A Life in Physics

Dirac. A Scientific Biography. HELGE KRAGH. Cambridge University Press, New York, 1990. x, 389 pp., illus. $44.50.

There is little doubt that Paul Dirac was one of the greatest theoretical physicists of all time. He wrote his first paper in 1924 and his last in 1984, producing altogether 190 publications, of which 89 were pure research papers of penetrating originality, written in a spare, almost ascetic style. In addition, Dirac was reputed to be introspective, taciturn, difficult to approach, shy, and private to the point of indifference and rudeness. To write a biography of such a person is a monumental task, requiring an inordinate amount of time and great courage. The physics profession owes Kragh a debt for producing a serious, well documented, informative biography of Dirac.

The book consists of 14 somewhat overlapping chapters, of which four are purely biographical and eight deal primarily with Dirac's spectacular scientific success. Also treated are his less successful efforts, not to say failures, and his approach to physics and life (which to him were nearly the same).

The first two scientific chapters deal with Dirac's initial contributions to quantum mechanics and with the Dirac equation. It is remarkable that the first of these chapters, which treats Dirac's introduction of Poisson brackets and his transformation theory, is the less incisive. It is little more than a reasonably well written summary, without much discussion or analysis, of some of Dirac's 1925–1926 papers, and manifests some carelessness. It is hard to believe that the mathematics of wave mechanics (complex analysis and differential equations) was little known in Cambridge in 1926; Oppenheimer's first initial did not stand for John; Schweber is misquoted; and Goudsmit is omitted from an enumeration of Dutch theoretical physicists (as of 1926). Altogether the discussion of Dirac's brilliant early work is adequate but not especially deep. By contrast, the chapter on the Dirac equation is well written and gives interesting insights into the process whereby Dirac arrived at his extraordinary results. The reactions to Dirac's equation are carefully recorded and discussed.

Three further chapters discuss the hole theory, the positron theory, and the quantization of the electromagnetic field. The scientific description is very good, if at times a bit abbreviated and incomplete. The fluctuating attitudes and the different approaches of the originators of quantum field theory, Dirac, Pauli, Heisenberg, and Bohr, are recorded in great detail. Dirac introduced creation and annihilation operators but did not like Jordan-Wigner quantization. Dirac also did not like the Heisenberg-Pauli formulation of quantum electrodynamics, but they in turn did not like either Dirac's formulation or his positron theory. Dirac paid no attention to the anti-Dirac paper by Pauli and Weisshopf. All this is noted but not analyzed. Kragh quotes Pais to the effect that the vacuum polarization in 1935 was Dirac's last contribution to physics. Though he adds that "this point may be debated," he does not do so. But it is clear from his account that after 1935 Dirac gradually moved out of the mainstream of physics. His criticism of quantum electrodynamics became more strident, his search for alternative formulations more extreme and even desperate. He became more and more insistent that the road to progress was via mathematical beauty. This is discussed carefully and completely in the last chapter. Dirac's various efforts met with very limited success, as Kragh shows in the chapter on the classical theory of the electron and the excellent chapter on cosmology.

In the chapters that are primarily biographical, Kragh provides an enormous amount of detail, much of which is new and interesting. Throughout the book there are many true and many apocryphal stories about Dirac, many of which have been part of the Dirac folklore for some time. Together they give an interesting, if not revealing, picture of Dirac. The biography is certainly an important, highly professional contribution to the history of quantum theory. A noteworthy feature of it, whether virtue or defect, is its lack of passion. Here is one of the world's greatest scientists, involved in an extraordinary intellectual endeavor, engaged in a truly titanic struggle with his peers, but none of this comes through in the detached style of the author. In the same vein, the intense dislike Dirac had for his father is politely mentioned, but its impact on his emotional life is only hinted at, and certainly not discussed or analyzed.

In the late '60s, before moving to Florida, Dirac spent a semester at the State University of New York at Stony Brook. This reviewer had the pleasure and privilege of taking long walks with him all through the semester. It is certainly true that Dirac was quiet and taciturn, but he liked to communicate; he just needed to be asked, and when he was he responded enthusiastically. He was extremely sensitive to natural beauty and ugliness and often commented on the deplorable physical state of the Stony Brook campus. His view of the world was idiosyncratic, intensely personal, and unreasonably rational. But he was a deeply compassionate human being with a dry and whimsical sense of humor, with concerns, hopes, fears, and ambitions. This person I missed in this biography; perhaps it was not the intention to have him there, but I missed him nevertheless.

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Pleistocene South Americans

Monte Verde. A Late Pleistocene Settlement in Chile. Vol. 1, Palaeoenvironment and Site Context. TOM D. DILLEHAY. Smithsonian Institution Press, Washington, DC, 1989. xxiv, 306 pp., illus. $49.95. Smithsonian Series in Archaeological Inquiry.

This book is no mere background report on an archeological site. It provides an outstanding example of thoroughly integrated multidisciplinary research and an important lesson in epistemology. Even without a detailed consideration of artifacts and cultural features, it presents convincing evidence of 12,000-to-13,000-year-old human occupation in southern Chile.

Any claim for human settlement of such antiquity, especially so far south of Alaska, the presumed point of entry for the first New World colonists, is likely to provoke skepticism. Widespread human occupation of North America is well documented beginning around 11,500 years ago, but the archeological record for earlier time periods is spotty and debatable. Claims for earlier archeological evidence have so often been found to be flawed that explicit and stringent criteria are sometimes recommended: a human skeleton or an assemblage of definite artifacts in undisturbed geological deposits associated with fossils of known age (that is, extinct mammals) or with material suitable for isotopic dating. Preliminary reports on Monte Verde (such as the account in *Scientific American* of October 1984) did not reveal clear conformity with such standards. The majority of the stone artifacts (90%) were said to be pebbles picked up from a

creek bed and minimally modified by use. The creek bed context itself raised the specter of fluvial deposition for the remarkably well-preserved wood and the scattered mastodon bones. Hut foundations made of small logs staked to the ground were reported, but this skeptic wondered whether the logs were naturally fallen trees with the "stakes" actually representing branches preserved on the underside of the trunks.

My skepticism was diminished and my interest aroused when in May 1989 I heard a conference report in which Dillehay explained that the stakes were made of a different species of wood from the logs through which they were driven and that some of the stakes were wrapped with reeds! Since then I have eagerly awaited this book, and it has not disappointed. But it is a challenging book, because it presents the case for human occupation at Monte Verde on the basis of the biotic and abiotic evidence, leaving the cultural features and artifacts for a subsequent volume. Dillehay admits that this approach imposes "a burden on the reader to understand and accept results not yet presented" (p. xx). The burden seems heavy in chapter 1, wherein summary statements present botanical, wood, bone, and stone items entirely as the remains of human activity with no apparent consideration of alternatives. Likewise, "huts" and other features are presented as residential and nonresidential architecture without even proof that they are artificially formed. Only in subsequent chapters is skepticism gradually dispelled. The very fact that Monte Verde is an open site with remarkable organic preservation (bone, wood, twigs, seeds, leaves, animal tissue) is initially puzzling, but it holds the key to the unusual history of the deposit and its veracity as a human settlement.

Dillehay and nine collaborators present data and interpretations concerning geology, stratigraphy, chronology, wood and other plant macrofossils, pollen, diatoms, mollusks, insects, and vertebrates. Each discipline seeks to account for its own data set, considering both natural and cultural processes that might explain the site formation and its state of preservation. These studies are admirable for their consideration of multiple working hypotheses. Several of them (dealing with aspects of geology, paleobotany, and vertebrate paleontology) ultimately arrive at the conclusion, through argument by elimination of alternatives, that human agencies must have been involved in the formation of the site. Those studies that do not reach this conclusion (pollen, diatoms, insects) pertain to small particles and organisms that exist beneath daily notice of humans (except specialist students).

Human activity is indicated by modification of raw material (bone and wood) in a few cases, but is more abundantly demonstrated by the importation of numerous items from disparate sources. For example, 75 species of plants are represented by macrofossils (wood, seeds, leaves, and so on) in the site deposits. Although 75% of these are local in the sense that they may have originated within 5 to 10 kilometers of the site, it is unlikely that all of them grew within the small catchment area of the creek. The other 25% are non-local and were imported from the Pacific coast in the west and the Andean grasslands in the east. One species, the boldo (*Peumus boldus*), is a forest tree found no nearer than 1000 kilometers north of the site. These plants are selectively represented by parts that are edible, combustible, medicinal, or useful in construction; unusable parts must have been discarded elsewhere, because they are rare in the site deposits. *Peumus boldus* is represented by its edible seeds and a masticated cud of its medicinal leaves. Other imported items include several kinds of stone raw material, clay, salt crystals, a bitumen-like substance, and possibly a paleocamelid scapula. The investigators carefully consider both natural and cultural agencies that could have brought these materials together at Monte Verde.

A major objective of this book is the use of abiotic and biotic evidence to reconstruct paleoenvironmental parameters. Site data, new regional data, and previous geological and paleoecological studies are integrated for this purpose. Due consideration is given to the effects of human selection, especially in the plant assemblage, and non-selected materials (diatoms, pollen, and insects) are especially important here. Nearly all the data suggest that the environment of 13,000 years ago was similar to that of the present. An exception is the pollen study, in which the environment at the time of occupation is interpreted as colder than now but ameliorating. To me, the pollen evidence from the Monte Verde site seems rather weak compared with the fossil insect record, from which a wonderfully detailed paleoenvironmental picture is developed (fig. 12.6). A debate between the palynologist (Heusser) and the paleoentomologist (Ashworth) has a long history (see abstracts of the 12th International Quaternary Association Congress, 1987). It represents a vigorous and healthy effort to integrate multiple lines of evidence, and Dillehay discusses this process at length in a concluding chapter.

The epistemological lesson of this book is that evidentiary standards erected in advance cannot prepare us for, and may blind us to, unusual deposits that contain previously undiscovered kinds of material remains. Our search for the earliest human colonists has been focused on clearly shaped stone artifacts and extinct megafauna, but Monte Verde shows that an early archaeological record can be read from imported plants and clay. It is disconcerting to me that my skepticism concerning an archeological site has been abated by a book that does not even present the artifacts and cultural features, and it is a mark of well-integrated Quaternary science that this work has such an effect.

If people were in southern Chile 12,000 to 13,000 years ago, were they there earlier? Dillehay reports a small assemblage of fractured stones that "show clear percussion scars or use wear on their edges" associated with radiocarbon dates approximately 33,000 years old, but he concludes that this material "must remain ambiguous" (p. 18). Near the end of the book he asks why there appears to be a cultural hiatus between 33,000 and 13,000 years ago. Surely this represents a conviction that a larger sample and a greater variety of abiotic and biotic data would reveal an unequivocal archeological record at least 33,000 years old. The completion of studies in a subsequent volume may shed more light on this potential as well as present the artifacts and cultural features of the 12,000-to-13,000-year-old human occupation at Monte Verde.

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