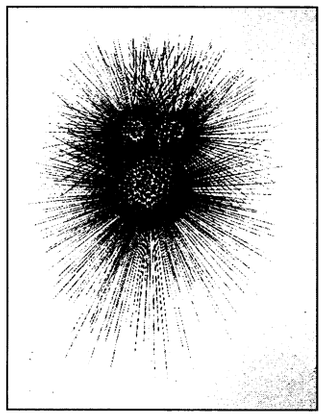
the deep sea was altered forevermore. Dredgings from abyssal depths demonstrated that the sediments at great depth were not uniformly composed of "*Globigerina* ooze" as previously thought. Instead, vast areas, which are below what today we understand as the calcium carbonate compensation depth, are covered by clay. Dredge hauls demonstrated that life not only existed in this environment but existed with species of "animals high in the zoological series." The vast amount of dredged material was parceled out to 76 taxonomic specialists. In all, 50 volumes were published on the scientific results of the voyage of the *Challenger*.



Globigerina bulloides d'Orbigny; after a drawing made by J. J. Wild aboard the *Challenger*.

The abyssal plains of the deep-sea make up the largest biotope on Earth. Among the most abundant and ubiquitous inhabitants of this vast area are the foraminifera. This group was assigned to H. B. Brady (1835–1891), a highly successful pharmacist who retired from that profession in 1876 to devote himself fully to the study of foraminifera. In 1884 he published his classic two-volume "Report on the Foraminifera Dredged by *H.M.S. Challenger*, during the years 1873–1876." He described hundreds of species, which were magnificently illustrated under his supervision by A. T. Hollick with 115 color plates. The quality of these plates has not been surpassed before or since.

Over a hundred years later, Brady's work remains a fundamental reference on the deep-sea foraminifera. However, the "British school" of foraminiferal taxonomy, of which Brady was a prominent member, took a very broad view of the species concept (that is, were lumpers). This viewpoint, when combined with the results of research that has gone on since severely limits the usefulness of Brady's work. In *The Challenger Foraminifera* Jones provides us with a fresh revision. The revision is based on Brady's specimens lodged in the Natural History Museum, London, and material figured in cited references. In all, 875 species including 238 type species belonging to 362 genera are treated. This monumentalrevision removes the taxonomic tarnish and, once again, illuminates Brady's masterpiece.

Brady's volumes are often unavailable to most researchers. When they are, their aged condition, especially that of the volume of plates, which is most thumbed by taxonomists, requires the researcher to proceed with care and trepidation. Jones's volume reproduces all 115 color plates and adds a couple more to elucidate particular specimens. I compared Jones's plates with the originals and am astonished at the fidelity of the reproductions.

Jones also provides us with a short history of the expedition. The purpose, the results, and the people involved are summarized (with pictures). His writing style is refreshing, and the text is a joy to read.

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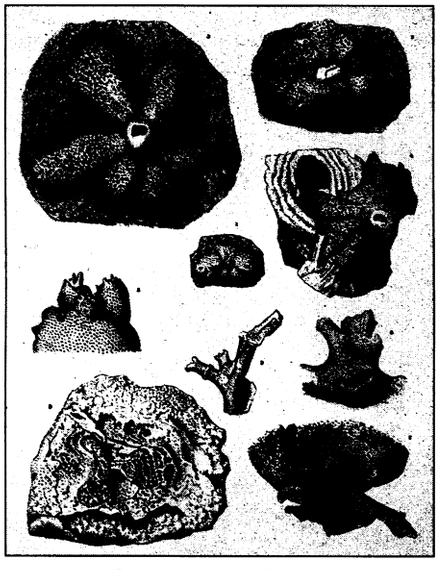
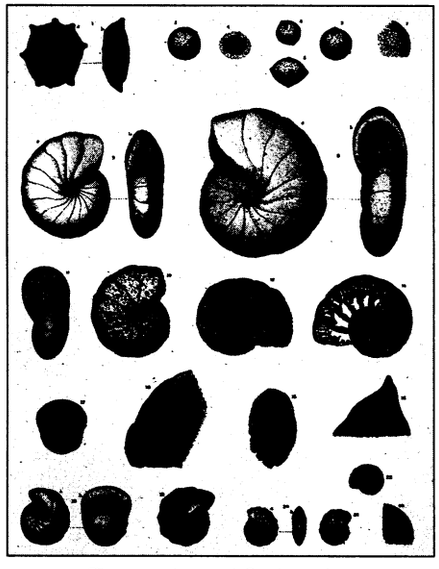


Carpenteria and *Polytrema*.



Thurammina and *Cyclammina*.

[Illustrations on these pages from the original *Challenger* Reports, reproduced in *The Challenger Foraminifera*; Natural History Museum, London]

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The Symbiotic Perspective

Evolution by Association. A History of Symbiosis. JAN SAPP. Oxford University Press, New York, 1994. xvii, 255 pp., $49.95 or £37.50; paper, $24.95 or £18.95.

In these pages in 1993 I reviewed a book by L. N. Khakina chronicling the contributions of Russian botanists to theories of symbiogenesis (the role of symbiosis in evolution). Khakina's book (*Concepts of Symbiogenesis*, Yale University Press) was not intended as a complete history of symbiosis research and theory, and the review ended with the remark that the book "whets the appetite for a thorough treatment of the modern era in the West." The wished-for book has now appeared, in the form of a thorough, balanced, and readable account of symbiosis research and theory from the 19th century to the present day.

In every generation biologists are fascinated by the phenomena of symbiosis. The remarkable adaptations of organisms to each other are irresistible subjects of study, however the phenomena are defined and filtered through prevailing doctrine. The study of symbiosis has never been recognized as a discipline and has not been as respectable as research on more orthodox topics such as fruit fly genetics. Ironically, from the eclectic body of knowledge that does exist about symbiosis has emerged one of the most profound conceptual revolutions in biology of the 20th century—the recognition that organelles of eukaryotic cells (mitochondria and chloroplasts) have their origins as symbiotic bacteria. Symbiosis is now taken quite seriously as a potential source of evolutionary innovation, and the topic has acquired a status and a corps of researchers that would have been hard to imagine half a century ago. The story of this remarkable turnaround is the subject of Sapp's book.

Many practicing scientists are impatient with the notion that doctrinal biases, the disciplinary organization of science, or, worse yet, philosophical and political ideas can profoundly influence the development of scientific knowledge, preferring to regard science as the inexorable triumph of sound data over error. Sapp accomplishes the delicate task of providing a competent account

(*Continued on page 1212*)

Botanical Illustration Through the Centuries

Bramble (*Rubus fructicosus*). From the Herbal of Apuleius, Bury St. Edmunds, Suffolk, around 1120. The earliest known manuscript of this widely copied herbal dates from about A.D. 700. In this version the artist apparently "for the moment abandoned the age-old habit of copying and turned to the plants themselves for his models." [Bodleian Library, Oxford; MS Bodl. 130, fol. 26r]

Fuller's teasel (*Dipsacus fullorum*). Woodcut from the Latin *Herbarius* produced by Peter Schöffer in 1484, a compilation of German plants intended to serve as "simple remedies for simple people." In this early work the figures are "little better than diagrams; correct proportion is rarely attempted." [Royal Collection]

Snowdrop (*Galanthus nivalis*). Watercolor by Wilfrid Blunt (1901-1987). Blunt taught art and wrote popular biographies. About his work on botanical illustration he said he "had no qualifications whatever for undertaking it beyond a fondness for flowers." [Private collection]

Cotton rose (*Hibiscus mutabilis*) with caterpillar, pupa, and butterfly of *Papilio androgeus*. Watercolor by Maria Sibylla Merian (1647-1717) for the *Metamorphosis Insectorum Surinamensium* (1705). Merian's art, sometimes inaccurate, "derived almost entirely from the great flower painters of seventeenth-century Holland." She and her daughter spent two years in South America collecting and painting plants and insects. [Royal Library, Windsor]

Norway spruce (*Picea abies*). Colored engraving by Michael Roesler from *Flora Danica* (1765) of a watercolor drawing by his son, Martin Roesler. "The *Flora Danica* . . . , with 3240 plates, ranks among the finest national flora ever completed."

Sorbus hybrida. Colored engraving by Michael Roesler in *Flora Danica* (1767) of a watercolor drawing by Martin Roesler. The Roeslers were brought to Copenhagen from Nuremberg to work on the *Flora Danica.*

Pasque-flower (*Pulsatilla patens*). Engraving by I. Saal after a drawing by A. Stech from Jakob Breyne's *Exoticarum . . . Centuria Prima* (Danzig, 1678-89). Breyne's plates were cited by Linnaeus.

Moraea neopavonia (left) and *Nivenia stokoei* (right). Watercolor drawings by Fay Anderson of Cape Town, South Africa (born 1931). Anderson has provided illustrations for monographs on the genera *Protea*, *Moraea*, and *Watsonia* in southern Africa. [Compton Herbarium, Kirstenbosch]

Haemanthus coccineus. Watercolor drawing by Ellaphie Ward-Hilhorst (born 1920). Ward-Hilhorst, "born and educated in Pretoria, . . . has devoted her talents to illustrating South African species of *Haemanthus* . . . and *Pelargonium.*" [Compton Herbarium, Kirstenbosch]

From ***The Art of Botanical Illustration*** by Wilfrid Blunt and William T. Stearn, first published in 1950 and now available in a revised and expanded (1994) edition published by the Antique Collectors' Club (Woodbridge, Suffolk, UK, and Wappingers' Falls, NY, USA) in association with the Royal Botanic Gardens, Kew (368 pp.; $59.50 or £29.95)

(*Continued from page 1209*)
of the research itself with its limitations and implications while placing it in the particularly rich broader context surrounding the subject of symbiosis and its potential role in evolution. Symbiosis aficionados who may have wondered how their field found its place in the pecking order of biology will experience a satisfying sense of revelation as the undercurrents are exposed. The association of symbiosis with natural theology in the 19th century, with socialism as opposed to social Darwinism in the early 20th century, and with Lamarckism in the battle for the neo-Darwinian synthesis tended to keep it at the periphery. This was exacerbated by the rise of the 20th-century disciplines of biology, which dismembered symbiosis research and prevented its cohesion.

I noted one key omission in Sapp's account. The discovery of hydrothermal vent communities (in which geochemical energy is harnessed by endosymbiotic bacteria to support the dominant macrofauna) in the 1970s provided a major boost to symbiosis research and theory. As Sapp points out, the emphasis in the study of microorganisms on their role as agents of disease relegated symbiosis to the status of an interesting curiosity, not a fundamental biological theme. The discovery of communities in which bacterial endosymbionts play a central role jolted many biologists into re-evaluating symbiosis from many perspectives and helped to bolster the field's emerging legitimacy.

The book is well written and convincing, weaving many threads into a coherent whole. However, some readers may be a bit disappointed that the vivid personalities involved do not emerge in this account. For example, the intellectual contributions of Lynn Margulis are well described and placed in their proper context, but there is no question that the unique confluence of her personality and background with her ideas influenced the course of development and fate of the serial endosymbiotic hypothesis (the notion that eukaryotic cells are the result of multiple endosymbioses). A woman scientist in an era when serious barriers existed for women in conventional scientific careers, she was initially an outsider and in some sense had less to lose by advocating an unorthodox point of view. Her flamboyant personality and maverick style sometimes alienated more conservative scientists and were a barrier to acceptance of her ideas (some of which remain highly controversial). Nonetheless, her energy and intensity may have been critical to keeping the issue alive until the technology developed and evidence emerged to turn the tide.

Sapp's book is a fine piece of scholarship, whole and satisfying in itself. Nevertheless, we await yet another book, one that reveals the human side of the story.

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The Dressed-Atom Approach

Atoms in Electromagnetic Fields. C. COHEN-TANNOUDJI. World Scientific, River Edge, NJ, 1994. xiv, 670 pp., illus. $108 or £85; paper, $53 or £42. World Scientific Series on Atomic, Molecular and Optical Physics, vol. 1.

Two years after Charles Townes had shared a Nobel physics prize with N. G. Basov and A. M. Prokhorov for the invention of the maser and the laser, the 1966 prize was awarded to Alfred Kastler alone for his origination—at the École Normale Supérieure, (ENS) in Paris, around 1950—of the technique of optical pumping (important to the operation of many masers and lasers). A graduate of the ENS in the 1920s, when French physics provided few opportunities for a research career, Kastler gradually worked his way up through positions at secondary schools and provincial universities, finally returning to Paris in 1941 as head the physical laboratory of the ENS. At war's end, determined to move his laboratory out of classical optical spectroscopy and into the exciting areas opened by the development of radio and microwave techniques during the war, Kastler sent his emissary, Jean Brossel, as postdoc to Francis Bitter at the Massachusetts Institute of Technology. Stimulated by the information Brossel funneled back to Paris, Kastler developed a distinctive perspective, which he then cultivated in conjunction with experimentalist Brossel: striving for a physical understanding of "atoms in electromagnetic fields" based on detailed analysis of cyclical processes of exciting the atom with light to higher energy states followed by decay through the emission of photons, with attention directed especially to the angular momenta of the photons and of the magnetically distinguishable sublevels of the atomic energy states and to the consequent alteration of the relative number of atoms in each of its possible energy states.

Over the last four decades Claude Cohen-Tannoudji has been the most talented and consistent prosecutor of Kastler's research program. Born in Algeria in 1933, Cohen-Tannoudji was himself schooled at the ENS in the late 1950s and has since worked in close collaboration with younger researchers coming up through that laboratory. Continually deepening the theoretical foundations of that distinctive perspective and widening its experimental applications, he was awarded the 1992 Lilienfeld Prize of the American Physical Society for "his unique contributions to the understanding of atomic systems in electromagnetic fields and for his expository skills" (*Physics Today* **45**, no. 6, 94 [June 1992]; the statement continues: "He has made singular contributions to the theory of 'dressed atoms,' optical pumping and cooling, and resonance fluorescence and has experimentally verified some of his predictions.") A member of the Paris Académie des Sciences and foreign member of the U.S. National Academy of Sciences, Cohen-Tannoudji holds—since 1973—one of the 50-odd personal teaching chairs that constitute the Collège de France.

World Scientific has performed a service for all with an interest in the most recent history of physics by inducing Cohen-Tannoudji to bring together—and by reproducing photographically in so well-produced a volume—this selection of his scientific papers. The 39 papers here included (only two are in French) are distributed with remarkable uniformity over the 31 years separating the first (Cohen-Tannoudji's 1961 doctoral thesis) from the last (1992, on laser cooling of atomic motion). They are grouped in seven topical sections, with introductions of a few lines to a couple of pages provided by Cohen-Tannoudji for each paper and each section. As the dates of publication of the papers in each section have relatively small temporal dispersion and the ordering of the sections is essentially chronologic, the volume gives the trajectory both of Cohen-Tannoudji's attention and of the development of his field. In this it is an effective complement to his recent systematic exposition: Claude Cohen-Tannoudji, Jacques Dupont-Roc, and Gilbert Grynberg, *Atom-Photon Interactions: Basic Processes and Applications* (Wiley, 1992; translated from the French edition, 1988).

The first section is concerned with the work that first made Cohen-Tannoudji's name, the small shifts in the energy levels of atoms resonantly absorbing photons from, and being stimulated to emit photons back into, an intense radiation field. This discovery—Cohen-Tannoudji theoretically predicted and then experimentally demon-