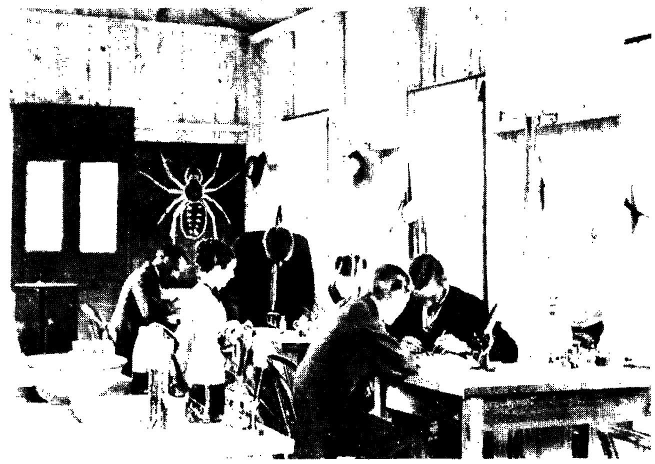
between the cognitive styles of artists and scientists. Thus, she indicates, "Women who might have been scientists become artists instead." Whatever the connection between art and science, Maria Martin was only one among several significant women illustrators in antebellum America.

For Almira Hart Lincoln Phelps, the necessary contacts with men in science came through informal boardinghouse conversations and public lectures. Sister to Emma Willard, the innovative founder of Troy Female Academy, Phelps was also encouraged by Amos Eaton of Rensselaer Polytechnic Institute. She wrote scientific textbooks and in several female academies taught her students the basics of botany, chemistry, and natural history more generally. Education became the major outlet for women intellectuals in the last half of the century.

Louise C. Allen (later Gregory) developed a program in home economics that predated that of Ellen Richards. Allen faced the increasingly articulated strictures against women studying science, such as those of Herbert Spencer, and took a teaching degree from the Illinois Normal School in Bloomington. After several years of school teaching and administration she headed the School of Domestic Science at the University of Illinois from 1870 to 1878. Having no access to an advanced degree, she upgraded her education by lectures, institutes, and summer school programs: health and physical education training at the University of Pennsylvania, physiology from Mary Blake at the Gannet School and chemistry at Harvard University in the Boston area, and food chemistry at the National School of Cookery in London. From this ad hoc study she developed a comprehensive program for the women at Illinois that existed for nearly a decade. By the time Florence Bascom took her Ph.D. degree from a reluctant Johns Hopkins University in 1893, women had gained limited access to advanced education. Her subsequent teaching career at Bryn Mawr led to a sequence of prominent women geologists whose connection to scientific education was at once both formal and personal.

The chapters on these women are, to use a 19th-century phrase, "familiar essays." We learn of family and friendships among women who, like men, relied on networks for support but whose connections were different. A domestic ideology meant that dynamic relationships seem at once to be more personal and intimate but less powerful and useful than those experienced by men. That fact is poignantly illustrated by the observation that these women, including Bascom to some degree, probably did not reach the mature production or the recognition accorded their male peers. In fact, the male connections remain ambiguous. Of these four women, Martin and Allen did little in science after their late marriages, Phelps spent considerable years as a widow, and Bascom never married. It appears that while 19th-century parents and siblings could provide support husbands and children were likely to be impediments. Other issues, too, require more systematic investigation. It remains an enigma, for example, why, if personal local factors were dominant, there were so few other daughters in science. If opportunities for formal education became increasingly important, why is the legacy of Phelps and Allen for individual students so uncertain?



Interior of the laboratory for the Summer School of the Peabody Museum of Salem, 1876. Women used informal institutes and summer schools like that pictured here to improve their skills in science. [Courtesy of Peabody Museum of Salem]

This book lacks the breadth of Margaret Rossiter's already classic *Women Scientists in America: Struggles and Strategies to 1840*, but it contributes a divergent point of view. Here we learn in intimate detail of the personal context that shaped the interests and defined opportunities of women interested in science. By reminding readers of the fullest meaning of education, Lois Barber Arnold points out that classroom study will never be sufficient to guarantee the recruitment and productivity of women in science.

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The Fundamentals of Physics

The Discovery of Subatomic Particles. STEVEN WEINBERG. Scientific American Library, New York, 1984 (distributor, Freeman, New York). xvi, 206 pp., illus. $27.95.

This book grew out of courses taught by the author at Harvard University and the University of Texas that were designed to acquaint students with no background in physics or mathematics with the great achievements of 20th-century physics. The present volume deals with the discovery of the electron, the determination of the atomic scale, and the discovery of the nucleus. Possible future volumes may cover such topics as quantum mechanics and relativity.

Attempts to present modern physics to the general reader immediately run into a fundamental problem. If one starts by first presenting all of the necessary background material on classical physics there is an excellent chance of losing most of one's audience. If, on the other hand, one goes directly to the more interesting topics the lack of background often forces the presentation to be superficial. This book utilizes an interesting compromise approach. It plunges directly into the first major theme, the discovery of the electron, but it contains a number of "flashback" sections in which the necessary classical physics is developed in detail as it is needed. The presentation is largely nonmathematical; there are a relatively small number of equations written out in words (on such topics as Newton's laws), but they can be omitted without loss of continuity if the reader desires. This approach works well, and Weinberg has succeeded in producing a fine book that should be both fascinating and accessible to the dedicated general reader. It should also be of interest to professional scientists and students who wish to learn more about the history of their field.

The opening chapter gives a brief overview of the book, an account of the early history of the Cavendish Laboratory (where so many of the important discoveries were made), and an introduction to scientific notation. The second chapter, on the discovery of the electron, is the longest and is the heart of the book. J. J. Thomson's experiments to determine the charge-to-mass ratio of cathode rays (electrons) are described in considerable detail, with flashback sections devoted to early ideas on electricity (including Benjamin Franklin's work), Newton's laws of motion, electric and magnetic forces, and heat and energy. It is emphasized that Thomson's achievement consisted not only in the charge-to-mass measurements but also in his willingness to interpret the cathode rays as the fundamental "atom" out of which the elements are constructed. (W. Kaufmann in Berlin had carried out similar measurements, but, under the influence of Mach, he did not claim to have discovered a fundamental particle.)

The chapter on the atomic scale is concerned with Millikan's measurement of the electron charge and its significance. In flashbacks on atomic weight, describing the work of Dalton, Gay-Lussac, Avogadro, and others and on electrolysis, dealing with Faraday's determination of the charge-to-mass ratio for ions, it is shown that following Thomson's work a single good measurement of the electron charge was all that was needed to determine not only the electron mass but also Avogadro's number and the masses and sizes of atoms. The early measurements by Townsend, Thomson, and Wilson of the charge-to-mass ratio of water droplets, with the average mass determined by their rate of fall through air, and Millikan's (and perhaps Fletcher's) important refinement of using oil drops are described in detail.

The chapter on the nucleus discusses the early history of radioactivity, the Geiger-Marsden discovery of large-angle scattering of alpha particles from a metal foil (which Rutherford described as being "almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you"), and Rutherford's interpretation that the alpha particles must be scattering from an atomic constituent (the nucleus) that is very much smaller than the atom itself. Moseley's measurement of atomic numbers using the Bohr formula, the subsequent atomic theory of the chemical elements, Chadwick's discovery of the neutron, and the evidence that the neutron is a fundamental particle and not a bound state of the proton and electron are then described.

The final chapter briefly describes photons, neutrinos, antiparticles, muons, pions, strange particles, and quarks. There are also 11 appendixes in which many of the topics of the book are reconsidered with the use of simple algebraic formulas.

The book is very well written and nicely produced. It is full of interesting photographs of people and apparatus. It succeeds not only in presenting many of the important results of modern and classical physics but also in giving a flavor of how physics was done in the 19th and early 20th centuries.

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Swirling Flows

Vortex Flow in Nature and Technology. HANS J. LUGT. Wiley-Interscience, New York, 1983. xviii, 297 pp., illus. $49.95. Translated from the German edition (Karlsruhe, 1979).

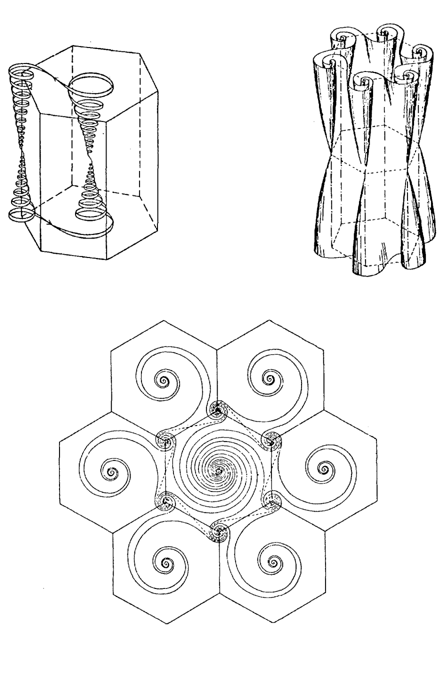
This handsome volume will delight anyone who sees beauty and order in the motion of a smoke ring or a dust devil. It is the work of a man in love with his subject, who spends his working hours computing the swirling flows around ships and aircraft and in his spare time observes their counterparts everywhere about him, from the leaves in his cup of tea to the Great Red Spot of Jupiter. He has surveyed the subject using virtually no equations (except in a mathematical supplement); he does use dozens of beautiful photographs from the laboratory and from nature and hundreds of sketches, graphs, and computer-generated pictures.

What is a vortex? It is, Lugt says, the rotating motion of material particles around a common center, also known as a whirl, an eddy, circulation, a cyclone, or a swirl; and almost every movement of matter may be considered vortical. In the first half of the book he deals with such flows on a human-sized scale and in the second half on a scale earth-sized or greater, where rotation and stratification are significant.

Examples are drawn from all of life: the bathtub vortex and the falling maple leaf, the flight of a boomerang and a wasp, the jet propulsion of a squid and the dangerous tip vortexes on the flight deck of an aircraft carrier. Then, as the scale expands, we learn the fascinating history of the development of the concept of the general circulation of our atmosphere and its watery images in the Sargasso Sea, the Gulf Stream, and El Niño. Still expanding, the book concludes with galactic vortexes, black holes, and the big bang.

This is a picture book, a book of history and philosophy, and an encyclopedia of natural and man-made phenomena; yet at the same time it is a textbook that can be recommended to any student of fluid mechanics. In particular, chapters 4 through 6 are intended as an unorthodox introduction, based on vorticity dynamics, to the theory of viscous fluids. Every reader will pick up useful tidbits: how to test whether an egg has been boiled, how a Frisbee flies, how pouring cold milk into hot coffee generates a spiral vortex. And even an expert on fluid mechanics on the human scale will find the second half of the book a pleasant introduction to the motion of the oceans and the atmosphere.

It is fun to read a technical book that



"Bénard cells in a rotating fluid. [*Top left*] Particle paths in a cell, perspective view; [*top right*] sketch of a cell which is distorted through rotation; [*bottom*] seven cells seen from above. The solid spiral lines represent particle paths, the dashed line is the border of the middle cell." [Reprinted in *Vortex Flow in Nature and Technology* from S. Chandrasekhar (1961)]