw at once it could be an aid in learning about the geometry of angles and space.

"In my young days," she wrote, "cards of different shapes were sold in pairs, in fancy shops, for making needle-books and pin cushions. The cards were intended to be painted on; and there was a row of holes around the edge by which twin cards were to be sewn together. As I could not paint, it got itself somehow suggested to me that I might decorate the cards by lacing silk threads across the blank spaces by means of the holes. When I was tired of so lacing that the threads crossed in the centre and covered the whole card, it occurred to me to vary the amusement by passing the thread from each hole to one not exactly opposite to it, thus leaving a space in the middle. I can feel now the delight with which I discovered that the little blank space so left in the middle of the card was bounded by a symmetrical curve made up of a tiny bit of each of my straight silk lines; that its shape depended upon, without being the same as, the outline of the card . . ."

A book about experiments with curve stitching came into print. It was written by a friend of Mary's and was called *A Rhythmic Approach to Mathematics*. Cards with patterns from ancient times mysteriously appeared in the book.

"Some of the patterns reproduced designs in old Celtic art; others in old Egyptian and Greek art; in fact," Mary wrote, "we are hearing from various parts of the world . . . (People say) 'you have reproduced the ornamental work on such or such a very old building.'"

The designs in this book reproduced basic designs that were used in Egyptian, Greek and Celtic art! To Mary, this showed that people's unconscious minds were similar--no matter when or where they lived.

"Psychic" Science

In Mary's time, many people asked questions about the spirit world. They wondered whether it existed and, if so, how it worked. They used the word "psychic" for anything to do with the spirit world. Mary had long thought about psychic happenings. She completed a book and called it *The Message of Psychic Science for Mothers and Nurses.*

At this time, Maurice was her employer, and he was also a minister in the Church of England. Maurice prided himself on being a tolerant man, but he stopped short of a book about psychic science. Mary's book talked about not only physical health but also mental health and called it science? Mary's book agreed there was such a thing as thought transference between people? This was going too far, Maurice thought!

Friends of his who also belonged to the Church of England blocked the publishing of Mary's book. It took fifteen long years before the book was finally printed. By that time Mary was no longer in Maurice's employ. His opposition could not stop her from publishing.

A Fair Exchange

Mary went to work as Secretary to James Hinton who had been an old friend of her father's. Hinton wrote about evolution and also about the art of thinking. It was the second subject that drew Mary to work with him.

Each had something to give the other. They studied the development of the mind. Mary taught Hinton mathematics and how to apply equations to the art of thinking.

The Magic of Numbers

It is possible, Mary believed, to express the basic notions of the universe in equations made of numbers and symbols. The number "1," for example, is the expression of unity in the universe. Zero is infinity. Anything could be translated into mathematical symbols: a rainbow, a butterfly chrysalis, a dust spiral. Mathematics gave power to discover truths in all fields of knowledge.

Mary wrote and talked about her beliefs with mystics from the East and psychologists from America. Founders of the progressive education movement in America studied her writings.

The Cranks

Mary had a group of friends who called themselves "the cranks." She met them at a vegetarian restaurant in London. After a time, they put out a magazine called "The Crank." Mary contributed many articles with catchy titles like "Are We Berserks or Christians?" Stuffy old Maurice couldn't stop her now!

For the next thirty years, books and articles poured out of Mary. Her titles show the wide range of her interests: "Mathematics in Occultism," "The Divining Rod," "The Schoolgirl Medium," "About Girls," "What One Might Say to a Schoolboy," "Hooliganism" (juvenile delinquency), *Philosophy and Fun of Algebra*, *The Logic of Love*.

For the twentieth-century reader, leafing through Mary's *Collected Writings* is a little like taking a trip with Alice through the looking glass: all sorts of odd ideas come skipping along, such as, "It is the moral duty of people not to go insane. Geniuses should live to be old rather than 'burning out' and dying young. Having secrets is a mistake."

Mary, for instance, made a rule for herself, when she was thirteen, never to keep secrets. That way she could publish whatever she wished and say whatever she chose.

Mary's daughters were grown up now and gone away, all except Lucy, who lived with her. Lucy was a chemist and she lectured at the London School of Medicine for Women. Her daughter, Alicia, was a mathematician of considerable talent who was said to have the ability to visualize figures in a fourth dimension. The youngest, Ethel, was a novelist.

Mary spoke at various clubs and societies, like the Parents' National Educational Union and the Christo-Theosophical Society. These meetings were open to all, and all shades of opinion were welcomed. They were attended by foreign scholars, ministers, editors, educators and other thinkers.

A Shocking Dream

Mary had grown up on religious sermons and found it hard to resist what she called "a little bit of preach." Yet she was always ready to deflate windbags or people she called "prigs." She may have been a bit of a prig but she didn't mind telling stories on herself.

For example, Mary had a dream which kept repeating itself. In the dream she went outside in a shocking condition.

She said, "I find myself . . . in the street without proper clothing, without bonnet and cloak, or even . . . my nightdress." (1)

When she had this dream, she always looked over the manuscripts which were waiting to be taken to the printer. She wanted to be certain that she had not revealed too much of herself in her writing. She did not want her "naked" feelings to show to the world.

World War I: The End of an Era

When World War I started, Mary's health was failing. She was sorry that she was too weak to knit sweaters and blankets for the war effort. Her contribution was to open her house to the many people who knew her.

"They came and found a quiet place for an hour, away from the turmoil of a country at war and the terrible news in the newspapers."

Mary was by now quite old. She had breathed life into wounded insects. She gave birth to five children--all living. She gave the power of thinking to students so they could find out what they needed to know to live well. She enlivened dry-as-dust mathematics classes for countless girls and boys. Now life was ebbing out of her.

Mary had been widowed for fifty years. She raised her family alone and now relatives as well as friends and even her own eyesight were slipping away.

"Ah me!" she wrote, "But it is a lonely world!" But she had a strong religious faith. And even sadness could be woven into a rich cloth--"If one knows the Artistic way of using the world's shadows . . . discords . . . and lurid dark silks. . . . "

Mary died at the age of 84. Her life spanned the Industrial Revolution in England. This period brought to England a new set of political and social challenges--public education, public health, trade unions, the cooperative movement.

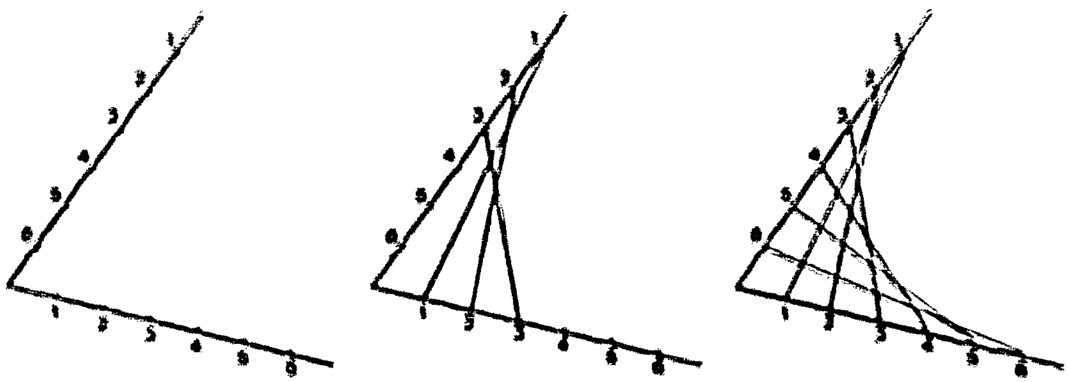
Mary called herself a mathematical psychologist. This meant she tried to understand how people (especially children) learned mathematics and science, using the reasoning parts of their minds, their physical bodies, and their unconscious processes.

Her work influenced many others of her time: "Within the first decade of the present century," wrote her biographer, "new methods of teaching many subjects had been developed. Experimental work went on . . ."

Today, in your own classroom, you may learn subjects the way Mary Boole taught them. Something may remind you of her ideas about how students learn, especially how they learn mathematics and science.

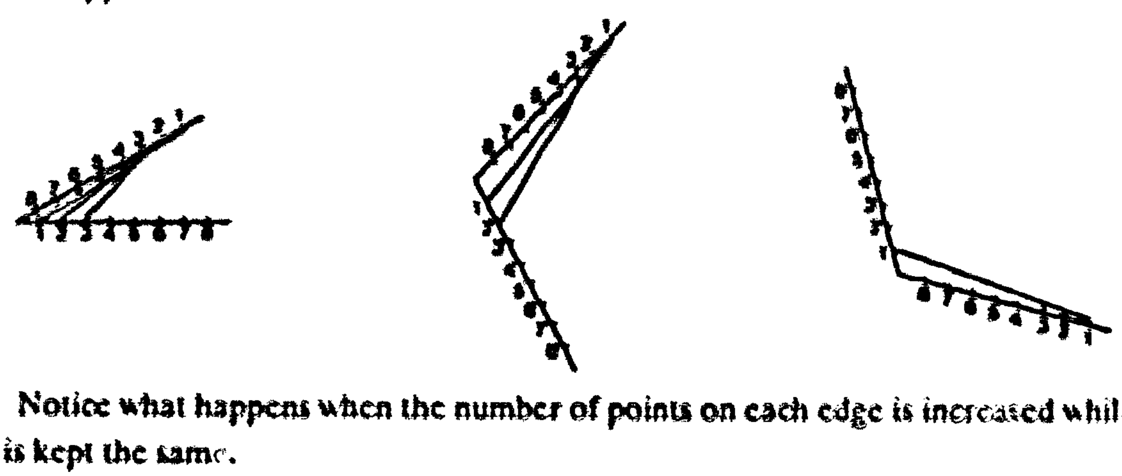
CURVE STITCHING

A nineteenth century mathematician and teacher, Mary Boole, developed a technique for making attractive designs by threading colored string through cardboard forms. Pictures of two of these cards, called Boole Curve-Sewing Cards, are included here. Curve stitching demonstrates an interesting mathematical idea. Curved lines can be formed solely by a series of straight lines. How can this amazing thing happen? Let's try it and see.

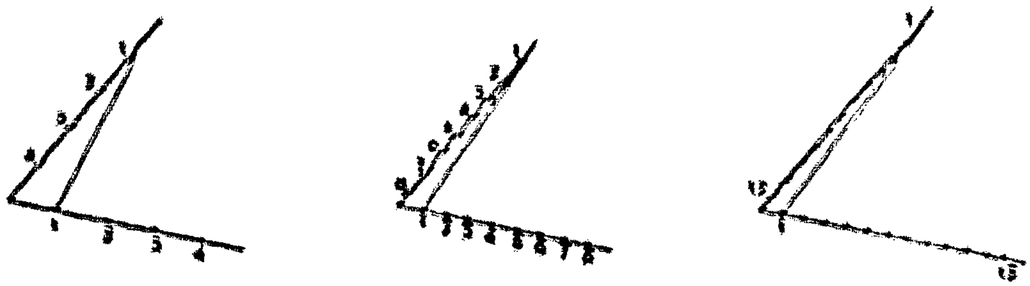


Notice the numbers drawn on both rays of the angles above. Draw a line connecting point 1 to point 1, another from point 2 to point 2, a third from point 3 to point 3. Keep doing this. Watch the trace of a curve appear as the lines are added.

If the spacing between points is kept the same while the width of the angle is changed, the shape of the curve will change. Connect the points in the figures below and see what happens.

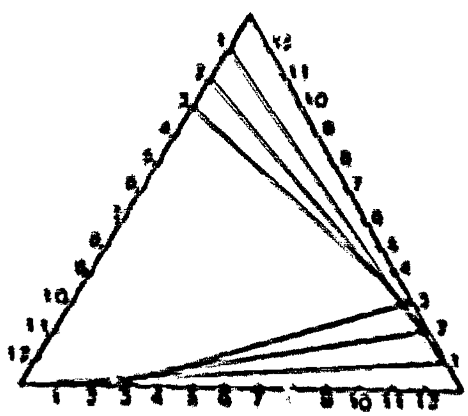


Notice what happens when the number of points on each edge is increased while the angle is kept the same.



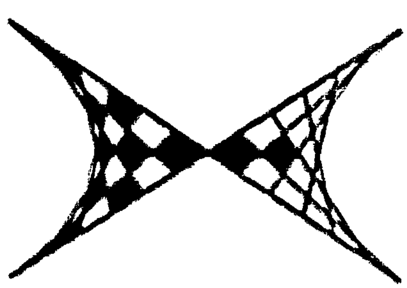
The more points, the smoother the curve!

Try connecting points on edges of other geometric figures. For example, try connecting the points on this triangle.

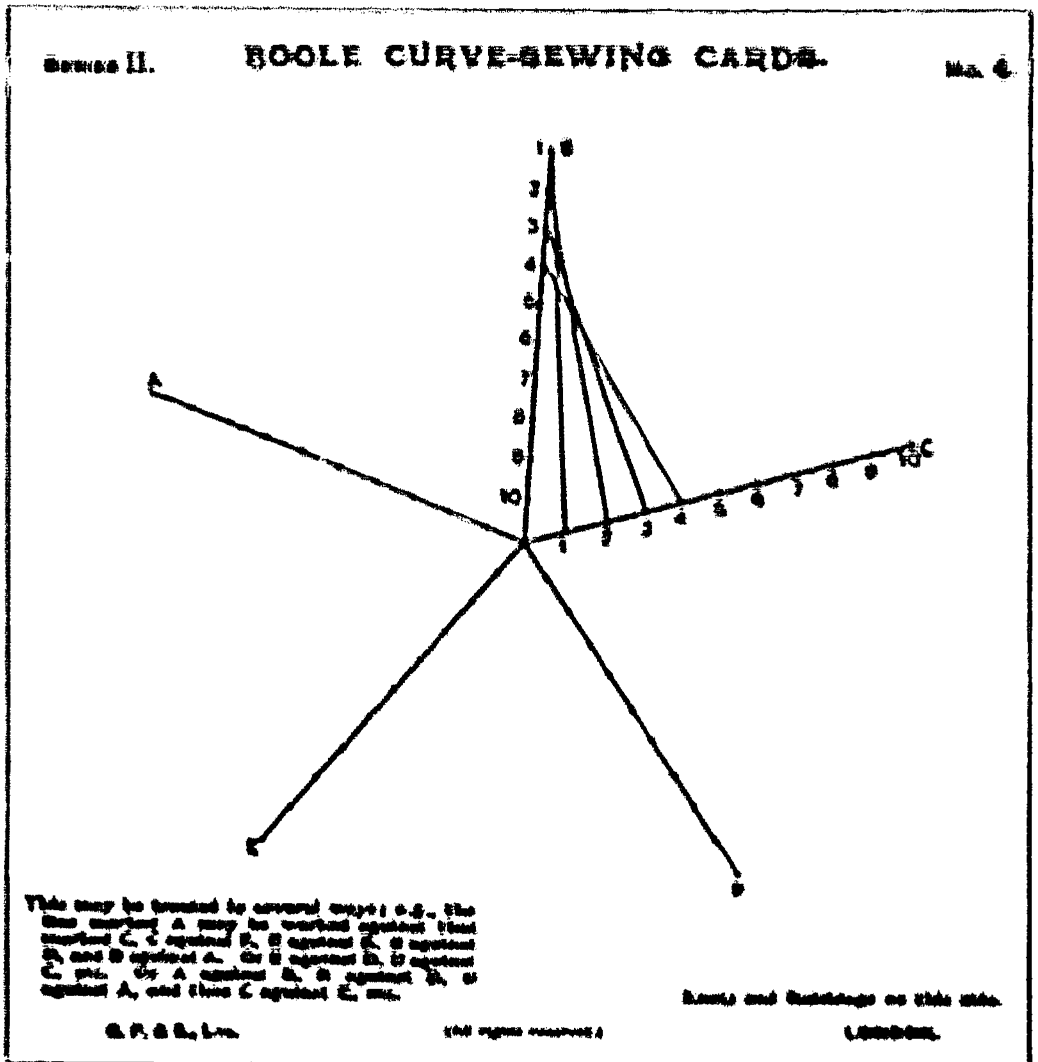


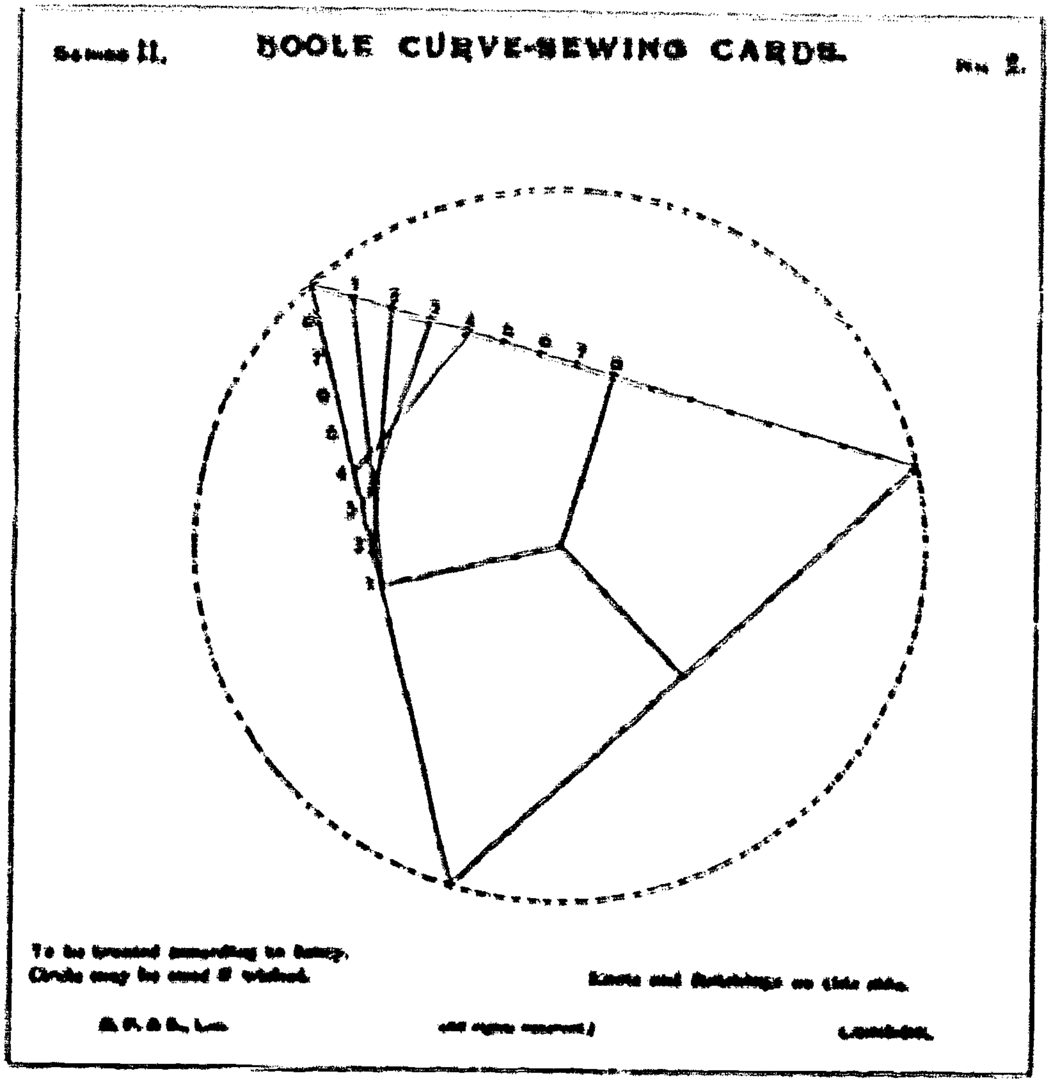
Experiment with other designs.

Make your own numbered shapes. Try coloring your designs like the illustration below. Many attractive designs can be made this way.



Here are pictures of two of Mary Boole's cards with numbers added in a few places. Connect the points in the usual way and watch the curved designs appear. Try connecting different edges. See how the designs change.





LINE DESIGNS by Dale Seymour, Linda Silvey and Joyce Snider is a book which suggests many more ideas you can try. (Creative Publications, P.O. Box 10328, Palo Alto, CA 94303)

SHADE ALL MULTIPLES OF 2 AND 3

EMMY NOETHER
1882-1935

An Ordinary Childhood

Emmy Noether was the greatest woman mathematician in the history of mathematics up to her time. Yet, when she was a young girl, no one would have predicted greatness for her.

Emmy was born in 1882, the oldest child in her family. She had three brothers, but two of them died at a young age. Her brother, Fritz, was two years younger than Emmy.

The Noether family lived in Erlangen, Germany. They were Jewish and, as part of their tradition they honored learning.

Emmy's father, Max, was a mathematics professor and research scientist at the University of Erlangen. He was a kind, jolly sort of man. Her mother, whose name was Ida Amalie, was a typical "hausfrau" who kept a tidy, well-run household.

For her entire childhood, Emmy lived in the same apartment in Erlangen. She was very near-sighted and wore thick glasses. She learned the skills that were taught to girls of the middle class. She learned to play the clavier, which is something like the piano. She cooked and dusted. She liked going to family parties where there was dancing. Emmy loved to dance.

Her life might have been that of any ordinary housewife. But, just about that time, young women in Germany were admitted to universities to earn degrees. Now a career in science was open to her.

Emmy was friendly and cheerful. She also was clever. From the start, she liked languages and studied French and English. When she finished high school, she took a test and was certified to teach French and English in schools for girls. If she had to, she could now earn her living. Life was following the expected pattern for a young woman of her time and place.

But Emmy's was not an ordinary family. Not only was her father a mathematician, her brother Fritz was following in his footsteps. Fritz entered the University of Erlangen to study mathematics. Emmy was eighteen and began to sit in on classes at the University. She did this for two years.

She took the examinations for entrance as a doctoral student in mathematics and passed. Now she was a student in good standing.

Five years later, she received her doctoral degree. She was the second woman in the history of the University to receive a doctoral degree in mathematics. (The first woman received her degree the year before Emmy.)

A Degree But No Job

Emmy Noether was ready for her career. There was only one problem: no women were permitted to take jobs as mathematics professors in her city, or indeed, anywhere in Germany!

Emmy worked without pay at the Mathematics Institute in Erlangen. Partly, she helped her father in his work and partly she worked on her own research. Sometimes she taught in her father's place when he was sick. She worked this way for the next ten years—from 1909 to 1919. Slowly, her reputation grew. She began to publish papers about her work. In her lifetime she published forty-five papers.

The first world war began in 1914. Emmy was a pacifist. She had high hopes that this terrible war would end and there would be a lasting peace in Germany. In 1918, Germany lost the war. The German monarchy was overthrown, the country became a republic, and women were given the vote. But even though Emmy could vote, she still received no salary whatsoever for her job.

A Growing Reputation

Two great mathematicians, Felix Klein and David Hilbert, were working at the University of Gottingen in Germany. They heard of Emmy and thought she could help them in their work on Einstein's general theory of relativity. They invited her to move to Gottingen in the hope that she could join the faculty.

But there were no women on the Gottingen faculty. Other faculty members said, "What will our soldiers think when they return to the University and find they are expected to learn at the feet of a woman?" Most German women were housewives. Prejudice against women ran high if they tried to become anything else.

Throughout these arguments between Hilbert and the rest of the faculty at Gottingen Emmy remained serene. She did not become bitter. She thought people were good, and kept that belief uppermost in her mind.

Emmy was now thirty-seven years old, and her reputation as a brilliant mathematician was growing fast. Finally, she received a place as a lecturer at the University of Gottingen. Instead of teaching for other professors, she could now teach courses under her own name. Three years after this, she finally received a small salary. This was timely because Germany's post-war economy was attacked by inflation, and money from her family's estate, which had helped to support her, petered out.

The Noether Boys

Emmy gathered a group of students around her at Gottingen. Her growing success as a mathematician attracted outstanding students. They came from Russia, the Netherlands, and other countries. They made a lively group--these "Noether Boys." (Years later, when Emmy taught at a women's college in the United States, her group was known as the "Noether Girls.")

Emmy's style of teaching was confusing. Her explanations were, as her student Van der Weyden put it, "rattled off at top speed." She would launch into these explanations, feverishly writing symbols on the board, leaving unfinished sentences in her wake, and a group of puzzled students sitting in front of her. Perhaps, being so near-sighted, she never noticed their puzzled expressions.

Once, after she had given a lecture to a large group of students--some regular students and some visitors--one passed a note up to her. It read, "The visitors have understood the lecture just as well as any of the regular students." (Or as badly!)

But not all of her students lacked understanding. A few, who were patient and attentive, caught on and became loyal followers. They learned to snatch the ideas she flung out, and put them to use in their own research. In this way, they advanced and became distinguished mathematicians in their own right. They never forgot their debt to Emmy Noether, and some gave her credit in their own works.

One of her former students, Alexandroff, invited her to Russia to the University of Moscow. He later wrote about her visit: "Emmy Noether very easily fit herself in with our life . . . she lived in a modest room in the KSU hostel near the Crimean Bridge, and most of the time she walked to the University. She was very much interested in the life of our country, especially in the life of Soviet young people. . ."

All during the twenties, Emmy's work in algebra progressed. Her work was part of the new algebra. Her work did not rely on adding or multiplying numbers or solving equations. Instead, her work in algebra dealt with ideas.

A Brilliant Mind, A Warm Personality

Emmy never hoarded her brilliant ideas like a miser. She was generous with her genius. Her students were like her own family. She was interested in their personal lives, and listened to their problems. She was "warm, like a loaf of bread," said Herman Weyl, one of her biographers.

Emmy had a deep voice, like a man's, and it was loud too. She laughed heartily. Though she was not tall, she was heavy-set. She looked solid, earth-bound. Yet her ideas soared with ease and grace, as did her lively spirit.

Departing the Homeland

In 1833, the Nazis, who had come to power in Germany with Hitler at their head, demanded that Jews be thrown out of all university positions. Emmy's brother, Fritz, had to move with his family to Siberia, where he was offered a position at the University of Tomsk. Emmy too had to leave Gottingen, and the beloved country of her birth. One of her Russian students, and a good friend, Alexandroff, desperately tried to secure a place for her at the University of Moscow. But before he could do this, American friends found her a job as visiting professor at Bryn Mawr, a wo[illegible]'s college near Philadelphia. Here, Emmy moved in 1933, when she was fifty-one yea[illegible]

A Woman Mathematician in America

Besides teaching and doing research at Bryn Mawr College, she gave weekly lectures at the nearby Institute for Advanced Study in Princeton, New Jersey, where Albert Einstein and other famous German refugees now worked.

As a professor at Bryn Mawr, Emmy Noether made quite an impression. A woman who was a student at Bryn Mawr at that time, Betty Morrow Bacon, recalls meeting Emmy soon after her arrival in America.

"Before she came we were told, 'This is one of the great people alive in the world today. It is an honor to have her at Bryn Mawr.'

"When I first saw her striding across the campus, I felt a little scared. Her expression seemed stern and forbidding. She was large and solid-looking and she wore a long dress. She didn't speak. She was not at all like other people I knew.

"There was a faraway look on her face, as though her mind was not in this world at all. What was she thinking of? Maybe she missed her old life in Germany. Maybe higher mathematics filled her thoughts. I never knew. . ."

Another student at Bryn Mawr, a graduate student in mathematics, Grace Shover Quinn, recalls her impressions of Emmy after she was settled into her new life at Bryn Mawr.

Emmy Noether . . . "was around five feet four inches tall and slightly rotund in build . . . she had a way of turning her head aside and looking into the distance when trying to think while talking. . . Her lectures were delivered in broken English. She often lapsed into her native German when she was bothered by some idea in lecturing . . .

"She loved to walk. She would take her students off for a jaunt on a Saturday afternoon. On these trips she would become so absorbed in her conversation on mathematics that she would forget about the traffic and her students would need to protect her."

Anna Pell Wheeler was Head of the Mathematics Department at Bryn Mawr. Professor Wheeler had studied at the University of Gottingen and understood the German life style. She could appreciate how Emmy's career was blocked in Germany because of her sex. She could understand the shock of being uprooted from the German culture, and transplanted to another world.

This was the first time Emmy had a department head who was both a mathematician and a woman. Up to this time, all her colleagues were men. When Emmy's old friends and former students came to Bryn Mawr to visit her, she introduced Professor Wheeler as her good friend.

Death: A Great Shock

In 1935, Emmy Noether entered the hospital to have an operation. She was getting well at the hospital when, suddenly, complications set in. Within hours she was dead--a great shock to her unsuspecting friends all over the world.

Emmy did not write about herself. Unlike her great mathematics ancestor, Sonya Kovalevskaya, she wrote no autobiography. But others talked of her and they remembered her.

Soon after her death her Russian friend, Alexandroff, gave a talk to the Moscow Mathematical Society. He said, "Emmy Noether . . . was the greatest of women mathematicians, a great scientist, an amazing teacher, and an unforgettable person . . ."

ABSTRACT ALGEBRA

Emmy Noether worked in a part of mathematics that is called abstract algebra. This kind of algebra is quite different from the algebra you learn in school.

In abstract algebra people talk about GROUPS and RINGS and FIELDS. Fields are more complicated than rings, and rings are more complicated than groups. Believe it or not, the simplest arithmetic you learn in school is far more complicated than many examples of groups or fields or rings.

If you don't believe this, try these examples.

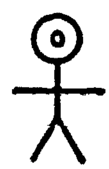
Meet Sticky

Imagine a stick figure that can move only its two arms . . . and these two arms can move only up or down.

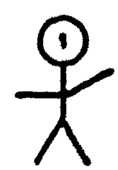
Suppose we want to describe the motions Sticky can do. If we do so in a certain way, we can turn Sticky and Sticky's motions into a full-fledged mathematical animal called a group.

Let's think about the four possible ways that Sticky can move. Let's label these four ways 0, 1, 2, and 3.

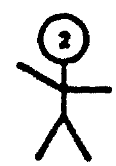
This is MOTION ⓪
Here Sticky does not move at all.



This is MOTION ①
Here Sticky moves right arm once.*



This is MOTION ②
Here Sticky moves left arm once.



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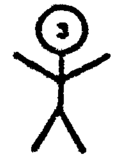
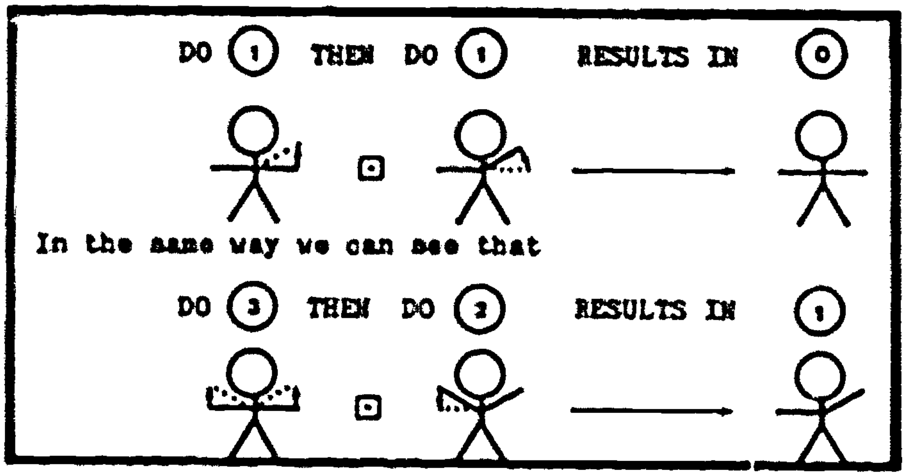
* By "move once" we mean, if arm(s) is straight out it moves UP. If arm(s) is UP, it moves STRAIGHT OUT.

This is MOTION 3.
Here Sticky moves both arms once.



If Sticky moves right arm twice, Sticky will be back in first position.
So we can write an **EQUATION.**

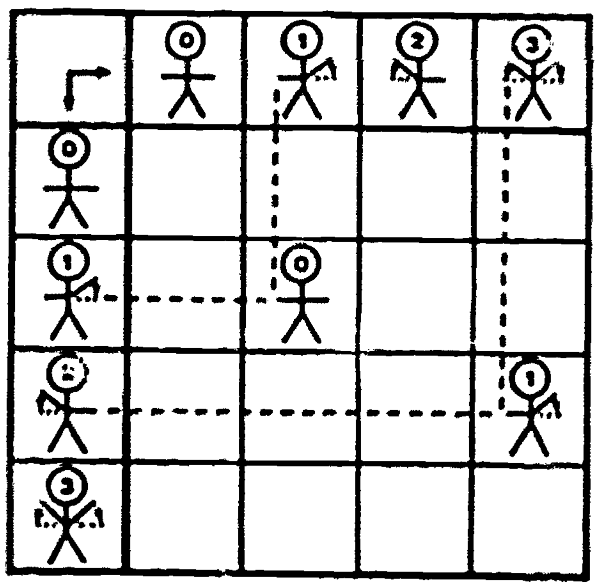
Just as we have learned in ordinary arithmetic that 3+3=6, we can say here:



See if you can fill in the table below. For each square first do the motion that the figure at the top is doing; then do the motion that the figure at the side is doing.

How do you end up?

That's the answer. Put this answer in the appropriate square.



Do you see that the figures in the squares make a pattern?

CLOCK ARITHMETIC

Another example of a group is the special arithmetic called clock arithmetic.

- Think about the face of a round old-fashioned clock.
- How many numbers do you see on it?

Suppose it is 10:00. You tell your friend you will be back in 3 hours. What time will you be back? Right you are. You will be back at 1:00.

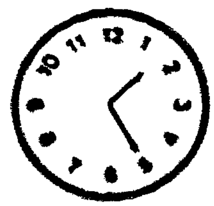
You can write a funny-looking arithmetic sentence . . . $10 \oplus 3 = 1$

Notice the circle around the +. That tells those who know, that we're doing addition around a circle. This is the special clock arithmetic. Look at the clock and finish the following sentences.

$5 \oplus 8 =$ ________

$8 \oplus 5 =$ ________

$11 \oplus 4 =$ ________



In ordinary arithmetic

$3 + 2 = 5$

$1 + 4 = 5$

$2 + 3 = 5$

$4 + 1 = 5$

$0 + 5 = 5$

$5 + 0 = 5$

These are all the different ways you can make 5 by adding just two whole numbers.

How about clock arithmetic?

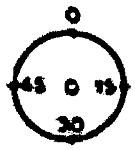
In clock arithmetic, how many ways can you make 5?

You can say that $11 \oplus 6 = 5$

$10 \oplus 7 = 5$

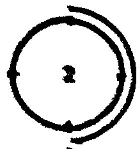
I'm sure you can think of many other ways.

Now let us consider a very simple example of clock arithmetic and its solution in the square at the bottom of the page. This clock has only 4 positions that matter. We can think of these as follow:

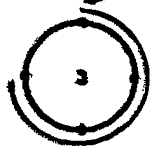


0 means stay where you are.

1 means move head 15 minutes.



2 means move ahead 30 minutes.



3 means move ahead 45 minutes.

Now do the additions as you did before, and complete the squares.

- Remember, 1 + 1 = 2 means move one step clockwise. Then move one more step clockwise, and you've arrived at position 2.

How about a 2 + 2 = __________?

- Notice the pattern of numbers when you've completed the square.

+	0	1	2	3
0				
1				
2				
3				

- Compare the difference in the patterns of the clock square and the Sticky square.

The pattern in each square comes out of exactly 4 numbers (or elements) and a rule for combining them.

- Why are the solution patterns different for these two squares?

Emmy Noether's work gave mathematicians new tools to solve old problems. In particular, she developed important new ways of classifying these kinds of situations in rings, the next more complicated structure after groups.

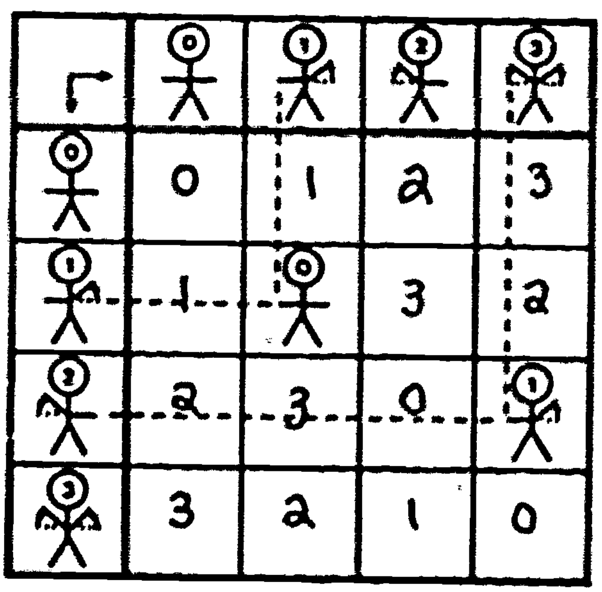
COMMON MULTIPLES OF 2 AND 3

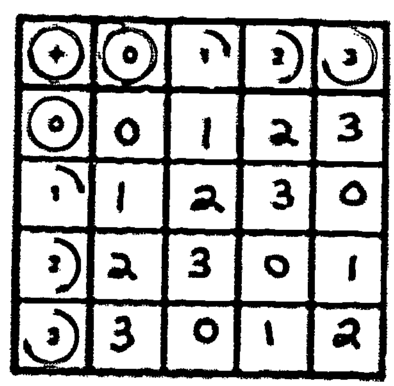
- All numbers that are common multiples of 2 and 3 are numbers that are multiples of 2 as well as multiples of 3.
- All multiples of 2 are even numbers. Therefore common multiples of 2 and 3 are even multiples of 3.
- See page 95 for details on "multiples of 3" test.

Using common multiples of 2 and 3, shade in Emmy Noether's picture on page 68

SOLUTIONS:

- Notice that for both squares, each number appears only once per row and column.
- If you were to fold the large square along the northwest/southeast diagonal, each half would match. This diagonal is a line of mirror symmetry.
- Notice how the number patterns differ for each square.





LENORE BLUM

LENORE BLUM

LENORE BLUM
1944-

A Tropical Paradise

The airplane carrying the two girls descended, and the city of Caracas, Venezuela, rose up to meet them. It was the dry season and fires in the mountains caught their eye. They saw small aircraft dropping chemicals to put out the flames. As they approached the airfield, the sun illuminated a landscape of palm trees and flowers, modern buildings and streets. To Lenore, the older one, this was paradise, and it was her new home!

Lenore and her sister had left their home in New York. The whole family was coming to live in South America. Here, Lenore's father hoped to make a good living in the import-export business.

The drive from the Caracas airport to their new home was full of strange sights. An attempted revolution was taking place. Opposition forces, who wanted to overthrow the dictator, had thrown tacks in the streets to puncture tires and disrupt the city. Christmas trees were tied to front fenders of cars to sweep away the tacks.

Their lodgings were wonderful--several rooms rented in a large house. Views from second-story windows showed the lush mountains. For the first time in her life she had a back yard. Unknown in New York! In the yard, a parrot squawked--gorgeous, brilliant-hued, tropical.

Lenore was nine and her sister, Harriet, was seven. They were going to attend the local school where only Spanish was spoken and no "foreigners" were enrolled. This would be quite a change for Lenore. Most of her friends had been American in the old school. Many were Jewish as she was; in fact, in New York she had hardly known anyone who was not Jewish.

65th Avenue, Queens

Home in New York had been an apartment on 65th Avenue in Queens. Her earliest memory was standing at the window watching her father, Irving, when he arrived home after World War II. From the candy store on the corner, she bought a Yiddish newspaper, "The Forward," for her grandmother, who lived with the family. Her grandmother spoke only Yiddish. Lenore understood Yiddish, and although she didn't speak it herself, she translated her grandmother's words into English when people came to visit.

When she was young, relatives commented to each other, "How artistic Lenore is!" Art was her favorite activity, though she usually didn't show her projects to others. One time she used an orange as a base and built a hand puppet from papier mache, using strips of newspaper and paint. The puppet had blond hair made from wool yarn. It was different from anything that could be bought in the stores. It had "personality."

Lenore visited libraries and museums with relatives and even by herself. She loved the dinosaurs at the Museum of Natural History and the wild animal habitats. Sometimes she traveled by subway to the New York Public Library and the great museums in Manhattan--the Metropolitan Museum of Art and the Museum of Modern Art. They filled her with wonder.

Her cousins, Ellen and Shelley, lived in her neighborhood and they, Harriet and she played together. This was in the early days of television and on one program, called "The Magic Cottage," children applied through the mail to be on the show and win prizes. All four girls eagerly applied. Shelley and Harriet were chosen. Ellen and Lenore talked and persuaded, persuaded and talked until the other two gave in. Ellen and Lenore appeared on the show.

Many of the prizes were of some value, such as a child's record player. But Lenore saw just what she wanted: a puppet which folded up into its own little case!

"Why didn't you pick the record player? It's much more valuable," the grownups wanted to know. Valuable? To the others, maybe, but not to Lenore.

Growing Up

The women in Lenore's family were very proud of their professions and she grew up with the idea that a profession was a very important thing for a woman to have. Rose, Lenore's mother, taught science in a New York high school. At one time she had studied to become a doctor. Rose's sisters often came to the house to visit Lenore's grandmother. Two of these women were lawyers and a third was a teacher.

They often spoke of their older brother, Sol, who had become a medical doctor. Though he had died at the age of 32, his presence was strongly felt. As the oldest child of an immigrant family, he had led the way.

Every now and then Lenore would take from the hall closet a violin that belonged to her Uncle Sol. She was like this uncle; she would do something special. It didn't really matter to her that later, when she took violin lessons, she showed no talent for the instrument. What mattered was that she felt there was a tradition of scholarship for her to follow.

Lenore went to a progressive school which didn't give grades. She loved school and loved the summers at Far Rockaway beach where she played with her sister and her cousins. She used New York, the largest American city, as her playground. She had plenty of free time. No one kept close track of her. This suited her perfectly.

There was one flaw, a fear that came and went: her beloved grandma might become ill when no one else was there. But the years of her childhood passed and her fear was never realized. Suddenly, she was moving away to South America.

South American Scenes

Caracas, Venezuela, in South America, was another link in the golden chain of events in the child's life. Lenore's first glimpse of the city confirmed her belief that good things would always happen to her.

The first day of school shattered the perfect picture. The boys in the class had learned a few words of English from American movies. "I love you," they whispered as they ran around the two American girls. How humiliating!

Then there was the principal. Here were two young American "ninas" who "no hablan Espanol." But they must learn to speak Spanish--pronto! The principal would teach them one hour each day in his office, beginning with the subjunctive tense of the verb.

Disaster! Lenore hadn't learned grammar even in her native English.

A further humiliation: school officials put Lenore back a grade so that her age would match her classmates. In the classroom the teacher, Senorita Candelaria, used a method of teaching that was altogether strange to Lenore. The students were given blue "cuadernos" or notebooks. They had to copy stories and pictures into their notebooks over and over until they matched those in their textbooks. Every cuaderno in Lenore's class looked exactly alike!

Meanwhile, right outside the windows, lay a city which at that time was one of the most beautiful in the world. Such a bright world, too, after sunless days in New York.

Two weeks was all Lenore lasted. "I quit!" she announced to her parents. And that went for her sister, too.

A Year of Freedom

Lenore's mother was a veteran teacher. School, in any country, held no secrets for her. Far better, from her point of view, to educate her daughters by exploring this brand new place than to leave them in the local school.

So the decision was made. For one year, Lenore, going on ten years old, and her sister, seven, did not go to school at all. Instead, they traveled on buses each day with their mother. They took in all the sights of the city. No formal lessons now, only informal ones that the city and its inhabitants had to teach. At the end of the day they went to the cafe where the "foreigners" met. The girls ordered ice cream sodas. Life became much easier for Lenore.

Homesickness

But another feeling crept in--homesickness. Lenore expressed it by writing a poem. It spoke about all the things she had left behind, about Thanksgiving, about her grandma. It was filled with longing. Her poem won a prize and was published in the English language newspaper, the "Caracas Daily Journal."

She also made a pencil sketch of her grandmother. The background for the sketch was engraved in Lenore's memory: the comfortable cushioned chair her grandmother had sat in, the gooseneck lamp so the elderly woman could sew and read the newspaper, the wall paper with its pink and rose flowers, the photograph of her grandmother's parents--

Russian peasants in kerchief and cap--mounted on the wall, the piano bench on one side of the chair and the little table for her sewing on the other.

But try as she might, Lenore couldn't get her grandmother's face right, not the way it really was. She left the sketch unfinished.

A new year started. A decision would have to be made about the girls' education. Seventy thousand Americans lived in Venezuela. They were oil company employees and their families. Many were wealthy and they had their own schools. The one in Caracas was called Escuela Campo Alegre.

Escuela Campo Alegre--The American School

Lenore's family could not afford the tuition at this school so Lenore's mother went back to work, teaching at the American school. Lenore and Harriet began classes there.

In mathematics, long division was being taught. The teacher gave an explanation. Lenore understood instantly. In fact, she understood all the new work. Though she had fallen behind because of the year's absence, she caught up and moved to the top of her class. From then on, until she graduated from high school at the age of sixteen, Lenore was the top student and mathematics was her favorite subject. Although she was a girl and the best student in mathematics, the others did not look down on her. They simply thought she was "different." Lenore made plenty of friends.

An Impression

Her family met another Jewish family in Caracas. There were four sons in the family. The oldest, whose name was Manuel, was serious and a little shy. From their first meeting Lenore made room in her heart for this boy. He was like her; they were simpatico. He was the one she would one day marry.

Lenore rarely saw Manuel in the next few years. He was four years older than she and soon went off to the States to study at the Massachusetts Institute of Technology (MIT). But he had made an impression.

Los Pavos

Like many teenagers, Lenore had many images of how she wanted to be. She was trying out a variety of roles and sometimes her actions seemed contradictory, even to herself.

When she was in high school, her friends were "los pavos," which was Caracas slang meaning the fast crowd. One day, while she was riding with a boyfriend on his motorcycle, they had an accident and crashed. Lenore fell on her head. She felt the wound where blood was clotting.

"My brains! My brains are spilling out!" thought the panicky thirteen-year-old. But, with only a head patch and two weeks' time, she was well again. Then and there she decided that motorcycles were not worth the risk.

Cars, clothes, bikes and romances were part of the American school scene. Money was thrown around and parties were frequent. Lenore's parents were tolerant. To them, she was the older daughter, the little girl who had taken care of her grandmother so faithfully. They set no limits, so Lenore set her own: a 1:30 curfew, and she never came home later.

A Coup

When Lenore first arrived in Caracas, an attempted revolution was taking place. Five years later, on New Years Day in 1958, the dictator, Colonel Marcos Perez Jimenez, was finally overthrown. The citizens of Caracas were jubilant. The hated secret police fled and ordinary people ran the country. Boy Scouts directed traffic and university students helped maintain order. Sometimes students who were friends of Lenore's took her with them on their patrols after the curfew fell at night. She loved being part of the excitement. The controlling junta--the new ruling group--promised elections in the fall. Every five years thereafter, free elections have taken place in Venezuela.

Searching for a Profession

Mathematics was Lenore's favorite subject. Instruction in mathematics at the high school Lenore attended was poor, and so she learned a whole year of mathematics on her own. When she expressed an interest in going on with mathematics in college, her teacher advised against it.

"Everything important was discovered 2000 years ago," he told her. "You don't want to go into a dead field."

Was that true? The sixteen-year-old transplanted New Yorker did not know. All she knew was when she looked at a proof on the board, her heart swelled. "It's so beautiful, so perfect." Mathematics cared for no one's opinion. Mathematics was, that was all.

Buildings, beautiful modern concrete forms were springing up all over the city of Caracas. Architecture was exciting, creative. Here was a career field that combined her two loves--mathematics and art. That is what her college major would be.

But where to apply? To MIT, of course, where Manuel was and where so much exciting work was being done.

To Lenore, MIT was the pinnacle, but, to her great dismay, she was not admitted. In response to her application, MIT officials said, "We have only twenty beds in the girls' dormitories and incoming students must live on campus." Only very few women were accepted. [This excuse of dormitory space was corrected some years later. One of the first women to graduate from MIT, Katharine McCormick, gave a large sum of money to be used solely to build a dormitory for women students.] Lenore decided to go to Carnegie Institute of Technology in Pittsburgh, Pennsylvania, instead.

Graduation Summer

Lenore was valedictorian of her high school graduating class. Manuel came to Caracas for the ceremony, and her senior prom was their first date. That summer, the two young people talked about many things: Freud and modern psychology, philosophy, and the make-up of the brain. A neuron could be expressed mathematically. Fascinating! More than ever now, she looked forward to college.

From Caracas to Pittsburgh

Pittsburgh was an industrial town, a maker of steel--old and dingy. Quite the opposite of sparkling Caracas. The students of architecture at Carnegie Tech were very serious about their career goals. They worked together in a room that took up an entire floor of a building. Often they worked through the night to finish projects. Older students offered criticism and advice. Everyone was helpful and friendly.

Mathematics is an important tool for architects and they were interested in learning formulas. Lenore on the other hand, was interested in learning where these formulas came from and why. She missed the beauty of mathematics.

In her second year at Carnegie Tech, Lenore changed her major from architecture to mathematics. She knew immediately that she had made the right choice.

Marriage and MIT

Lenore was now eighteen years old and she and Manuel married. They moved to Boston and rented a small apartment. The young couple's home was open to a growing circle of friends.

Manuel worked in Warren McCulloch's Neuro-Physiology Lab at MIT. Here people from all over the world--from Australia, England, Israel, Holland, Italy--came to work. These people were electrical engineers, mathe'mati'cians, philosophers, biologists, psychologists. They came together to work on a common problem--the understanding of the brain.

Lenore's and Manuel's apartment became a gathering place for the young people in the evenings. Eating, singing and playing drums in the small living room gave way to lively debates. One might recite a jazzed-up version of "Jabberwocky," a poem by Lewis Carroll. A poem by William Blake could start a discussion about infinity (and other mysterious ideas) that would last through the night.

"To see a World in a grain of sand,
And a Heaven in a wildflower,
Hold Infinity in the palm of your hand,
And Eternity in an hour."

"Auguries of Innocence,"
first stanza, by William Blake.

Continuing College

Since she was now living in Boston, Lenore applied and was accepted at Simmons, a women's college. She hadn't the courage to apply again to MIT.

Mathematics classes at Simmons were not sophisticated enough. The college administrators agreed to send Lenore to MIT to take a course in modern algebra. The teacher was Isadore Singer.

"Here was a class with substance, depth, pace--everything I'd imagined a good course to be. It was hard, it was deep, it was abstract . . . I trusted this guy who was teaching it. He was a top mathematical researcher. The topics were important; they were leading somewhere. He wasn't just reading it out of a book." Lenore was transformed!

She was very quiet in class. She didn't know where she stood. She was just grateful to be there. The class was huge, nearly 100 students. Lenore finished the semester as one of the top students. Yet, when she applied to the graduate program in the Mathematics Department, she was told by the admissions officer, "MIT is no place for women. Here is a list of fine graduate schools. Apply to these," the man told her. "I would give my own daughters the same advice."

Lenore felt devastated. It looked as though she would again be turned down by the only place she wanted to go, a place where exciting mathematics was happening.

That weekend, there was a party at MIT and Professor Singer was there. He overheard a group of people discussing "the girl who wants to enroll in the graduate mathematics program."

"Who was she?" Singer wondered. It was Lenore Blum. Professor Singer spoke up: she was one of his best students.

Within a few days Lenore received a letter of acceptance from MIT. (Times have changed. Today, MIT brochures state, "MIT is a place for women.")

Graduate School

Lenore decided she would start off graduate school with a bang. Most people took two or three courses each semester. Lenore would take eight. It was said that if a woman married she would not finish the program. Lenore was married and she would finish. It was said that a woman with a baby would drop out. Lenore would have a baby and remain. In spite of everything she would continue.

At first, life was difficult. Eight courses were more than anyone could handle. Lenore dropped them one by one.

Manuel had his group he was on her own. Her co-workers were not used to working with a woman eq: ne even tried to drive a wedge between her and Manuel, for reasons Lenore couldn't fathom.

There were two other women in her class, both married and both with babies. But even though they had surely met similar obstacles, there was no feeling of being involved in a common struggle.

Nevertheless, later on in the program, an older woman student spent a lot of time helping Lenore prepare for the crucial oral examinations. Lenore began to realize how women could help women.

A Fantastic Baby

She and Manuel had planned the arrival of their baby to coincide with the end of the school year. They took natural childbirth classes, which were quite unusual at the time, and on the last day of classes, went directly from MIT to the hospital to have the baby.

Lenore nursed her new baby, whose name was Avrim. He was " . . . so fantastic. We really had a lot of love for him right from the start." She was very happy.

Lenore, Manuel and Baby Avrim were always on the go. The new parents eagerly tried out the newest in baby gear such as paper diapers, infant seats and porta-cribs.

Child care centers were very rare. Babysitters were hard to come by. Fortunately, Manuel had an office in the basement at MIT and they cared for the baby there.

Working on a Thesis: Logic and Algebra

Lenore went on with her work. She did not wait for an advisor to set her to work on a topic. She found her own topic which became her thesis.

Some mathematicians were successfully using new methods of logic to solve old problems in algebra. What an intriguing idea! Lenore taught herself logic and carefully studied these methods and how they were applied. She wanted to understand why they worked. She thought and thought about this from many different angles.

But what to do with Avrim? He was now a toddler and needed a lot of attention. Fortunately, during this period, Lenore's mother was able to come to Boston to help care for him.

MIT had set aside a group of rooms especially for women students. This is where Lenore would work. The rooms were located right under the famous MIT dome in the main building. Here she made herself at home. She brought her papers and books and set up her working space.

Lenore became engrossed in study and thought. Sometimes she worked through the night. She bought food from the vending machines in the basement and slept in the lounge. Day turned into night. She lost track of time.

Slowly patterns started to emerge. Lenore began to see common features in the problems she was studying. She realized that one simple but powerful rule could solve them all. She understood this rule so well that she could explain it to the logic group in the mathematics department and show them why it worked.

This rule and its proof became her first theorem. Later she used this rule to discover new results in algebra herself. This work was to become her thesis, but first she needed an advisor.

A logic professor, Gerald Sacks, had recently come to MIT and was enthusiastic about Lenore's work. He was the natural choice. She became part of the logic group and was included in all their discussions and talks. Now she really belonged!

People who were respected in her field came to hear about her work when she defended her thesis. The work she did earned her the doctoral degree. She received a post-doctoral fellowship and could go to work any place she chose for one year.

Berkeley was the obvious place to go. The mathematics department was one of the best in the country. A famous logician, Julia Robinson, lived there, and Manuel had a job offer, there as well. [Julia Robinson was the first woman appointed Professor in the Berkeley Mathematics Department, the first woman elected to the National Academy of Sciences, and the first woman president of the American Mathematical Society.]

Berkeley, California

Politics was part of the Berkeley scene. It was 1968. People marched in the streets. They demonstrated against the war in Vietnam. They gathered to protest turning a park into a parking lot. They talked and they organized. Out of the Free Speech Movement came a new spirit. It was an exciting time.

Bright blue skies and Spanish tile roofs nestling in green hills reminded her of Caracas. People wore colorful, free-flowing clothing. Lenore felt she was coming home.

During her post-doctoral year at Berkeley, Lenore received several job offers. People at Yale were eager to work with her and offered her a position as assistant professor. She had offers from MIT and from Berkeley. Manuel had a job at Berkeley and so Lenore took the Berkeley offer, even though it was the lowest rank. The position was lecturer in mathematics.

These were important things to consider but Lenore did not realize this at the time. Although discussions with her employers raised her hopes, no tenure or job security went with the position. What was worse, she had no professional group at Berkeley to support her career growth.

A Turn of Events

After two years as lecturer at Berkeley, Lenore was told she would not be re-hired. People assumed she would become another faculty wife. Lenore's talent and training prepared her to work at the highest level. But there were no women in positions at that level at any of the top mathematics departments in the country. What to do?

About this time three concerned professors in the Berkeley Mathematics Department [Moe Hirsch, John Rhodes, and Steve Smale] sponsored a series of talks on mathematics and social responsibility. Lenore was asked to organize a panel on women and mathematics. She gathered together scholars [Ravenna Helson, Sheila Johannsen, and Elizabeth Scott] who spoke about the history of women in mathematics and their present status. Several hundred people packed the lecture hall; this was the first such panel anywhere in the country. All of a sudden, Lenore became known as the expert on women and mathematics on the West Coast.

On the East Coast, women mathematicians had also begun to organize. That winter Mary Gray, of American University, led a protest at the mathematics meetings in Atlantic City. She wanted women to be part of the decision-making groups in the mathematics societies. During the spring, Mary issued a Newsletter and called for support. The Association for Women in Mathematics (AWM) had begun.

At first, Lenore was reluctant to join. She wanted to be known as a mathematician not as a *woman* mathematician. But soon she became convinced: the situation for women in mathematics would not change without the AWM. [Mary Gray was the first president of the AWM and Alice Schafer of Wellesley College the second. Later, Lenore became president. Other presidents have been Judy Roitman of the University of Kansas, and Bhama Srinivasan of the University of Illinois at Chicago Circle.]

The AWM and Change

It was 1971 and the beginning of a new era for Lenore and other women mathematicians. They spoke out. They wrote letters. They sponsored talks and panels and debates. In their newsletter, they pointed out how it was harder, sometimes impossible, for women mathematicians to get good jobs. They asked tough questions and they were not always popular. But they gained courage and support from one another.

For the first time, Lenore made friends with women who understood and valued her work. Two of these women, Judy Roitman, a logician and Bonnie Miller, an astrophysicist, were particularly important for Lenore.

"Without their friendship, I could not have accomplished what I have," she says. "When I felt down and out, they boosted my spirits. And when things went well, they cheered me on. Even today, we keep in close touch, though we now live in different parts of the country."

The situation began to change. By the middle of the 1970's, women mathematicians were becoming more visible. They were invited to present their research results at important professional meetings. They were elected to high positions in the professional associations. This kind of activity is very important for the career growth of mathematicians.

By the end of the 1970's, women mathematicians were getting better jobs, some in top departments. Indeed, by its tenth birthday, the AWM had brought about many important changes for women in mathematics.

A New Direction

In the fall of 1973, Lenore was hired to teach a class in college algebra at Mills College, a women's college in Oakland, California. She thought the course was dull. It repeated high school work and didn't seem to lead anywhere. In the middle of it she said, "I am going to teach you something much more useful--calculus!" Then and there, she realized that a carefully designed "pre-calculus" course could open doors for many women.

Some girls drop mathematics in high school because they think it's hard and boring. They think it's not important for their future. Then, when they get to college, they want to enter fields like medicine, business, engineering and computer science, which require a knowledge of higher mathematics. A good pre-calculus course can introduce them to calculus and higher mathematic[illegible] It helps bridge a gap for women students.

Lenore helped her students feel the excitement of mathematics and helped them gain confidence so they could really do it. She taught them to look for pictures in equations. Is it a straight line? Is it a rising curve? She showed them that people solve problems in different ways. Sometimes, guessing is a good way.

She said, "You can learn these things; you don't have to be born a math whiz."

Lenore always knew that what she was saying was much bigger than this one class. This one class grew into a program. Lenore became Head of the new Department of Mathematics and Computer Science at Mills College.

Students at Mills started to study calculus, computer science, statistics--courses that would help women enter fields that they did not even think of in the past. Some new fields for women to consider were science, engineering, medicine and economics. By 1980, more students at Mills were taking classes in mathematics and computer science than in any other subject. They were also getting summer jobs in these technical fields. What a change!

The Math/Science Network

Meanwhile, progress was being made on other fronts. At the Lawrence Hall of Science in Berkeley, after-school classes in mathematics and science were being offered for grade school students. Nancy Kreinberg, a director of the program, noticed that very few girls were taking these classes. She decided to do something about this. She started "Math for Girls."

"Math for Girls" is a special class for six- to twelve-year-olds. Here, young girls get together to solve puzzles and play challenging games--activities which help develop important problem-solving skills. Their teachers are college women who enjoy mathematics, science and engineering.

Nancy worked with young girls and Lenore worked with college women, but soon they found out they had a lot in common. One summer aft[illegible] 1975, they met with like-minded scientists and educators to share ideas. Quickly [illegible]alized they were onto something big. They could combine many resources and talents in the community and create a powerful force for change. The Math/Science Network was on its way!

Lenore and Nancy took their message across the country.

"Encourage young women to take as much mathematics as they can," they said. "It's important for their future." Thousands and thousands of young women heard this message as they attended Network events.

It was thrilling to make important things happen. But where was the little girl who liked to go off, do mathematics, make drawings, and dream?

Pulling in the Reins

With the coming of the 1980's, Lenore pulled in the reins. She decided to return to her work as a research mathematician.

Taking a leave of absence for a year from Mills College, Lenore returned to MIT. Manuel and Avrim, her family, stayed on the West Coast, where Lenore visited them frequently. She continued to lecture at universities around the country on women and mathematics.

Back to Research: Mathematics and Computer Science

In her research, Lenore uses mathematics to study why some problems are hard for computers and why some are easy--and why some problems can't even be solved at all!

Several years earlier, she and Manuel had written a paper together. They were interested in designing computers that could learn from examples in much the same way young children do. Lenore's new work explores these ideas further.

Research goes very slowly. "Some days," Lenore says, "I may sit at my desk for hours and scribble only a few lines. But each day, my understanding increases, and I begin to see things fall into place. I view my work as the beginning of a ten-year program."

Finding interconnections between her work and other projects, working among creative people who value her work--these are Lenore's rewards.

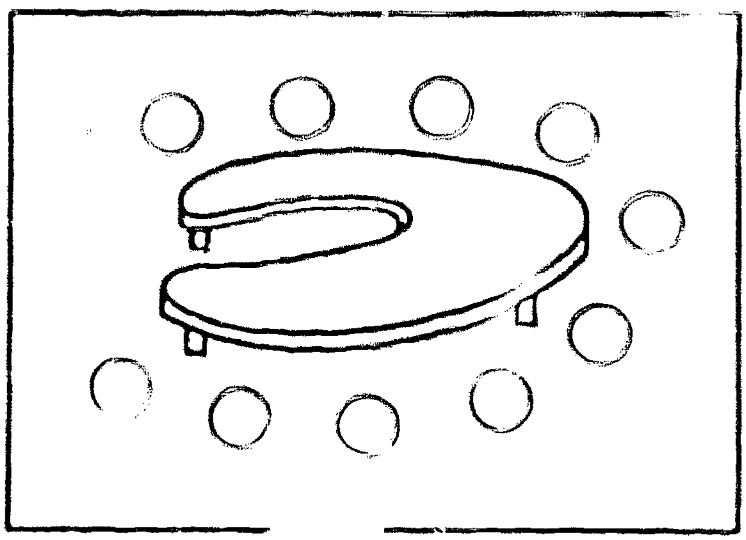
"It's exciting," she says, "to talk with other people and see how what we do fits together."

The Math-Science Network Today

Lenore helped start the Math/Science Network, a San Francisco-based group. The Network encourages young women to study mathematics in order to qualify for many careers, such as engineering, medicine, and computer science.

The Math/Science Network meets once a month. At the meetings people talk while seated around a horseshoe-shaped table. Let's pretend that there are ten people at this meeting. Who is sitting where? Can you figure it out?

Lenore is seated to the left of Len (not necessarily next to). Elizabeth is to the left of Lenore. Nancy is between Rita and Len, with Rita on her right. Elizabeth is to the right of Diane and Carol is left of Len. Carol is between Jan and Elizabeth. Flora is between Lenore and Elizabeth. Oh yes! And Lucy comes in late, walks to the end of the table, and sits down next to Rita.



(Move names on slips of paper. Much easier that way!)

MULTIPLES OF 3

There is an easy way to find out whether a number is a multiple of 3, since all multiples of 3 have a digital sum that is 3, or 6, or 9.

What is a digital sum?

You know what an ordinary sum is. A digital sum is the result of adding digits. Every number has a digital sum which is found by adding its digits. Here are some examples of how to find the digital sum of a number.

- 26 is a two digit number. Its digits are 2 and 6. Its digital sum is 8 since 2 + 6 = 8.

- 45 is another two digit number. Its digits are 4 and 5. Its digital sum is 9 since 4 + 5 = 9. (45 is also a multiple of 3 since its digital sum is 9.)

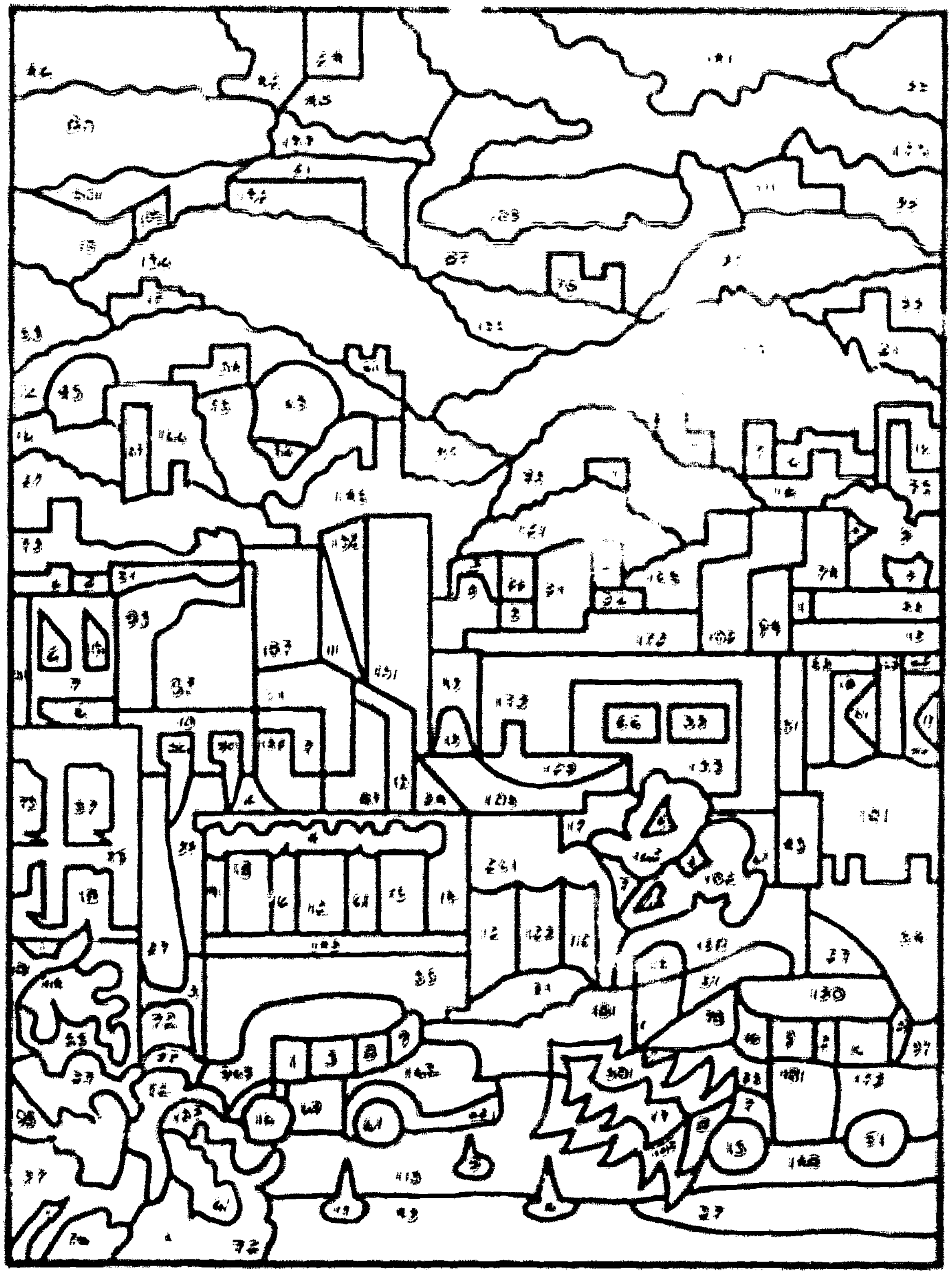
- To find the digital sum of 458, add 4 + 5 + 8 to get 17. Since 17 is not a one digit number it is not the digital sum we need. Continue to add 1 + 7 to get 8 which is the digital sum of 458. (Remember, the digital sum we want to look at is a one digit number from 1 through 9.)

- To find the digital sum of 525 add 5 + 2 + 5 to get 12. Then add 1 + 2 to get 3 which is the digital sum of 525. Since 3 is a multiple of 3, 525 is also a multiple of 3. (If you don't believe this, divide 525 by 3 to convince yourself.)

Practice your new, fast, test for multiples of 3. Shade all multiples of 3 to complete the picture of Caracas on p. 96.

CARACAS

SHADE ALL MULTIPLES OF 3



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