Out of the Shadows: Contributions of Twentieth-Century Women to Physics

Why are there not more prominent female physicists? Throughout history women have been denied access to higher learning and scientific laboratories. Today, traditional barriers faced by women in higher education have been breached. However, the female pioneers who overcame discrimination and became major players in their fields remain largely in the shadows. The importance of their work, achievements and contributions to science deserve recognition; the names of these pioneers deserve to be known.

Out of the Shadows will help to bring a more gender-balanced perception of physicists. Here are detailed descriptions of important, original contributions made by women in the century from 1876 to 1976. Many female physicists and mathematicians, historically excluded from participation in science, emerged in this time. It was a period in which there was great progress in science and in the liberation of women from centuries of repression. This book documents both aspects of recent history. Many of the authors here are themselves distinguished scientists who have been actively engaged in the fields of physics about which they write. They write about modern developments in their fields with remarkable clarity and readability. The fields are as diverse as astrophysics, bio-molecular structure, chaos theory, geophysics, nuclear physics, particle physics, and surface physics. The writers include detailed accounts of important discoveries, place them in their historical context, give references to original papers, suggest books for further reading, and provide scientific biographies. The discoveries are well-established and fundamental to modern physics. It is not well known, however, that many were made by women.

NINA BYERS received her Ph.D. in Physics from the University of Chicago in 1956, where she was taught by many eminent physicists

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including Enrico Fermi, Maria Goeppert Mayer and Murray Gell-Mann. Since then, she has undertaken research and teaching at many institutions including the University of Birmingham, the University of Oxford, UK, Stanford University and the University of California at Los Angeles. She has held numerous posts in scientific societies including Councillor-at-Large and Member of the Panel on Public Affairs of the American Physical Society (APS), President of the APS Forum on Physics and Society and President of the APS Forum on History of Physics as well as Member-at-Large of Section B (physics) of the American Association for the Advancement of Science. She has published many papers in scientific journals, reporting research results in theoretical physics in the fields of elementary particle physics and superconductivity. More recently, she has published papers and given invited talks on the history of physics on such subjects as Emmy Noether, Enrico Fermi and Leo Szilard, and Women in Physics in Fermi's Time. She is the initiator and organizer of an electronic archive making available on the internet the contributions of twentieth-century women to physics http://cwp.library.ucla.edu/.

GARY A. WILLIAMS received his Ph.D. in Physics from the University of California, Berkeley, in 1974. In 1975 he joined the faculty of the University of California at Los Angeles, where he has been ever since. He is the author of over 100 research articles in the field of low temperature physics, specializing in experimental and theoretical studies of the superfluid phase transition of liquid helium.

Out of the Shadows

Contributions of Twentieth-Century Women to Physics

Edited by

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This book is dedicated to all the women whose contributions should be in it and are not. There are very many. Among them are the women who remain in the shadows of the history of physics, the women who would have become physicists if the way had been open to them, and younger women whose contributions to physics have been made after 1976 and who continue to advance science.

More particularly we dedicate this book to the more than two hundred twentieth-century women whose contributions to physics are documented in the CWP website <http://cwp.library.ucla.edu>, forty of whom are subjects of the chapters of this book. All of these were inspirations for the creation of this book.

Nina Byers and Gary Williams

"This book fills a vacuum in the history of physics. For the first time we have in one place clear accounts of careers and contributions to physics of forty distinguished women from a variety of fields. In particular the authors are informed insiders with intimate knowledge of their fields who often provide fresh information about their subjects. Let us hope that this book will inspire physicists to include these women in their lectures and textbooks so that no one will ever again badger women students with taunts like 'What's a nice girl like you doing in Physics 55?'"

Margaret W. Rossiter
MacArthur Prize Fellow 1989–1994
Marie Underhill Knoll Professor of the History of Science
Cornell University

"As this inspiring gallery of heroines makes plain, there's no such thing as female science – just female scientists, including some very great ones. Their achievements span a vast range of mathematics, physics, and astronomy. In Out of the Shadows, experts lucidly explain what they did, and the lives they led. I was mesmerized, and edified."

Frank Wilczek
Nobel Prize in Physics 2004
Herman Feshbach Professor of Physics
Massachusetts Institute of Technology

"*Out of the Shadows* gives us fascinating accounts of some of the ground-breaking achivements of women physicists and astronomers, many of whom have never received the recognition they truly deserve. It is a much needed book. In it a reader can learn, for example, about how Henrietta Swan Leavitt provided the first method of measuring inter-galactic distances, and how Cecilia Payne-Gaposchkin, in studies of spectra from stars, discovered that most of the luminous matter in the universe consists of hydrogen and helium. Both of these were advances crucial to the development of astrophysics and modern cosmology. This wonderful book beautifully illustrates that scientific talent has absolutely nothing to do with gender."

Jerome I. Friedman
Nobel Prize in Physics 1990
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Foreword

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This book is a portrait gallery of women who have made outstanding contributions to physics. There are forty of them. It was a good idea to collect their lives and achievements in one volume. Any aspiring woman physicist can see here that the choice of role models is wide. She may choose an experimenter like Chien-Shiung Wu, an observer like Jocelyn Bell Burnell, or a theorist like Cécile DeWitt-Morette. I hope this book will be widely read by teachers as well as students. My only regret is that many outstanding younger physicists whose careers are still on the rise are not included, such as Claire Max, Ellen Williams, Penny Sackett and Sara Seager. They would be more appropriate role models for an average modern teenager than the grand and remote figures of the past such as Marie Curie (see Chapter 4) and Emmy Noether (see Chapter 8). Curie and Noether are wonderful role models if you only dream of dedicating your heart and soul to science. Max and Williams and Sackett and Seager are better if you are also worried about making a living and raising a family under modern conditions.

I am lucky to have had six of the forty as colleagues and friends, besides many other outstanding women who did not make the list. When I was a young student in England in 1942, I heard Mary Cartwright (see Chapter 15) lecture about the pathological behavior of nonlinear amplifiers. The radars in World War II were driven by amplifiers, which behaved badly when pushed to high power levels. The Royal Air Force blamed the manufacturers and sent the radars back for repair. Cartwright showed that the manufacturers were not to blame. The Van der Pol equation was to blame. The Van der Pol equation is the standard equation describing a nonlinear amplifier. Cartwright studied the solutions of the Van der Pol equation and discovered the unexpected phenomenon that is now called chaos. As the power is increased, the periodic solutions go through an infinite sequence of period doublings and finally become aperiodic. The aperiodic solutions have disastrous effects on the radar, but have a beautifully intricate topological structure. These discoveries were published at the end of the war, but nobody paid much attention to her papers and she went on to other things. She became famous as a pure mathematician. Twenty years later, chaos was rediscovered by the meteorologist Ed Lorenz and became one of the most fashionable parts of physics. In recent years I have been calling attention to Cartwright's work. In 1993, I received an indignant letter from Cartwright, scolding me because I gave her more credit than she thought she deserved. I still claim that she is one of the original discoverers of chaos. She died, full of years and honors, in 1998.

When I started my career as a physicist in the 1940s, we were all survivors of World War II. It did not make much difference whether you were male or female. Rich and poor, women and men, we all got equal rations of food, and sharing of burdens was taken for granted. I came to Cornell University as a student in 1947, when most of the experimental physicists were busy building a new synchrotron and had no time for doing experiments. Hans Bethe used to say that it was only the shortage of steel that kept experimental physics alive in the USA at that time. One of the physicists who were keeping experimental physics alive was Vanna Cocconi. She did not wait for the synchrotron to be finished. She did experiments in particle physics using cosmic rays, driving a truck full of cosmic-ray detectors to the top of Mount Evans in Colorado. She discovered the phenomenon of nuclear spallation, observing the large bursts of neutrons emitted when a high-energy cosmic ray collides with a heavy nucleus. She and her husband, Giuseppe, shared the burdens of driving the truck, building cloud chambers and electronic circuits, raising a baby and running a household. Once a week, I watched with admiration the spectacle of Giuseppe scrubbing the kitchen floor while Vanna fed the baby. For any young woman who chooses Vanna as a role model, the first priority should be to find a husband like Giuseppe. Both of them later became leaders in the European particle-physics laboratory (CERN) at Geneva, Vanna as an experimenter, Giuseppe as a theorist. In the 1960s, Vanna helped set up the large bubble chamber at CERN. Later, she ran a beautiful experiment studying multiple production of pions in proton–proton collisions. Just as a highly excited heavy nucleus emits a shower of neutrons, a highly excited proton emits a shower of pions. She demonstrated the autocorrelation of pions due to quantum statistics. This verified that pions obey Bose–Einstein statistics, and also gave a direct measurement of the size of the fireball out of which the pions emerge. Vanna died in 1998. If this book ever goes into a second edition, she should be included.

After a year at Cornell, I came to the Institute for Advanced Study in Princeton, one of ten young physicists invited by our director Robert Oppenheimer. When we arrived, our office building was still under construction and Oppenheimer was away in Europe, so we all sat around a big table in Oppenheimer's office. That gave us a good chance to get to know one another. Two of us were women, Sheila Power from Ireland and Cécile Morette (see Chapter 29) from France. It was immediately obvious that Cécile was the brightest and most enterprising of the bunch. Before anyone else, she seized on the new idea of Richard Feynman, the path-integral description of quantum processes, and made it her life's work to develop path-integrals into a rigorous mathematical discipline. At a time when Feynman's idea was still regarded as crazy or irrelevant by the majority of physicists, she forced us to take it seriously.

Theoretical physics in France was at that time at a low ebb. The grand old men, Louis de Broglie and his contemporaries, were no longer active. The lives of the younger generation had been disrupted by the war. Cécile decided that the time had come to rejuvenate French physics, and she saw a way to do it. She raised enough money to buy a delapidated farm near the village of Les Houches in the French Alps, and founded the Les Houches Summer School.

Cowsheds were converted into dormitories, and students came from all over Europe to learn modern physics. She ran the school with enormous competence and enthusiasm. I had the pleasure of teaching there for the summer of 1954, and taught the most gifted group of students that I ever encountered. Many of the students in my class became professors and leaders of research in various countries. The most gifted of all was Georges Charpak, who won a well-earned Nobel Prize for physics in 1992. He and Cécile were kindred spirits, organizing hikes in the mountains when the weather was good, organizing games and charades in the dormitory when it was bad and arguing incessantly about physics.

Besides the Les Houches Summer School that she ran herself, Cécile also played a part in the founding of another institution, the Institut des Hautes Etudes Scientifiques (IHES) at Bures-sur-Yvette on the southern edge of Paris. IHES is a French equivalent of the Institute for Advanced Study at Princeton. I remember vividly the day in 1948 when Cécile, then newly arrived at Princeton, brought a distinguished looking French visitor to lunch at the Institute. She told the visitor that France needed an Institute for Advanced Study too, privately funded and independent of government. She made arrangements for him to meet with Robert Oppenheimer. The visitor was impressed by Cécile's vision. He said he would try to do something about it. His name was Léon Motchane. A few years later he became the founder and first director of IHES. The Les Houches Summer School and IHES did the job for which Cécile designed them. They opened the door for a new generation of young people to become the leaders of French physics. Both institutions are still flourishing today. All it took to accomplish this revolution was one young woman with courage and imagination. When the revolution was still a dream in Cécile's head, we used to tease her, saying that she was a reincarnation of Joan of Arc. She said, no, she was not Joan of Arc, because she had no intention of being burned at the stake. To avoid being burned at the stake, she settled in America and started a new career at the University of North Carolina, so that she had an independent base from which to organize the revolution in France.

I have described these three women, Mary Cartwright, Vanna Cocconi and Cécile DeWitt-Morette, because they are the most memorable of my female mentors. I knew them and admired them when I was young and impressionable. Unfortunately, none of them was American-born. Fifty years ago when I was a student, physics in America was far more male-dominated than physics in Europe. Today, America still lags behind Europe in the advancement of women. I recently collected statistics of the numbers of women and men who have been members of the School of Natural Sciences at the Institute for Advanced Study in Princeton. The fraction of women has not increased since I first came to the Institute in 1948. It was then, and has remained ever since, about ten percent. In American history there was no Joan of Arc.

A few years ago, the Russian mathematician Mikhail Monastyrsky wrote a little book with the title, *Modern Mathematics in the Light of the Fields Medals*. It is a historical survey, describing the people who won Fields Medals for outstanding contributions to twentieth-century mathematics. A Fields Medal for a mathematician is the equivalent of a Nobel Prize for a physicist. Monastyrsky wrote his book first in Russian and then translated it himself into English. He told me that he had great difficulty getting it published, both in Russia and in America. The Russian publishers said, "Too many Jews." The American publishers said, "Not enough women." Political correctness makes different demands in different countries. His book has now been successfully published in both languages, but the problem of the under-representation of women remains. Monastyrsky's history does not provide inspiring role models for the next generation of women mathematicians. This book does better. It provides plenty of role models for the next generation of women physicists. It says to any young woman aspiring to a career in physics, "Welcome to the club."