the contributors to this volume testify eloquently, albeit unconsciously, to this fact (for example: historians "know history and dates and authorships wonderfully," "you get all the little things you can dig up, little obscure publications that there is no evidence anyone ever saw," "the underbrush, all this difficulty of dates, sources, priorities, is straightened out"—a common misapprehension, here voiced by three different physicists). Certainly the failure of the physicists to understand the historians' aims and concerns had much to do with the failure of the conference to produce any effective interchange between the physicists and the historians; the discussion, under the eyes of video cameras, remained almost entirely among the physicists, who rather misunderstood the few questions from historians.

But if nuclear physicists are to be held responsible for the failure of the history of nuclear physics to be constituted as a scholarly field, it is not because they have failed qua historians or qua historical informants, but qua physicists. In contrast with the clarity, simplicity, and completeness of the physics of the extranuclear structure of the atom, a scientific development with a well-defined terminus ad quem and forming a well-established subject of historical scholarship, in the physics of the nucleus there is even to this day no specifiable nuclear force. There is no definitive solution of the problem of nuclear structure and processes, but only a variety of partial, more or less comprehensive, points of view. Because the physicists have not completed their task, the historians remain reluctant to enter upon theirs.

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Gravitational Waves

Sources of Gravitational Radiation. Proceedings of a workshop, Seattle, July 1978. LARRY L. SMARR, Ed. Cambridge University Press, New York, 1979. xiv, 506 pp., illus. $19.95.

Gravitational waves are propagating ripples of tidal gravitational stress. In Einstein's theory of general relativity (and nearly all other plausible theories of relativistic gravity) the waves are generated by rapidly changing accelerations of massive bodies. Asymmetrically imploding and exploding supernovae will do the job nicely. The waves traverse empty space at the speed of light, their energy becoming diluted by the normal inverse-square law. Gravitational waves, even as weak as they are when they reach the earth, can in principle be detected by the small accelerations that they give to one free mass relative to another that is separated by some distance or by the small stresses that they induce in elastic solids.

There is a certain genteel omission in the title of this fascinating and important book of symposium proceedings. The subject of *detecting* gravitational radiation is one of the book's main concerns. But that subject, some people think, is still slightly disreputable after the much publicized—alas, erroneous—"detection" of gravitational waves a decade ago. The book ought to do much to dispel such notions of disreputability. It is crammed full of hard laboratory information and (albeit not so hard) theoretical calculations. Theorists and experimentalists in this field are learning to speak the same language, and they are plotting their results (best estimates of source strengths from astrophysical sources and best estimates of achievable sensitivities in detectors, respectively) on the same graphs. Today the sources are below the sensitivities, but the gap is rapidly narrowing.

There is a growing consensus that two sorts of gravitational wave experiments are worth pushing hard. The first (and the longer recognized) is to detect kilohertz signals from collapsing supernovae in galaxies out to the Virgo cluster. The event rate ought to be on the order of one a month. The techniques of choice are ground-based (read "NSF-supported"), either with large monocrystal bars of sapphire or silicon or with multipass and high-power laser interferometry. The second experiment is to detect waves of much lower frequency, millihertz, which may have been produced by the collapse of massive black holes in the centers of quasars. One might "see" these collapses out to cosmological distances and therefore back in time to nearly the beginning of the universe. This frequency band and required sensitivity can only be obtained with a space-based (read "NASA-supported") development program. The techniques under consideration are precision Doppler tracking of already planned spacecraft, but with two-frequency up- and down-link telemetry and a dedicated mission with an onboard hydrogen maser clock.

A broad and interesting mix of physics and astronomy goes into the theoretical calculations of wave sources, and this variety is ably represented in the volume. Arnett's review of gravitational collapse in evolved stars does a particularly good job of demythologizing a subject that is usually adrift in a sea of numerical simulation, and (on the other hand) Wilson gives a clear exposition of how relativistic numerical hydrodynamics is actually done. At least half a dozen other papers could be singled out for their high quality and general interest. Two papers are edited transcripts of discussion sessions. Far from the dry pontification that usually dominates such sessions, these discussions—at least as edited by Epstein and Clark—read as free-wheeling brainstorming sessions that stand as remarkable portraits of an evolving and eclectic subject.

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Island Study

The Terrestrial Ecology of Aldabra. Papers from a meeting, March 1977. Royal Society, London, 1979. 264 pp., illus. + index. £21.65. First published in *Philosophical Transactions* of the Royal Society of London, series B, vol. 286.

Aldabra is an atoll in the Indian Ocean and the home of giant tortoises. About 15 years ago the British Ministry of Defence planned to build a military air base in an area of the atoll now known to support 60 percent of the tortoise population. The plan encountered serious opposition from conservation groups, and the Royal Society of London, while pressing for the abandonment of the air base scheme, sent a major scientific expedition to the atoll in 1967. Before the end of the year the scheme was indeed abandoned, and the Royal Society then switched its plans from short-term fact-finding to more comprehensive studies. Ten years later the Society held a two-day discussion of research progress. This book is a collection of the 23 papers presented at the discussion.

The major shortcoming of the volume is a lack of integration, which reflects the rather fragmented and uncoordinated nature of some of the research it reports. Nevertheless, there is no better source of information about Aldabra and its inhabitants. There are papers on geological and recent history, rainfall, soils and soil organisms, vegetation, seed dispersal, insects, crabs, land and sea birds, and turtles and tortoises. Of particular interest from the point of view of equilibrium island biogeography theory, which is frequently referred to, is the discovery of viable propagules of about 50 species of plants not found growing on Aldabra. They were picked up from the shores during a 20-month period. Of particular interest from the point of view of conservation is one of the world's rarest species of bird, the brush warbler *Nesillas aldabranus*. These birds are restricted to a thin strip of dense shrub. R. P. Prŷs-Jones saw only five individuals in two years and estimated the population size to be no more than 25.

Understandably, tortoises receive the most attention. Where did they come from? Probably from Madagascar, by floating or swimming, and the fossil evidence shows they colonized at least three times, most recently during the 80,000 years since the last total submergence of the atoll. At one time there were several species of giant tortoises on islands in the western part of the Indian Ocean, but by the 19th century they had died out or were driven extinct by the combined effects of human exploitation, disturbance of their habitat, and harassment from pigs, rats, and so on—except for the population on Aldabra. And this one must have narrowly missed the fate of the others, for a visitor to the atoll in 1906 saw none. Apparently it was a dry period on Aldabra then, to judge from rainfall records on other islands. Thereafter the population increased, under a wetter climatic regime, and has now reached a size of between 134,000 and 167,000 individuals. This seems to be close to the carrying capacity of the atoll.

M. J. Coe, D. Bourn, and I. R. Swingland make a good case for the idea that numbers of tortoises are limited by the amount of food and shade. For example, tortoises make forays up to 300 meters from shade trees, then return to forestall overheating, leaving a perceptible cutoff boundary in the vegetation. An interesting suggestion is made about how past rainfall helps to keep the tortoises alive in dry periods through its effects upon the vegetation. Rainfall percolates through rock and soil to accumulate as a large lens, and this lens is raised close to the surface and within the reach of plants only by high spring tides. Detailed studies of the tortoises have also revealed the age at which they first breed (17 to 23 years), their clutch sizes, their mortality and recruitment patterns, and other such information, so these animals are now better known demographically than are their more famous cousins on the Galápagos.

The implicit theme of this book is that the atoll is undergoing natural recurrent change on the scale of decades. Long-term studies are therefore essential for a proper understanding of its populations. In March of this year, the Royal Society will hand over the prime responsibility for operating the research station it built to another (unidentified) body. I hope a sense of the importance of long-term studies, and especially of the continuity of present ones, will be conveyed at the same time so that the benefits of past research will be fully realized.

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Darwin's Theology

Charles Darwin and the Problem of Creation. Neal C. Gillespie. University of Chicago Press, Chicago, 1979. xiv, 202 pp. $16.50.

The problem with which Gillespie says he began was to explain the surprising amount of "positive theological content" in the *Origin of Species*. To do so, and particularly to understand in what ways creation was a problem for Darwin, Gillespie wisely undertakes an examination of the ideas not only of Darwin but of his contemporaries. He shows that theological considerations played a major role in the biological science of Darwin's day, including Darwin's, and from this he argues that the reason there is so much theology in the *Origin* is that theological issues were still live ones for Darwin and, more important, that special creation was a "living and powerful idea" among his professional colleagues, one that required him to attack it with whatever weapons would be effective, including ridicule. Because theological issues were important for Darwin himself, he attacked on a theological as well as a scientific front. This is eminently reasonable. Even though by the 1850's the idea of miracles had been largely abandoned (to a greater extent than Gillespie allows), it is probably true that many biologists had not yet admitted the scientific and theological implications of doing without them. A shift in imagination was required, and this Darwin endeavored to effect.

Gillespie locates his discussion of Darwin and creation in a larger framework. He presents the 19th century as a period in which there were in existence two "epistemes," borrowing the term, but I think not the concept, from Michel Foucault. He calls one "creationism" and says that the creationist "saw the world and everything in it as being the result of direct or indirect divine activity" (p. 3). The other is "positivism," characterized as "that attitude toward nature that became common . . . in the nineteenth century, and which saw the purpose of science to be the discovery of laws which reflected the operation of purely natural or 'secondary' causes" (p. 8). (I do not think, and Gillespie perhaps would agree [p. 1], that either of these is what Foucault means by "episteme.") Gillespie says that the 19th century witnessed the transition from one episteme to another. In introducing his discussion he makes some very sensible remarks to the effect that in history epistemes, and also Kuhnian paradigms, are not discontinuous but are "dialectically related through human experience"; in other words, that the historian must seek to explain the development of a new episteme over time, rather than merely describing successively existing epistemes. In saying this Gillespie poses an important problem, but he does not seem to me to have succeeded in solving it for the 19th century. Partly this is because as a definition of an episteme or paradigm, or simply as a categorization of the views of many of Darwin's contemporaries, "creationism" is inadequate. Gillespie makes the idea of special creation the heart of "creationism," but he is forced to admit that one form of this idea—creation by law—could (and did) embrace transmutationism. There are good grounds for saying that Darwin himself believed in creation by law. More seriously, Gillespie does not really offer any explanation of why there was a shift to "positivism," instead contenting himself with occasional references to a growing positivism within science.

It is in discussing Darwin's theism that Gillespie makes his most useful, and much needed, contribution to Darwin scholarship. Because during his pre-Malthus speculations Darwin became a "materialist"—in the early-19th-century sense of the word—the idea has gotten around recently that from this early period he was an agnostic or an atheist. But a careful examination of the very notes that prove his materialism proves also that this materialism was theistic. As W. F. Cannon put it, Darwin thought that his materialism "made God grander than other ways of thinking did" (*J. Geol. Soc.* **132**, 379 [1976]). Gillespie rightly insists that to ignore or attempt to explain away Darwin's theism is to cut oneself off from understanding much of Darwin's science.

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