tinually referred to as reflecting this "dilution." On the other hand, Blake does spend considerable space examining a number of related endogenous processes, presumably linked to the dilution hypothesis. In chapter 5 she reports a strong negative influence of family size on verbal scores of young persons, reflecting cognitive learning, which is responsive to parental attention and which predicts the amount of schooling attained. In chapter 7 she shows that young people from smaller families have higher educational aspirations in part because parental desires regarding children's amount of schooling, which are linked to family size, directly influence children's educational goals. Her other efforts to implicate dilution of parental resources as the mechanism by which family size effects operate are somewhat vitiated by negative findings. For example, she speculates (chapter 7) that family size might predict parental values regarding "intellectual curiosity" versus "obedience to parents," which might in turn affect schooling attainment. Her analysis indicates there are no family size differences in these variables, once parental socioeconomic characteristics are controlled. Generally speaking, Blake's attempts to find the endogenous aspects of family environments linked to family size differences, or some reflection thereof, are interesting and reveal imaginative uses of available data, but are essentially inconclusive.

Blake also examines the ordinal position of children as a factor affecting development and schooling attainment. She concludes, on the basis of past theory and research, as well as her own empirical analysis, that birth-order effects on cognitive skills are nonexistent once proper statistical controls are introduced for family size and socioeconomic level. In this context she gives considerable attention to Robert Zajonc's well-publicized claim (see for example *Science* **192**, 227–236 [1976]) that the downward trend in Scholastic Aptitude Test scores over the 1960s and 1970s might be explained by increasing average birth-order in these cohorts. Using a more extended series of average birth-order and SAT score data, she finds little support for Zajonc's speculation, but she notes that the SAT decline tracks well with lagged increases in average completed fertility of women. However, she calls for the analysis of more appropriate individual-level data and cautions against overinterpreting such aggregate time-series.

Blake's results are highly consistent with substantial amounts of literature. However, her interpretations of the effects as reflecting the dilution of parental resources may be premature. Though she makes a strong case that the effects of family size do not represent unmeasured exogenous influences, I would note that such conclusions rest on a set of assumptions about the adequacy and completeness of measures of between-family differences in socioeconomic experience. Before one concludes that associations of family size with schooling processes reflect the influences of family size on endogenous factors, as the dilution hypothesis does, one should be able at a minimum to identify and measure those factors and statistically interpret their role in transmitting such effects.

Overall, Blake seems too ready to embrace the conclusion that large families are bad for children and only good things will come of the "sibsize" revolution. Whereas the possibility that there may be more than an occasional offset to the advantages of small families is not fully explored, Blake devotes considerable effort to refuting the idea that solitary children suffer personality deficits. A more balanced approach to the issue of family size might give greater attention to non-intellective criteria. Having a number of siblings may help develop other traits beneficial to self and society, such as ability to get along and cooperate with others, to share one's belongings, and to care for and help others. One would hope that the questions future generations will ask regarding the desired number of children and their ultimate "quality" will not be answered solely on the basis of criteria associated with amounts of schooling.

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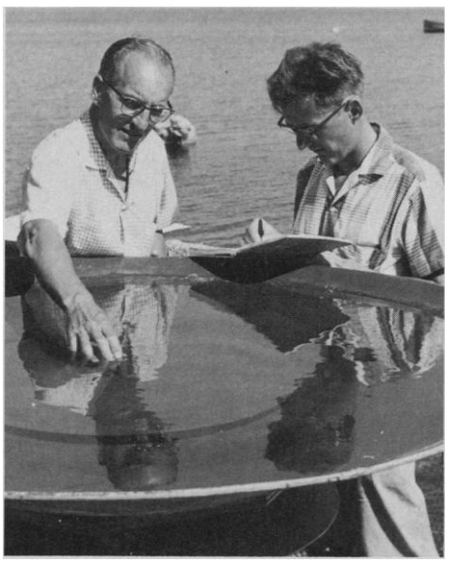
Aquatic Studies

Breaking New Waters. A Century of Limnology at the University of Wisconsin. ANNAMARIE L. BECKEL. With a chapter by Frank Egerton. Wisconsin Academy of Sciences, Arts and Letters, Madison, 1987 (available from Center for Limnology, University of Wisconsin, Madison). xiv, 122 pp., illus. Paper, $10. Special issue of *Transactions* of the Wisconsin Academy.

Few first-rate scientific groups remain first-rate for more than a decade. I was therefore anxious to read this little volume describing a group that has remained near the top of its discipline for a century and the three scientists who founded and directed it. Much of the history recorded in the volume was obtained first-hand, by interviews with people who were students or young scientists who worked with Edward A. Birge and Chancey Juday during the formative years of limnology at Wisconsin. This would not have been possible for much longer, for many of those interviewed are now in their 70s and 80s.



"A. D. Hasler and Wolfgang Braemer, a German ethologist from the Max Planck Institut, studying sun-compass orientation in fish, about 1957. Fish were placed in the center of the tank and trained to enter only the northerly compartments. The shade, peace, and quiet of a chamber were the rewards. Electric shock was given if incorrect direction was taken." [From *Breaking New Waters*; Arthur Hasler]

The portrait of Birge shows one of the most remarkable men to practice science in this century. The first several decades of his life reveal nothing unusual as far as scientific work goes: a few papers published, a department chairmanship followed by a deanship and a university presidency. However, following this career, from which most scientists would retire fully satisfied, Birge embarked on an enterprise that was to leave a permanent mark on ecological science: the integrated, multidisciplinary study of lakes—not just a few lakes, but hundreds of them. At the age of 73, Birge established a research station in then-remote northern Wisconsin. In his 80s he was still participating in field programs beyond the physical capabilities of most 20-year-olds and publishing papers that were all-time classics. He received limnology's most prestigious award, the Naumann-Thienemann Medal, at 98. One is a little disappointed that the book is limited to reciting Birge's achievements, revealing few details of the life of this remarkable individual.

The personal side of Juday, the Robin of the Wisconsin dynamic duo, is even less developed. He is described as a workaholic whose curiosity and fascination with lakes rivaled Birge's. His personality seems to have complemented Birge's perfectly; while

the latter acted as the front man and undoubtedly was the one in the limelight, Juday kept the research program organized and functioning, forming key liaisons with students, which seems to have been difficult for Birge, perhaps because he was a full two generations older than most of them. Yet Juday was a prodigious scientist in his own right. Years ago, I was shocked to find that his "annual energy budget for an inland lake," published in 1940, was superior to most of the energetics studies done under the International Biological Program 30 years later. The paper also avoids the mathematical and conceptual errors found in R. Lindemann's much more famous theoretical paper on energetics, which was published two years after it. A glimpse of the rivalry between the extremely empirical Wisconsin school and the more theoretically based Yale limnologists under G. E. Hutchinson is also provided in the discussion of Birge's and Juday's views of Lindemann's work.

The depression and Second World War seem to have taken a temporary toll on Wisconsin's limnological activities, particularly since both Birge and Juday were in their final years. But the legacy was strong enough to survive until it could be revitalized by Arthur Hasler. What is unusual about Hasler's direction is that he did not simply retool Wisconsin's aquatic science to reflect the strength of his own specialties but kept alive the strong tradition of multidisciplinary research that Birge had begun. Hasler brought the Trout Lake Station back from near-extinction to become one of the world's most thriving aquatic science establishments. He also recognized the tremendous value of the records of old but carefully performed analyses of chemistry and biology in northern Wisconsin. I have visited both Trout Lake and Madison laboratories recently, and it is clear that Hasler has had the foresight to ensure that limnology at Wisconsin would remain strong after his retirement—a consideration most famous scientists ignore.

The book is well illustrated with pictures of apparatus, individuals, and field sites from early in the century. It is a pleasure to read—I picked it up late one evening and finished it just as the first birds were beginning to call.

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"E. A. Birge and C. Juday with plankton trap on Lake Mendota, about 1917." [From *Breaking New Waters*; State Historical Society of Wisconsin]

Anoxic Life

Biology of Anaerobic Microorganisms. ALEXANDER J. B. ZEHNDER, Ed. Wiley-Interscience, New York, 1988. xiv, 872 pp., illus. $89.95. Wiley Series in Ecological and Applied Microbiology.

Anaerobic microorganisms, which generally cannot grow in the presence of oxygen, abound in nature. Even we humans swarm with them: over 97% of our microflora consists of anaerobic microorganisms, including more than 90% of the bacterial flora on human skin. The diverse metabolic capabilities of anaerobes make them inherently interesting to physiologists and biochemists. Unlike aerobes, whose catabolic metabolism is basically to reduce oxygen to water and oxidize organic compounds to carbon dioxide, anaerobes reduce a variety of organic and inorganic compounds (such as carbon dioxide, sulfate, nitrate, fumarate, even iron and manganese) and produce all sorts of end-products of metabolism, many of which are useful (including acetic acid, propionic acid, lactic acid, ethanol, and methane). Anaerobic microorganisms also play major roles in the global cycling of carbon, nitrogen, and sulfur.

In spite of the importance of the organisms, research into anaerobic life has lagged, primarily because these microorganisms were considered difficult to work with. In the late 1970s, however, the announcement of the discovery of the archaebacteria, of which the major group is the anaerobic, methanogenic bacteria, concomitant with the publication of refined techniques to handle anaerobes, caused a rapid increase in research on anaerobes. The rise of biotechnology provided further impetus. It is pleasing finally to see a book that includes all the important aspects of anaerobic microbiology.

This book contains 14 chapters written by 19 contributors. In addition to the traditional subjects—purple and green phototrophs, nitrate reducers, sulfate reducers, and methanogens—less common topics appear: iron and manganese reduction, anaerobic lignin degradation, and the anaerobic fermentation of lipids. The chapter on acetogenesis, which makes an effective transition between those on lipid fermentation and methanogenesis, brings a fresh outlook to this frequently reviewed process.

The material on the better-known anaerobes (phototrophs, nitrate reducers, sulfate reducers, and methanogens) is usefully organized in pairs of chapters, one on ecology and the other on biochemistry.

Two key themes appear repeatedly throughout this book—geochemistry and