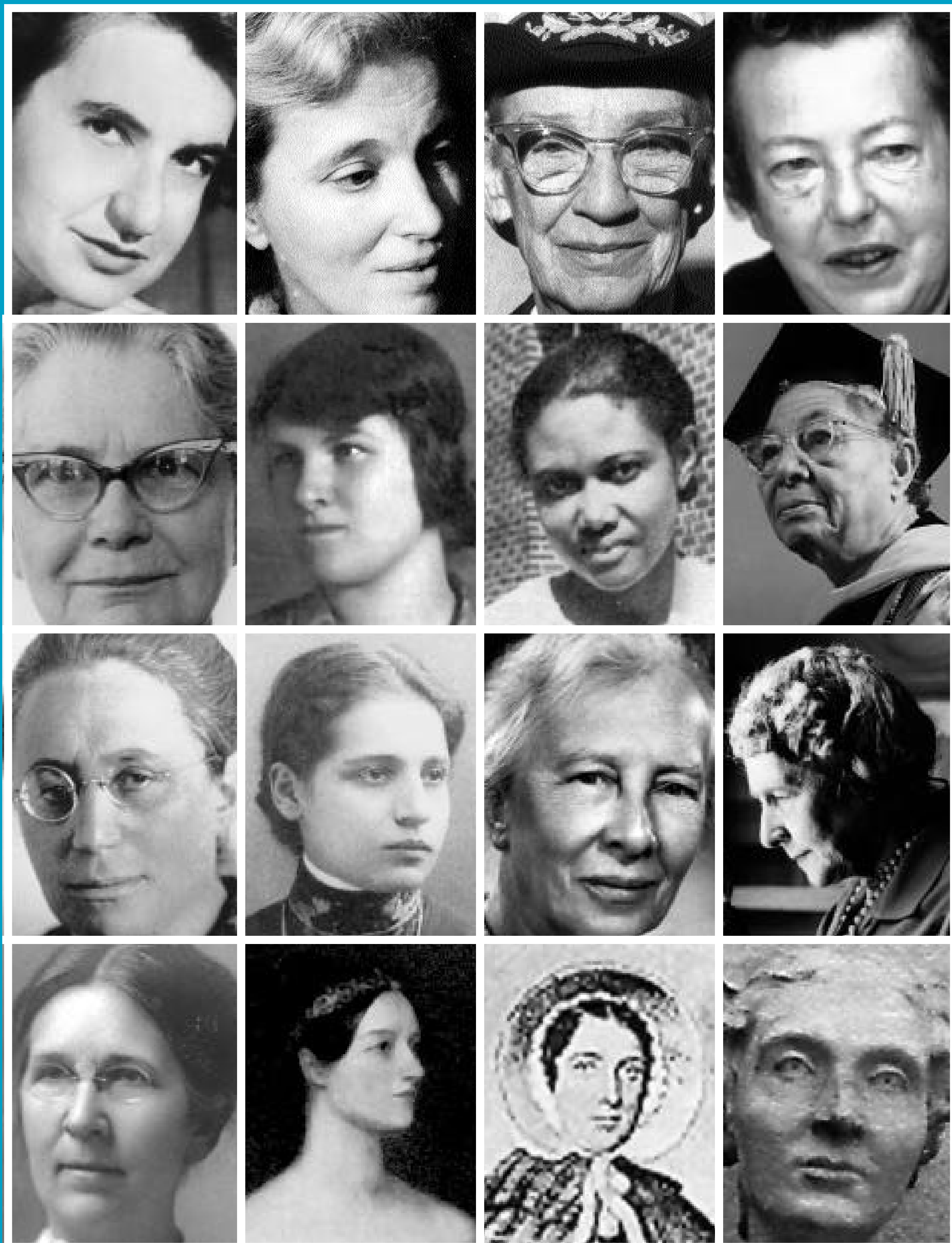

WOMEN IN SCIENCE

A Selection of 16 Significant Contributors

INTRODUCTION

The women scientists profiled here span several centuries and several nationalities. Despite many barriers, women all over the world have participated in unraveling the secrets of nature since the dawn of civilization. As historian of science Naomi Oreskes said recently, "The question is not why there haven't been more women in science; the question is rather why we have not heard more about them." Most of the women whose stories are told here, in fact, were active in recent times, when the sciences had already become professionalized endeavors.

This publication stems from a project undertaken at the San Diego Supercomputer Center (SDSC) in early 1997, when a new wing was added to the center's building. It featured a classroom designed for workshops in the most advanced computational and visualization techniques. The classroom was furnished with 16 new Silicon Graphics workstations*

The machines had Internet addresses, which were strings of numbers, but since humans misremember numbers, they all needed memorable names as well. To recognize the several educational programs that SDSC directs at girls and young women interested in careers in the sciences,† we named each machine after a woman who had a career in or made a significant contribution to a scientific discipline. Brief biographies were written for each woman selected, and these were put on the walls of the classroom. They were also gathered in this pamphlet, which we hope to distribute to audiences beyond our computational laboratory.

Many of the women celebrated here were mathematicians, physicists, or astronomers, all fields strongly related to the computational sciences. But there are also two biologists, two biochemists, a geological pioneer, a doctor, and an industrial psychologist, which is also appropriate, as these fields are also developing significant computational components.

The common thread running through their stories is their record of accomplishment. Each was able to make a significant contribution and each achieved recognition in her field. To one degree or another, all of these women faced obstacles to their scientific work that arose simply because they were women. Many were hardly permitted to get an education; some were allowed to work only without the pay or privileges accorded to men doing the same work. Engaging in normal scientific collaborations was an impossibility for some and a great difficulty for others, barred as they were from the milieux in which male scientists met and conversed.

But these women in science were also women specifically situated in time and place. They also struggled in common with their male counterparts against fascism, racism, and discrimination based on class and ethnicity. Some achieved such pinnacles as the Nobel Prize, while others have been nearly lost to history. We find that, in simply naming some computers, we have been privileged to enter a rich historical territory, one little enough explored—and we invite you to share it with us. ■

ACKNOWLEDGMENTS

Many individuals helped gather the information and pictures presented here. Those whom we are delighted to thank include Bonnie Bird, Executive Secretary, The Royal Astronomical Society; Clare Bunce and the PRstaff at Cold Spring Harbor Laboratory; Lynda Claassen, Steve Coy, and Bradley Westerbrook, UCSD Libraries, Mandeville Special Collections; Deborah Day, Archivist, Scripps Institution of Oceanography, UCSD; Leo Dolenski, Bryn Mawr College; Patrice Donoghue, Assistant Curator, Harvard University Archives; Joyce Hansen, Austin Hansen Collection, Schomburg Center; Leon and Cynthia Pitts Harkleroad, Cornell University Department of Mathematics and Cornell Theory Center; Dorothy Kaupe, San Diego Historical Society; Purdue University Technical Information Service; Ruth Sime, Sacramento City College; Hugh Torrens, Keele University; Agnes Túska, Mathematics Department, California State University, Fresno; and Tom Zinnen, Pam Peters, and Vivian Lee Ward, Access Excellence Web Site. We also wish to acknowledge our colleague Anke Kamrath, who asked for help in naming the machines, and our leader, Ann Redelfs, Director of External Relations at SDSC, for her steady encouragement. —*MM and LS*

* *Specifically, these were Indigo 2 "Killer Impact" workstations with R10000 processors, 128 Mbytes of memory apiece, fast Ethernet cards, and videoconferencing hardware. A significant discount obtained from Silicon Graphics, Inc., enabled SDSC to inaugurate the new classroom.*

† *These include a Girl Scout Science Interest Group and an ongoing program directed at young and minority high-school level women; see the SDSC web site for more information: http://www.sdsc.edu/Education/.*

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ROSALIND ELSIE FRANKLIN

BORN: LONDON, ENGLAND, JULY 25, 1920
DIED: LONDON, ENGLAND, APRIL 16, 1958

Pioneer Molecular Biologist

There is probably no other woman scientist with as much controversy surrounding her life and work as Rosalind Franklin. Franklin was responsible for much of the research and discovery work that led to the understanding of the structure of deoxyribonucleic acid, DNA. The story of DNA is a tale of competition and intrigue, told one way in James Watson's book *The Double Helix*, and quite another in Anne Sayre's study, *Rosalind Franklin and DNA*. James Watson, Francis Crick, and Maurice Wilkins received a Nobel Prize for the double-helix model of DNA in 1962, four years after Franklin's death at age 37 from ovarian cancer.

Franklin excelled at science and attended one of the few girls' schools in London that taught physics and chemistry. When she was 15, she decided to become a scientist. Her father was decidedly against higher education for women and wanted Rosalind to be a social worker. Ultimately he relented, and in 1938 she enrolled at Newnham College, Cambridge, graduating in 1941. She held a graduate fellowship for a year, but quit in 1942 to work at the British Coal Utilization Research Association, where she made fundamental studies of carbon and graphite microstructures. This work was the basis of her doctorate in physical chemistry, which she earned from Cambridge University in 1945.

After Cambridge, she spent three productive years (1947-1950) in Paris at the Laboratoire Central des Services Chimiques de L'Etat, where she learned X-ray diffraction techniques. In 1951, she returned to England as a research associate in John Randall's laboratory at King's College, Cambridge.

It was in Randall's lab that she crossed paths with Maurice Wilkins. She and Wilkins led separate research groups and had separate projects, although both were concerned with DNA. When Randall gave Franklin responsibility for her DNA project, no one had worked on it for months. Wilkins was away at the time, and when he returned he misunderstood her role, behaving as though she were a technical assistant. Both scientists were actually peers. His mistake, acknowledged but never overcome, was not surprising given the climate for women at Cambridge then. Only males were allowed in the university dining rooms, and after hours Franklin's colleagues went to men-only pubs.

But Franklin persisted on the DNA project. J. D. Bernal called her X-ray photographs of DNA, "the most beautiful X-ray photographs of any substance ever taken." Between 1951 and 1953 Rosalind Franklin came very close to solving the DNA structure. She was beaten to publication by Crick and Watson in part because of the friction between Wilkins and herself. At one point, Wilkins showed Watson one of Franklin's crystallographic portraits of DNA. When he saw the picture, the solution became apparent to him, and the results went into an article in *Nature* almost immediately. Franklin's work did appear as a supporting article in the same issue of the journal.

A debate about the amount of credit due to Franklin continues. What is clear is that she did have a meaningful role in learning the structure of DNA and that she was a scientist of the first rank. Franklin moved to J. D. Bernal's lab at Birkbeck College, where she did very fruitful work on the tobacco mosaic virus. She also began work on the polio virus. In the summer of 1956, Rosalind Franklin became ill with cancer. She died less than two years later. ■

DOROTHY CROWFOOT HODGKIN, OM

BORN: CAIRO, EGYPT, MAY 12, 1910
DIED: SHIPSTON-ON-STOUR, ENGLAND, JULY 29, 1994

A Founder of Protein Crystallography

Scientific biographers do not, in general, find much correlation between good character and great science. There are a few exceptions. Historians have unanimously agreed, for example, that Charles Darwin was a particularly admirable, even lovable, figure: a collegial scientist, devoted father, faithful supporter of young colleagues, sincere, honest, and without personal enemies.

The Darwin of our age is certainly Dorothy Crowfoot Hodgkin. In the words of colleague Max Perutz (Nobelist for his solution of the hemoglobin molecule), she was "a great chemist, a saintly, gentle and tolerant lover of people, and a devoted protagonist of peace." In a short space it is impossible to discuss both the significance of her science and the scope of her tireless activity for world peace.

Concentrating first on her contributions to science, she is known as a founder of the science of protein crystallography. She and her mentor, J.D. Bernal, were the first to successfully apply X-ray diffraction to crystals of biological substances, beginning with pepsin in 1934. Hodgkin's contributions to crystallography included solutions of the structures of cholesterol, lactoglobulin, ferritin, tobacco mosaic virus, penicillin, vitamin B-12, and insulin (a solution on which she worked for 34 years), as well as the development of methods for indexing and processing X-ray intensities. After the work with Bernal, she established her own laboratory at Oxford, described in the memoirs of her many students as an unfailingly joyful and productive environment.*

The challenges were always huge, as every new technique seemed to reach limits that constrained the size of protein that could be successfully solved, and each protein tackled presented special problems of its own. Hodgkin was elected a Fellow of the Royal Society in 1947 after publishing the structure of penicillin and was awarded the Nobel Prize in Chemistry in 1964 for her solution of vitamin B-12. The solution of the insulin structure came in 1969, after many years of struggle. Hodgkin and her collaborators produced a more refined solution in 1988, one that took full advantage of computational techniques that can now reduce the time for protein solutions from years to months or weeks.

Hodgkin was the first of four daughters of John and Grace Crowfoot. Her father was an archaeologist working for the Ministry of Education in Cairo and her mother, an accomplished artist, was an expert on Coptic textiles. Dorothy married Thomas Hodgkin, an expert in African Studies, in 1937, and they had three children.

Hodgkin's role in the arena of science policy and international relations was a constant complement to her own scientific work. The entire family distinguished itself over more than three decades by working in the public arena for the cause of world peace. She belonged to many international peace organizations and, owing to Cold War restrictions, was not permitted to obtain a U.S. visa until 1990. Although she was over 80 and extremely crippled by rheumatoid arthritis, she lost no time in making a grand tour of U.S. institutions to discuss insulin, the history of crystallography, and its future. Her talks drew standing-room-only crowds at every stop. She suffered a stroke and died in 1994. ■

* *Guy Dodson, Jenny P. Glusker, and David Sayre (Eds.), 1981:* Structural studies on molecules of biological interest: A volume in honour of Professor Dorothy Hodgkin. *(Oxford: The Clarendon Press).*

ADMIRAL GRACE MURRAY HOPPER

BORN: NEW YORK, NEW YORK, DECEMBER 9, 1906
DIED: ARLINGTON, VIRGINIA, JANUARY 1, 1992

Pioneer Computer Scientist

The new discipline of computing and the sciences that depend upon it have led the way in making space for women's participation on an equal basis. That was in some ways true for Grace Murray Hopper, and it is all the more true for women today because of Hopper's work.

Grace Brewster Murray graduated from Vassar with a B.A. in mathematics in 1928 and worked under algebraist Oystein Ore at Yale for her M.A. (1930) and Ph.D. (1934). She married Vincent Foster Hopper, an educator, in 1930 and began teaching mathematics at Vassar in 1931. She had achieved the rank of associate professor in 1941 when she won a faculty fellowship for study at New York University's Courant Institute for Mathematics.

Hopper had come from a family with military traditions, thus it was not surprising to anyone when she resigned her Vassar post to join the Navy WAVES (Women Accepted for Voluntary Emergency Service) in December 1943. She was commissioned a lieutenant in July 1944 and reported to the Bureau of Ordnance Computation Project at Harvard University, where she was the third person to join the research team of professor (and Naval Reserve lieutenant) Howard H. Aiken. She recalled that he greeted her with the words, "Where the hell have you been?" and pointed to his electromechanical Mark I computing machine, saying "Here, compute the coefficients of the arc tangent series by next Thursday."

Hopper plunged in and learned to program the machine, putting together a 500-page *Manual of Operations for the Automatic Sequence-Controlled Calculator* in which she outlined the fundamental operating principles of computing machines. By the end of World War II in 1945, Hopper was working on the Mark II version of the machine. Although her marriage was dissolved at this point, and though she had no children, she did not resume her maiden name. Hopper was appointed to the Harvard faculty as a research fellow, and in 1949 she joined the newly formed Eckert-Mauchly Corporation.

Hopper never again held only one job at a time. She remained associated with Eckert-Mauchly and its successors (Remington-Rand, Sperry-Rand, and Univac) until her official "retirement" in 1971. Her work took her back and forth among institutions in the military, private industry, business, and academe. In December 1983 she was promoted to commodore in a ceremony at the White House. When the post of commodore was merged with that of rear admiral, two years later, she became Admiral Hopper. She was one of the first software engineers and, indeed, one of the most incisive strategic "futurists" in the world of computing.

Perhaps her best-known contribution to computing was the invention of the *compiler*, the intermediate program that translates English language instructions into the language of the target computer. She did this, she said, because she was lazy and hoped that "the programmer may return to being a mathematician." Her work embodied or foreshadowed enormous numbers of developments that are now the bones of digital computing: subroutines, formula translation, relative addressing, the linking loader, code optimization, and even symbolic manipulation of the kind embodied in *Mathematica* and *Maple*.

Throughout her life, it was her service to her country of which she was most proud. Appropriately, Admiral Hopper was buried with full Naval honors at Arlington National Cemetery on January 7, 1992. ■

MARIA GOEPPERT-MAYER

BORN: KATTOWITZE, GERMANY, JULY 28, 1906
DIED: LA JOLLA, CALIFORNIA, FEBRUARY 20, 1972

Nobelist in Physics

Maria Goeppert-Mayer developed the nuclear shell model of atomic nuclei, an achievement honored when she became the third woman ever awarded the Nobel Prize for physics, in 1963. She shared the prize with J. Hans D. Jensen, who had independently developed a similar model, and with theoretician Eugene Wigner.

Although she lived a life of scholarly privilege, with the support of her family and many notable scientists, she was not able to secure full-time work in her field until she was 53. Mayer performed most of her scientific work as a volunteer.

Maria Göppert came from a family of academics. Her father was a professor of pediatrics and the seventh generation of university scholars in his family. When Maria was four, he moved the family from Kattowitze to Göttingen so he could teach there. Maria idolized her father. It was expected that she acquire an education because of her family pedigree in academics. Maria attended a small private school that prepared girls for the university entrance exams. In 1924 she enrolled at Göttingen in mathematics.

Göttingen was then a world center for physics (and the new study of quantum mechanics). The Göppert family had friends who were prominent scientists, and Maria's social contacts included Niels Bohr and her teacher, Max Born. While attending Born's physics seminar, Maria decided to study physics instead of mathematics. Born's other students included Fermi, Oppenheimer, Dirac, and von Neumann. Maria thrived in this environment. For her dissertation (1930), she calculated the probability that an electron orbiting an atom's nucleus would emit two photons of light as it jumped to an orbit closer to the nucleus. Her challenging calculation was confirmed experimentally in the 1960s.

Maria married physical chemist Joseph E. Mayer in 1930 and together they moved to Baltimore, where Joe was a professor at Johns Hopkins. Maria adopted a hyphenated form of their names and anglicized the spelling. She had an attic office and a mixed assortment of honorary job titles, but no pay. She nevertheless produced ten papers, a textbook, and her daughter Maria Ann during her time in Baltimore. She was pregnant with her son John in 1938, when Joe unexpectedly lost his job. They left Hopkins for Columbia University.

There, they wrote a classic textbook, *Statistical Mechanics*. Again, Goeppert-Mayer had office space, but no pay. During the Second World War, she worked on uranium isotope separation, under Harold Urey and others who helped develop the atom bomb. After the war, the Columbia physicists moved to Chicago, and the Mayers followed.

Maria worked at the Institute for Nuclear Studies at the University of Chicago and at the Argonne National Laboratory. In 1948 she started her work on the nuclear shell model. Chicago received her willingly and gave her great respect, but no salary. In 1956, she was elected to the National Academy of Sciences. Three years later, she and Joe accepted professorships at the new University of California campus at San Diego.

When the Nobel Prize was awarded to her in 1963, a San Diego newspaper ran the headline "S.D. Mother Wins Nobel Prize." Shortly afterward, her health began to decline and she died in 1972. ■

HELEN SAWYER HOGG

BORN: LOWELL, MASSACHUSETTS, AUGUST 1, 1905
DIED: RICHMOND HILL, ONTARIO, JANUARY 28, 1993

A Gift of Stars

An astronomer who brought the gift of the stars to everyone, Helen Sawyer Hogg led a life of remarkable achievement. She is well known for her research on variable stars in globular clusters, but she is perhaps best remembered for her astronomy column, which ran in the *Toronto Star* from 1951 to 1981. Helen wanted everyone to find the same joy in the stars that she did. She encouraged women to enter science, and her students remember her for her enthusiasm and warmth.

She entered Mount Holyoke College with the intention of studying chemistry, but in 1925 she changed her mind and began her study of astronomy. Her decision was fixed permanently a year later when Annie Jump Cannon visited Mount Holyoke. Indeed, on graduating in 1926, Sawyer went to the Harvard Observatory to work with Cannon and Harlow Shapley on star clusters. She obtained her doctorate in 1931 from Radcliffe College. (Harvard did not give graduate degrees in science to women at that time.)

In 1930, she married Frank Hogg, a fellow astronomy student at Harvard. Together they moved to Victoria, British Columbia, to work at the Dominion Astrophysical Observatory where Frank had a job. Helen was not hired with her husband, and she had to work as his volunteer assistant.

Hogg started her work on variable stars in globular clusters while in Victoria. She developed a technique for measuring the distance of galaxies beyond the Milky Way. She took pictures of variable stars and catalogued the cyclical changes in their brightness, which she then used to calculate their distance. Her detailed observations were published in catalogs that are still used today.

In 1935, the family moved to Ontario so that Frank could take a job at the University of Toronto. Helen became an assistant at the David Dunlop Observatory, where she would work until her death. She also taught at the University of Toronto and became a professor in 1957. In 1940-1941 she was a visiting professor and acting chair of the department of astronomy at Mount Holyoke College, and in 1955-1956 she was a program director in astronomy for the National Science Foundation. She was considered a world expert on the night sky.

In 1950 she won the Annie Jump Cannon prize of the American Astronomical Society. In 1967 she was awarded the Centennial Medal of Canada and in 1976 she was made a Companion of the Order of Canada—one of the highest honors in the nation. She became the first woman president of the physical sciences section of the Royal Society of Canada in 1960. She was also the first female president of the Royal Canadian Institute (1964-1965) and founding president of the Canadian Astronomical Society (1971-1972).

She remained active in astronomy until late in life. She published more than 200 papers during her long and distinguished career. In addition, she wrote *The Stars Belong to Everyone*, a popular guide to astronomy, and hosted an astronomy television series in the 1970s. Hogg received honorary degrees from six Canadian and U.S. universities. Both the Canadian National Museum of Science and Technology's observatory in Ottawa and the University of Toronto's southern observatory in Chile were named for her. When Helen Sawyer Hogg died of a heart attack in 1993, she had been a leading authority in astronomy for more than 60 years. ■

RÓZSA PÉTER

BORN: BUDAPEST, HUNGARY, FEBRUARY 17, 1905
DIED: BUDAPEST, HUNGARY, FEBRUARY 16, 1977

Founder of Recursive Function Theory

Rózsa Péter (originally Politzer) grew up in a country torn by war and civil strife in which simply living from day to day was never easy. She made major contributions to mathematical theory for which she received some recognition in her lifetime, but her name, which should be written together with the names of the founders of computational theory (Gödel, Turing, Church, Kleene), is all but forgotten today. In this, she no doubt shares the fate of other Eastern European scientists of the same period.

"No other field can offer, to such an extent as mathematics, the joy of discovery, which is perhaps the greatest human joy,"* said Rózsa Péter in her lectures to general audiences, which were often titled "Mathematics is Beautiful." In the mouth of another, this might be a naive effusion; for her, it was hard-won wisdom.

Péter enrolled at Eötvös Loránd University in 1922 with the intention of studying chemistry but soon discovered that her real interest was mathematics. She studied with world-famous mathematicians, including Lipót Fejér and Jósef Kürschák, and it was here that she met a longtime collaborator, László Kalmár, who first called her attention to the subject of recursive functions.

After she graduated in 1927, Péter lived by taking tutoring jobs and high-school teaching. She also began graduate studies. Kalmár told her about Gödel's work on the subject of incompleteness,† whereupon she devised her own, different proofs, focusing on the recursive functions used by Gödel. She gave a paper on the recursive functions at the International Congress of Mathematicians in Zurich in 1932, where she first proposed that such functions be studied as a separate subfield of mathematics. More papers followed, and she received her Ph.D. *summa cum laude* in 1935. In 1937, she became a contributing editor of the *Journal of Symbolic Logic*.

Forbidden to teach by the Fascist laws passed in 1939, and briefly confined to the ghetto in Budapest, Péter continued working during the war years. In 1943, she wrote and printed a book, *Playing with Infinity*, a discussion of ideas in number theory and logic for the lay reader. Many copies were destroyed by bombing and the book was not distributed until the war ended. She lost her brother and many friends and fellow mathematicians to Fascism, and a foreword to later editions of *Playing with Infinity*¶ memorializes them.

In 1945, the war over, she obtained her first regular position at the Budapest Teachers' College. In 1951 she published a monograph, *Recursive Functions*, which went through many editions and which earned her the state's Kossuth Award. When the teachers' college was closed in 1955, she became a professor at Eötvös Loránd University, until her retirement in 1975. In 1976, she published *Recursive Functions in Computer Theory*.

She was called Aunt Rózsa by generations of students and worked to increase opportunities in mathematics for girls and young women. She died on the eve of her birthday in 1977. In her eulogy, her student Ferenc Genzwein recalled that she taught "that facts are only good for bursting open the wrappings of the mind and spirit" in the "endless search for truth."§ ■

* *"Mathematics is Beautiful," an address delivered to high school teachers and students in 1963 and published in the journal* Mathematik in der Schule 2 *(1964), pp. 81-90. An English translation by Leon Harkleroad (Cornell University) was published in* The Mathematical Intelligencer 12 *(1990), pp. 58-64. We are indebted to Leon Harkleroad for permission to quote from published and unpublished materials.*

† *Related in "Rózsa Péter: Recursive Function Theory's Founding Mother," by Edie Morris (University of Louisville) and Leon Harkleroad, published with Péter's speech in* The Mathematical Intelligencer, *op. cit.*

¶ *Translated and published in the United States by Dover in 1976.*

§ *Translated by Leon Harkleroad, personal communication.*

ROGER ARLINER YOUNG

Born: Clifton Forge, Virginia, 1899
Died: New Orleans, November 9, 1964.

Lifelong Struggle of a Zoologist

Roger Arliner Young was the first African-American woman to receive a doctorate in zoology, after years of juggling research and teaching with the burden of caring for her invalid mother. Her story is one of grit and perseverance.

Roger Arliner Young grew up in Burgettstown, Pennsylvania. In 1916, she entered Howard University. In 1921, she took her first science course, under Ernest Everett Just, a prominent black biologist and head of the zoology department at Howard. Although her grades were poor, Just saw some promise and started mentoring Young. She graduated with a bachelor's degree in 1923.

Her relationship with Just improved her skills, and he continued working with her. According to his biographer, Just probably chose a woman protégé because he thought men more likely to pursue lucrative careers in medicine than to remain in academe.* Just helped Young find funding to attend graduate school.

In 1924 she entered the University of Chicago part-time. Her grades improved dramatically. She was asked to join Sigma Xi, an unusual honor for a master's student. She also began publishing her research. Her first article, "On the Excretory Apparatus in Paramecium," appeared in *Science* in September 1924. She obtained her master's degree in 1926.

Just invited Young to work with him during the summers at the Marine Biological Laboratory, Woods Hole, Massachusetts, starting in 1927. Young assisted him with research on the fertilization process in marine organisms. She also worked on the processes of hydration and dehydration in living cells. Her expertise grew, and Just called her a "real genius in zoology."

Early in 1929, Young stood in for Just as head of the Howard zoology department while Just worked on a grant project in Europe. It was the first of many trips to Europe for Just and the first of many stand-in appointments for Young. In the fall of that year, Young returned to Chicago to start a Ph.D. under the direction of Frank Lillie, the embryologist who had been Just's mentor at Woods Hole. But she failed her qualifying exams in January 1930.

She had given little indication of stress, but the failure to qualify was devastating. She was broke and still had to care for her mother. She left and told no one her whereabouts. Lillie, deeply concerned, wrote the president of Howard about her mental condition. She eventually returned to Howard to teach and continued working at Woods Hole in the summers, but her relationship with Just cooled considerably.

Just started easing her out of her position in 1933. There had been rumors about romance between Just and Young. Various accusations were exchanged. They had a confrontation in 1935, and in 1936 she was fired, ostensibly for missing classes and mistreating lab equipment.

She took her firing as an opportunity. In June 1937, she went to the University of Pennsylvania to begin a doctorate under L. V. Heilbrunn, who had befriended her at Woods Hole and gave her the aid she needed to continue. She earned her Ph.D. in 1940.

She took an assistant professorship at the North Carolina College for Negroes in Raleigh. Unfortunately, her mental health failed again. She worked short contracts in Texas and at Jackson State College in Mississippi. While in Mississippi in the late 1950s, she was hospitalized at the State Mental Asylum. She was discharged in 1962 and she went to Southern University in New Orleans. She died, poor and alone, on November 9, 1964. ■

* *Kenneth R. Manning, 1983:* Black Apollo of Science: The Life of Ernest Everett Just *(New York: Oxford University Press), p. 147.*

MAY EDWARD CHINN

BORN: GREAT BARRINGTON, MASS., APRIL 15, 1896
DIED: NEW YORK CITY, DECEMBER 1, 1980

Physician

May Edward Chinn did not plan on becoming a doctor. Originally she wanted to be a musician, but she changed from music to science after receiving encouragement from a professor at Columbia Teachers College. This fortuitous decision led to a distinguished career in medicine. When May Chinn died in 1980, she was the recipient of honorary degrees from New York University and Columbia University. Her work in cancer research helped in the development of the Pap smear, a test for early detection of cervical cancer. She was the first African-American woman to graduate from Bellevue Hospital Medical College, one of the first female African-American physicians in New York City, and the first African-American woman to intern at Harlem Hospital.

Chinn's father escaped slavery from a Virginia plantation at the age of 11. Her mother was an indigenous American from the Chickahominy tribe who placed great value on education. She worked as a live-in housekeeper for the Tiffanys, the well-known family of artisans and jewelers, in their mansion on Long Island. She saved money from her meager wages to send May to a boarding school in New Jersey, an experience which ended when May contracted osteomyelitis of the jaw and returned to New York for surgery. The Tiffanys treated young May as family and exposed her to music, which would become her lifelong hobby. They also taught her German and French. When patriarch Charles Tiffany died, May and her mother moved back to New York City.

Chinn continued her schooling but did not complete high school, she said, due to poverty and heartache over a lost boyfriend. She decided to take the entrance examinations for Columbia Teachers College on a whim, when a friend received a scholarship there. To her surprise, she passed the exams and enrolled in 1917. In her senior year, Chinn found a job in clinical pathology as a lab technician. She worked full time in the lab, completing her courses at night. She graduated in 1921 and continued working.

In 1926 she graduated from Bellevue Medical School and interned at Harlem Hospital. During this time she rode along with the paramedics on ambulance calls—and was the first woman to do it. She could not get privileges at the hospitals when she graduated, so she started her own family practice. She treated people who otherwise would not have received medical care and she often went into dangerous neighborhoods. Because of her interest in improving the health conditions of her patients in Harlem, she took a master's degree in Public Health from Columbia University in 1933.

During the 1940s, May Chinn became interested in the diseases of her elderly patients, many of whom developed cancer. Although she had finally received admitting privileges at Harlem Hospital in 1940, she could practice at no other hospital. She finally started working at the Strang Clinic, a cancer research facility, in 1944, and practiced there in addition to her private practice for 29 years. Chinn became a member of the Society of Surgical Oncology and in 1975 started a society to help African-American women go to medical school. She also served on the Surgeon-General's advisory committee on urban affairs. She did not retire from private practice until she was 81 years old. ■

EMMY NOETHER

BORN: ERLANGEN, GERMANY, MARCH 23, 1882
DIED: BRYN MAWR, PENNSYLVANIA, APRIL 14, 1935

Creative Mathematical Genius

It might be that Emmy Noether was designed for mathematical greatness. Her father Max was a math professor at the University of Erlangen. Scholarship was in her family; two of her three brothers became scientists as well. Emmy would surpass them all. Ultimately Max would become best known as Emmy Noether's father.

Amalie Emmy Noether spent an average childhood learning the arts that were expected of upper middle class girls. Girls were not allowed to attend the college preparatory schools. Instead, she went to a general "finishing school," and in 1900 was certified to teach English and French. But rather than teaching, she pursued a university education in mathematics

She audited classes at Erlangen as one of two women among thousands of men, then took the entrance exam. She entered the University of Göttingen in 1903, again as an auditor, and transferred back to Erlangen in 1904 when the university finally let women enroll. She received her mathematics Ph.D. in 1907.

Noether worked at the Mathematical Institute of Erlangen, without pay or title, from 1908 to 1915. It was during this time that she collaborated with the algebraist Ernst Otto Fischer and started work on the more general, theoretical algebra for which she would later be recognized. She also worked with the prominent mathematicians Hermann Minkowski, Felix Klein, and David Hilbert, whom she had met at Göttingen. In 1915 she joined the Mathematical Institute in Göttingen and started working with Klein and Hilbert on Einstein's general relativity theory. In 1918 she proved two theorems that were basic for both general relativity and elementary particle physics. One is still known as "Noether's Theorem."

But she still could not join the faculty at Göttingen University because of her gender. Noether was only allowed to lecture under Hilbert's name, as his assistant. Hilbert and Albert Einstein interceded for her, and in 1919 she obtained her permission to lecture, although still without a salary. In 1922 she became an "associate professor without tenure" and began to receive a small salary. Her status did not change while she remained at Göttingen, owing not only to prejudices against women, but also because she was a Jew, a Social Democrat, and a pacifist.*

During the 1920s Noether did foundational work on abstract algebra, working in group theory, ring theory, group representations, and number theory. Her mathematics would be very useful for physicists and crystallographers, but it was controversial then. There was debate whether mathematics should be conceptual and abstract (intuitionist) or more physically based and applied (constructionist). Noether's conceptual approach to algebra led to a body of principles unifying algebra, geometry, linear algebra, topology, and logic.

In 1928-29 she was a visiting professor at the University of Moscow. In 1930, she taught at Frankfurt. The International Mathematical Congress in Zurich asked her to give a plenary lecture in 1932, and in the same year she was awarded the prestigious Ackermann-Teubner Memorial Prize in mathematics.

Nevertheless, in April 1933 she was denied permission to teach by the Nazi government. It was too dangerous for her to stay in Germany, and in September she accepted a guest professorship at Bryn Mawr College. She also lectured at the Institute for Advanced Study in Princeton. The guest position was extended, but in April 1935 she had surgery to remove a uterine tumor and died from a postoperative infection. ■

* *Gottfried E. Noether, "Emmy Noether (1882-1935)," in Louise S. Grinstein and Paul J. Campbell:* Women of Mathematics: A Bibliographic Sourcebook *(New York, Greenwood Press), 1987, pp. 165-170.*

LISE MEITNER

Born: Vienna, Austria, November 7, 1878
Died: Cambridge, England, October 27, 1968

A Battle for Ultimate Truth

In 1945, the Royal Swedish Academy of Sciences awarded the Nobel Prize in Chemistry to Otto Hahn for the discovery of nuclear fission, overlooking the physicist Lise Meitner, who collaborated with him in the discovery and gave the first theoretical explanation of the fission process.

While Meitner was celebrated after World War II as "the mother of the atomic bomb," she had no role in it, and her true scientific contribution became, if anything, more obscure in subsequent years. A new biography by Ruth Lewin Sime* tells Meitner's often paradoxical story and sets forth the daily sequence of events that constituted the discovery of fission and, subsequently, the "forgetting" of the role of one discoverer.

Lise Meitner was the third of eight children of a Viennese Jewish family. In 1908, two of Lise's sisters became Catholics and she herself became a Protestant. While conscientious, these conversions counted for nothing after Hitler came to power. Owing to Austrian restrictions on female education, Lise Meitner only entered the University of Vienna in 1901. With Ludwig Boltzmann as her teacher, she learned quickly that physics was her calling. Years later, Meitner's nephew, Otto Robert Frisch, wrote that "Boltzmann gave her the vision of physics as a battle for ultimate truth, a vision she never lost."†

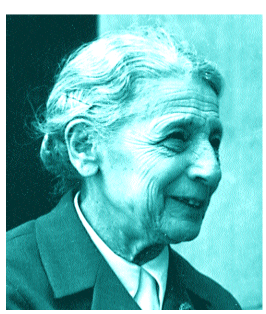
Doctorate in hand, she went to Berlin in 1907 to study with Max Planck. She began to work with a chemist, Otto Hahn, she doing the physics and he the chemistry of radioactive substances. The collaboration continued for 30 years, each heading a section in Berlin's Kaiser Wilhelm Institute for Chemistry. Together and independently they achieved important results in the new field of nuclear physics, competing with Irène Curie, Frédéric Joliot, and other foreign groups.

In 1934, Enrico Fermi produced radioactive isotopes by neutron bombardment, coming to a puzzle only with uranium. There were several products; were any of them transuranic elements? Meitner drew Hahn and also Fritz Strassmann into a new collaboration to probe the possibilities. By 1938, the puzzle had only grown.

After the *Anschluss* (German annexation of Austria in March 1938), Lise Meitner had to emigrate. In the summer of 1938, she went to Manne Siegbahn's institute in Stockholm. As Sime writes, "Neither asked to join Siegbahn's group nor given the resources to form her own, she had laboratory space but no collaborators, equipment, or technical support, not even her own set of keys..."¶ She corresponded with Hahn as he and Strassmann tried to identify their "transuranes."

On November 13, 1938, Hahn met secretly with Meitner in Copenhagen. At her suggestion, Hahn and Strassmann performed further tests on a uranium product they thought was radium. When they found that it was in fact barium, they published their results in *Naturwissenschaften* (January 6, 1939). Simultaneously, Meitner and Frisch explained (and named) nuclear fission, using Bohr's "liquid drop" model of the nucleus; their paper appeared in *Nature* (February 11, 1939). The proof of fission required Meitner's and Frisch's physical insight as much as the chemical findings of Hahn and Strassmann.

But the separation of the former collaborators and Lise's scientific and actual exile led to the Nobel committee's failure to understand her part in the work. Later Hahn rationalized her exclusion and others buried her role ever deeper. The Nobel "mistake," never acknowledged, was partly rectified in 1966, when Hahn, Meitner, and Strassmann were awarded the U.S. Fermi Prize. ■



* *Ruth Lewin Sime, 1996:* Lise Meitner: A Life in Physics *(University of California Press)*.

† Op. cit., *p. 17.*

¶ Ibid., *p. 219.*

LILLIAN MOLLER GILBRETH

BORN: OAKLAND, CALIFORNIA, MAY 24, 1878
DIED: PHOENIX, ARIZONA, JANUARY 2, 1972

Mother of Modern Management

Lillian Gilbreth was the mother of modern management. Together with her husband Frank, she pioneered industrial management techniques still in use today. She was one of the first "superwomen" to combine a career with her home life. She was a prolific author, the recipient of many honorary degrees, and the mother of 12. She is perhaps best remembered for motherhood. Her children wrote the popular books *Cheaper by the Dozen* and *Belles on Their Toes* about their experiences growing up with such a large and famous family. But Lillian Moller Gilbreth was not only a mother; she was an engineer and an industrial psychologist.

Lillian excelled in high school and decided that she wanted to study literature and music. Her father did not believe in higher education for women. He felt they needed only enough knowledge to manage a home gracefully. But Lillian persuaded him to let her attend the University of California at Berkeley while living at home and maintaining her family duties. When she obtained her B.A. in literature in 1900, she was the first woman to speak at a University of California commencement.

She went to Columbia, but illness forced a return to California after her first year. Undaunted, she went back to Berkeley and received a master's degree in literature in 1902. She celebrated by planning a vacation. She spent some time in Boston before embarking, and there she met her future husband.

Frank Gilbreth, who never went to college, was interested in efficiency in the workplace. His enthusiasm for the subject was contagious. He proposed to Lillian Moller three weeks after her return from Europe, and together they began their study of scientific management principles. Frank started a consulting business and Lillian worked at his side. They began their family and in 1910 moved to Rhode Island, where Gilbreth took her doctorate in psychology at Brown University in 1915—with four young children in tow at the ceremony.

But where Frank was concerned with the technical aspects of worker efficiency, Lillian was concerned with the human aspects of time management. Her ideas were not widely adopted during her lifetime, but they indicated the direction that modern management would take. She recognized that workers are motivated by indirect incentives (among which she included money) and direct incentives, such as job satisfaction. Her work with Frank helped create job standardization, incentive wage-plans, and job simplification. Finally, she was among the first to recognize the effects of fatigue and stress on time management.

Lillian Gilbreth continued her work alone after Frank's death in 1924. In 1926, she became the first woman member of the American Society of Mechanical Engineers. She went to Purdue in 1935 as a professor of management and the first female professor in the engineering school. In her consulting business, she worked with GE and other firms to improve the design of kitchens and household appliances. She even created new techniques to help disabled women accomplish common household tasks.

She did not retire from professional work until she was in her 80s. She traveled widely, speaking and writing about management issues. In 1966, she won the Hoover Medal of the American Society of Civil Engineers. She died at the age of 92, the recipient of more than a dozen honorary degrees. Her ability to combine a career and family led to her being called, by the *California Monthly* in 1944, "a genius in the art of living." ■

ANNIE JUMP CANNON

BORN: DOVER, DELAWARE, DECEMBER 11, 1863
DIED: CAMBRIDGE, MASSACHUSETTS, APRIL 13, 1941

Theorist of Star Spectra

Oh, Be A Fine Girl—Kiss Me! This phrase has helped several generations of astronomers to learn the spectral classifications of stars. Ironically, this mnemonic device, still used today, refers to a scheme developed by a woman.

Annie Jump Cannon was the eldest of three daughters of Wilson Cannon, a Delaware shipbuilder and state senator, and his second wife, Mary Jump. Annie's mother taught her the constellations and stimulated her interest in astronomy. At Wellesley, Annie studied physics and astronomy and learned to make spectroscopic measurements. On her graduation in 1884, she returned to Delaware for a decade, but became impatient to get back to astronomy. After the death of her mother in 1894, Cannon worked at Wellesley as a junior physics teacher and became a "special student" of astronomy at Radcliffe.

In 1896, she became a member of the group that historians of science have dubbed "Pickering's Women," women hired by Harvard College Observatory director Edward Pickering to reduce data and carry out astronomical calculations. Pickering's approach to science was thoroughly Baconian: "the first step is to accumulate the facts."* The accumulating was supported by a fund set up in 1886 by Anna Draper, widow of Henry Draper, a wealthy physician and amateur astronomer.

Pickering conceived the Henry Draper Memorial as a long-term project to obtain optical spectra of as many stars as possible and to index and classify stars by their spectra. While the measurements were difficult enough, the development of a reasonable classification scheme proved as much a problem in "theory" (which Pickering was slow to recognize) as "fact accumulation."

The analysis was begun in 1886 by Nettie Farrar, who left after a few months to be married. Her place was taken by Williamina Fleming, the first of Pickering's female crew to be recognized in the astronomical community at large. Fleming examined the spectra of more than 10,000 stars and developed a classification system containing 22 classes. The work was carried further by Antonia Maury, who developed her own classification system. The system was cumbersome by comparison with Fleming's, and Pickering could not sympathize with Maury's insistence on theoretical (what we would today call astrophysical) concerns that underlay her scheme.

It was left to Annie Jump Cannon to continue, beginning with an examination of bright southern hemisphere stars. To these she applied yet a third scheme, derived from Fleming's and Maury's, an "arbitrary" division of stars into the spectral classes O, B, A, F, G, K, M, and so on. It was as "theory-laden" as Maury's ordering, but greatly simplified. Her "eye" for stellar spectra was phenomenal, and her Draper catalogs (which ultimately listed nearly 400,000 stars) were valued as the work of a single observer.

Cannon also published catalogs of variable stars (including 300 she discovered). Her career spanned more than forty years, during which women in science won grudging acceptance. She received many "firsts" (first recipient of an honorary doctorate from Oxford, first woman elected an officer of the American Astronomical Society, etc.). At Harvard she was named Curator of Astronomical Photographs, but it was only in 1938, two years before her retirement, that she obtained a regular Harvard appointment as William C. Bond Astronomer. ■

* *Quoted by Pamela Mack in her article, "Straying from their orbits: Women in astronomy in America," in G. Kass-Simon, P. Farnes, and D. Nash, 1990:* Women of Science: Righting the Record *(Bloomington, Indiana University Press), p. 91.*

ROSA SMITH EIGENMANN

BORN: MONMOUTH, ILLINOIS, OCTOBER 7, 1858
DIED: SAN DIEGO, CALIFORNIA, JANUARY 12, 1947

"First Woman Ichthyologist of Any Accomplishments"

In the dark, rocky caves beneath San Diego's Point Loma Peninsula live schools of little, pink, blind fish, six or seven inches long. They were discovered and later described and classified by a young woman named Rosa Smith. The blind goby, *Typhlogobius californiensis* (now *Othonops eos*) inaugurated her career. According to famed marine biologist Carl L. Hubbs, "Rosa Smith was indeed the first woman ichthyologist of any accomplishments."*

Smith was the last of nine children. Her parents had come from California to Illinois to launch a newspaper, but they returned when their frail, tubercular youngest was advised to seek a warmer climate. Rosa finished her secondary schooling at Point Loma Seminary, taking a lively interest in the natural history of the region. She joined the San Diego Society of Natural History and began, as an amateur, to collect, observe, and identify local species of animals and plants.

In 1879, the noted ichthyologist David Starr Jordan came to San Diego. One of Rosa Smith's daughters wrote that Jordan met Rosa Smith while renting a horse and buggy from her father, but another daughter believed they met at the Society of Natural History. There, the story went, Jordan heard Smith read a paper on a new species of fish (very likely the blind goby), was deeply impressed, and urged her to study with him at Indiana University.

Rosa spent the summer of 1880 on a natural history tour in Europe with Jordan and his students, then attended Indiana University for two years, but was called home owing to illness in her family and did not graduate. Before she left, Jordan introduced her to a young German student of his named Carl H. Eigenmann, who was in the process of obtaining a doctorate in ichthyology.

Back in San Diego, Rosa Smith undertook the formal description and publication of the various species of blind goby and other fish, and she kept up an exchange of papers and correspondence with Carl Eigenmann. Before they married on August 20, 1887, she had published nearly 20 papers on her own. They collaborated first on a study of South American freshwater fishes in the collections at Harvard, and Rosa Eigenmann was the first woman allowed to attend graduate-level classes there.

In 1891, Jordan became chancellor of Stanford University, and Carl Eigenmann was left to head the zoology department at Indiana University. He ultimately became department chair and, later, Dean of the Graduate School. The five Eigenmann children included a disabled daughter and a son who was eventually institutionalized, and the burden of child care fell heavily on Rosa Eigenmann. Nevertheless, she managed to collaborate with her husband on 15 more papers. Eigenmann and Eigenmann were first to describe some 150 species of fish.

When Carl Eigenmann had a stroke in 1927, Rosa returned with him to San Diego, where he died on April 24. She stayed in San Diego with her children but was not scientifically active. Her brief but productive career had been pursued in spite of all obstacles, and she once wrote, "in science as everywhere else in the domain of thought woman should be judged by the same standard as her brother. Her work must not simply be well done *for a woman*."

* *Letter from Carl L. Hubbs to Edward T. James, Editor,* Notable American Women, *6 October 1964, in Hubbs Papers, SIO Archives, UCSD, MC5, Box 9, Folder 111.*

ADA BYRON, COUNTESS OF LOVELACE

BORN: LONDON, ENGLAND, DECEMBER 10, 1815
DIED: LONDON, ENGLAND, NOVEMBER 27, 1852

Analyst, Metaphysician, and Founder of Scientific Computing

Ada Byron was the daughter of a brief marriage between the Romantic poet Lord Byron and Anne Isabelle Milbanke, who separated from Byron just a month after Ada was born. Four months later, Byron left England forever. Ada never met her father (who died in Greece in 1823) and was raised by her mother, Lady Byron. Her life was an apotheosis of struggle between emotion and reason, subjectivism and objectivism, poetics and mathematics, ill health and bursts of energy.

Lady Byron wished her daughter to be unlike her poetical father, and she saw to it that Ada received tutoring in mathematics and music, as disciplines to counter dangerous poetic tendencies. But Ada's complex inheritance became apparent as early as 1828, when she produced the design for a flying machine. It was mathematics that gave her life its wings.

Lady Byron and Ada moved in an elite London society, one in which gentlemen not members of the clergy or occupied with politics or the affairs of a regiment were quite likely to spend their time and fortunes pursuing botany, geology, or astronomy. In the early nineteenth century there were no "professional" scientists (indeed, the word "scientist" was only coined by William Whewell in 1836)—but the participation of noblewomen in intellectual pursuits was not widely encouraged.

One of the gentlemanly scientists of the era was to become Ada's lifelong friend. Charles Babbage, Lucasian professor of mathematics at Cambridge, was known as the inventor of the Difference Engine, an elaborate calculating machine that operated by the method of finite differences. Ada met Babbage in 1833, when she was just 17, and they began a voluminous correspondence on the topics of mathematics, logic, and ultimately all subjects.

In 1835, Ada married William King, ten years her senior, and when King inherited a noble title in 1838, they became the Earl and Countess of Lovelace. Ada had three children. The family and its fortunes were very much directed by Lady Byron, whose domineering was rarely opposed by King.

Babbage had made plans in 1834 for a new kind of calculating machine (although the Difference Engine was not finished), an Analytical Engine. His Parliamentary sponsors refused to support a second machine with the first unfinished, but Babbage found sympathy for his new project abroad. In 1842, an Italian mathematician, Louis Menebrea, published a memoir in French on the subject of the Analytical Engine. Babbage enlisted Ada as translator for the memoir, and during a nine-month period in 1842-43, she worked feverishly on the article and a set of *Notes* she appended to it. These are the source of her enduring fame.

Ada called herself "an Analyst (& Metaphysician)," and the combination was put to use in the *Notes.* She understood the plans for the device as well as Babbage but was better at articulating its promise. She rightly saw it as what we would call a general-purpose computer. It was suited for "developping [sic] and tabulating any function whatever. . . the engine [is] the material expression of any indefinite function of any degree of generality and complexity." Her *Notes* anticipate future developments, including computer-generated music.

Ada died of cancer in 1852, at the age of 37, and was buried beside the father she never knew. Her contributions to science were resurrected only recently, but many new biographies* attest to the fascination of Babbage's "Enchantress of Numbers." ■

* *Doris Langley Moore, 1977:* Ada: Countess of Lovelace *(London: John Murray); Joan Baum, 1986:* The Calculating Passion of Ada Byron *(Archon Books); Betty A. Toole, 1992:* Ada, the Enchantress of Numbers *(Mill Valley, CA: Strawberry Press).*

MARY ANNING

BORN: LYME REGIS, ENGLAND, MAY 21, 1799
DIED: LYME REGIS, ENGLAND, MARCH 9, 1847

Finder of Fossils

Mary Anning lived through a life of privation and hardship to become what one source called "the greatest fossilist the world ever knew."* Anning is credited with finding the first specimen of *Ichthyosaurus* acknowledged by the Geological Society in London. She also discovered the first nearly complete example of the *Plesiosaurus*; the first British *Pterodactylus macronyx*, a fossil flying reptile; the *Squaloraja* fossil fish, a transitional link between sharks and rays; and finally the *Plesiosaurus macrocephalus*.

Her history is incomplete and contradictory. Some accounts of her life have been fictionalized, and her childhood discoveries have been mythologized. She was a curiosity in her own time, bringing tourism to her home town of Lyme Regis. Only her personal qualities and her long experience brought her any recognition at all, since she was a woman, of a lower social class, and from a provincial area at a time when upper-class London men, gentlemanly scholars, received the bulk of the credit for geological discoveries.

Anning learned to collect fossils from her father, Richard, a cabinet maker by trade and a fossil collector by avocation. But he died at 44 in 1810, leaving his family destitute. They relied on charity to survive.

Fossil collecting was a dangerous business in the seaside town. Anning walked and waded under unstable cliffs at low tide, looking for specimens dislodged from the rocks. During her teenage years, the family built both a reputation and a business as fossil hunters. In 1817 they met Lieutenant-Colonel Thomas Birch, a well-to-do fossil collector who became a supporter of the family. He attributed major discoveries in the area to them, and he arranged to sell his personal collection of fossils for the family's benefit. Most of Anning's fossils were sold to institutions and private collectors, but museums tended to credit only people who donated the fossils to the institution. Therefore, it has been difficult for historians to trace many fossils that Mary Anning located; the best known are a small *Ichthyosaurus* discovered in 1821 and the first *Plesiosaurus*, unearthed in 1823.

Mary had some recognition for her intellectual mastery of the anatomy of her subjects, from Lady Harriet Silvester, who visited Anning in 1824 and recorded in her diary:

> *the extraordinary thing in this young woman is that she had made herself so thoroughly acquainted with the science that the moment she finds any bones she knows to what tribe they belong. . . . by reading and application she has arrived to that greater degree of knowledge as to be in the habit of writing and talking with professors and other clever men on the subject, and they all acknowledge that she understands more of the science than anyone else in this kingdom.*†

Visitors to Lyme increased as Anning won the respect of contemporary scientists. In the last decade of her life she received an annuity from the British Association for the Advancement of Science (1838). The Geological Society of London collected a stipend for her and she was named the first Honorary Member of the new Dorset County Museum, one year before her death from breast cancer. Her obituary was published in the *Quarterly Journal* of the Geological Society—an organization that would not admit women until 1904. ■

* *Annotation on an undated letter from Mary Anning to one of the Misses Philpot of Lyme, in the collection of the American Philosophical Society, Philadelphia, cited in Torrens, Hugh: "Mary Anning (1799-1847) of Lyme: 'the greatest fossilist the world ever knew,'* British Journal for the History of Science, *25: 257-84, 1995.*

† Ibid., *p. 265.*

SOPHIE GERMAIN

Born: Paris, April 1, 1776
Died: Paris, June 26, 1831

Revolutionary Mathematician

By all accounts, Sophie Germain was a somewhat withdrawn child. She was the second of three daughters of a Parisian silk merchant, Ambroise-François Germain. One sister married a government official and the other a physician. Sophie never married, lived at home all her life, and pursued her mathematical studies with what her recent biographers term "limitless passion and devotion."*

Her first biographer, an Italian mathematician named Libri, is the source of two stories told about Germain that seem to frame her personality. As a 13-year-old, while talk of the Revolution swirled in her household, she withdrew to her father's library. There she read about Archimedes, so engrossed in his mathematical musings that he ignored a Roman invader of Syracuse, who thereupon killed him. She may have seen in Archimedes' mathematics "an environment where she too could live untouched by the confusion of social reality."† She studied mathematics on her own, and Libri relates that her parents were so opposed to her behavior that she took to studying at night. They responded by leaving her fire unlit and taking her candles. Sophie studied anyway, swaddled in blankets, by the light of smuggled candles.

On the establishment in 1795 of the Ecole Polytechnique, which women could not attend, Germain befriended students and obtained their lecture notes. She submitted a memoir to the mathematician J. L. Lagrange under a male student's name. Lagrange saw talent in the work, sought out the author, and was bowled over to discover it had been written by a woman. She continued to study, corresponding with leading mathematicians of the day.

Her mathematical work shifted from number theory to more applied mathematics. The occasion was the demonstration by a visitor to Paris, one E. F. F. Chladni, of curious patterns produced on small glass plates covered with sand and played, as though the plates were violins, by using a bow. The sand moved about until it reached the nodes, and the array of patterns resulting from the "playing" of different notes caused great excitement among the Parisian polymaths. It was the first "scientific visualization" of two-dimensional harmonic motion. Napoleon authorized an extraordinary prize for the best mathematical explanation of the phenomenon, and a contest announcement was issued.

Sophie Germain's entry was the only one. While it contained mathematical flaws and was rejected, her approach was correct. All the other possible entrants in the contest were prisoners of the ruling paradigm, consideration of the underlying molecular structure theorized for materials. The mathematical methodologies appropriate to the molecular view could not cope with the problem. But Germain was not so encumbered.

Various mathematicians helped her to pursue a new application, and she won the prize on her third attempt, in 1816. The very public prizewinning gained her some attention. But her gender kept her "always on the outside, like a foreigner, at a distance from the professional scientific culture."¶

Perhaps only a lone genius like Germain was constituted to thrive in such isolation, leaving her work of pure intellection like a beacon to later generations of women who dared to do mathematics for the joy of it. ■

* *Louis L. Bucciarelli and Nancy Dworsky, 1980:* Sophie Germain: An Essay in the History of the Theory of Elasticity *(Dordrecht: D. Reidel), p. 10.*

† Ibid. *(But in fact she [or the history book] drew the wrong conclusion. Archimedes did not die for his absent-mindedness but was a target of the Roman soldiers precisely because he had been the "brains" behind the Syracusan defenses, directing the building of catapults and even developing a mirror system to focus light on the Roman ships and set their sails afire.)*

¶ Ibid., *p. 30.*

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WRITERS: Merry Maisel and Laura Smart

GRAPHIC DESIGN: Gail W. Bamber

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