began. However, he fails to mention, even by way of refutation, Gorman's evidence for plant domestication in Thailand before 7000 B.C. (*Science* **163**, 672 [1969]).

The origin and movement of the major Old World plants and animals are summarized, and aperçus of minor domesticates are presented. Isaac argues that, after domestication started in a rather broadly defined Near Eastern hearth, population movements introduced these to other regions, where contacts led to secondary domestication of local biota. Some of the secondary domesticates are conceptualized as "bridging domesticates," plants that helped to transfer domesticates, poorly adapted to one area, to places where they could flourish. "Substitute domestication" is the replacement of an introduced domesticate by a more recently developed native plant. Regrettably, Isaac's model does not account for the domestication of many plants and animals. It does not explain the domestication of most of Africa's indigenous plants or elucidate why China is, in his terms, a center solely of secondary domestication. Furthermore, convincing archeological data support the proposition that domestication in the New World was independent of an Old World stimulus.

In reviewing theoretical ideas concerning the origins of domestication, Isaac offers valuable critiques of Sauer, Vavilov, and others. But his revival and extension of Eduard Hahn's belief that religion was the primary basis of domestication, a theme making this book unique, sheds new light on this basic question. Isaac postulates that certain plants and animals with crescent- or lunar-shaped horns were domesticated to fullfill a continuous need for ritual offerings. on the basis of an analysis of myths with a slain god motif, he proposes that another "revolution" occurred, with primacy in the Near Eastern Neolithic, which changed man's religious philosophy toward the animate world. He evokes this argument to reject an ecological or economic interpretation of domestication.

Isaac naively criticizes archeology while ignoring the fact that recent work actually supports and strengthens some of his basic hypotheses. Less reliance on outdated secondary sources and a better comprehension of the contributions of anthropological archeologists and paleoethnobotanists would have prevented the use of inaccurate evidence. For example, Tell Mureybat in Syria and Ali Kosh in Iran are far more important for understanding the beginnings of domestication than are the Natufian sites, which Isaac mistakenly dates too early and which have no evidence of domestication. In addition, the alleged fortification around Jericho is Neolithic and not Natufian. Contrary to Isaac, terracing actually occurred earlier elsewhere in Asia. And finally, the presence of gazelle and antelope bones in later Near Eastern sites does not mean these animals were domesticated.

Domestication is a very complex subject, with educated guessing a rule of the game. The criticisms notwithstanding, Isaac has compiled a succinct and readable book. It is unfortunate that serious misinterpretations and omissions, recognizable to the scholar, were missed by the series editor and reviewers, for their presence does not commend this otherwise interesting book to beginning students or to laymen.

RICHARD I. FORD
Museum of Anthropology,
University of Michigan, Ann Arbor

Ovines in the Wild

Mountain Sheep. A Study in Behavior and Evolution. VALERIUS GEIST. University of Chicago Press, Chicago, 1971. xvi, 384 pp. + plates. $14.50. Wildlife Behavior and Ecology.

Mountain sheep are found on all northern continents and are characterized by considerable diversity, especially in horn shape. This book documents a highly detailed behavioral study of the bighorn sheep, *Ovis canadensis,* in several regions of British Columbia and Alberta. It also includes data from the author's studies of Dall's sheep, Stone's sheep, moose, and mountain goat. Geist's investigation places him among the ranks of those biologists who believe that the best way to understand the behavior and ecology of large mammals is to go and live with them for all seasons of the year. To the names Fraser Darling, Murie, Schaller, Carpenter, and Goodall must now be added Geist. However, this book is much more than an account of field studies. On the basis of his behavior studies, Geist advances a theory of sheep evolution which suggests "that evolutionary changes can be adaptations not to the physical habitat but to changes in the social environment." He fairly acknowledges his intellectual debt to J. F. Eisenberg, who suggested in 1966 that the type of society demonstrated by each species of mammal is closely related to and a function of its separate ecology.

Geist suggests that, early in their evolution, sheep developed a new defense against horn blows in combat. Instead of relying on a thick hide and an inhibition against entering combat, sheep "caught and neutralised" horn blows with the head. The structure of the head and horns altered and males could thus fight without injuring each other. Selection against fighting was reduced. Selection for sociality arose (i) because mountain sheep live on small patches of stable grassland which are generally all occupied, so that selection will act against dispersing juveniles and juveniles will tend to inherit home ranges from adults, and (ii) because of the development of "neotenization," whereby juvenile characters are retained in adults. As a result, young rams (although sexually mature) have a long period of postpubertal physical maturation, and in the first year of life closely resemble adult females. Bighorn sheep are thus a behaviorist's "dream species," for it is possible to exactly predict a male's hierarchical position by the size of his horns. Space does not permit a complete description of Geist's theory of sheep evolution, except to mention that he relates increased horn size to the distance a race has moved into previously glaciated terrain. By comparing horn development and aggressive behavior patterns, Geist explains the evolution and present distribution of the six known species of wild sheep and their many races.

The book is not without minor faults. Several references are made to a paper by Watson *et al.,* 1956, but it is not listed in the bibliography. Geist makes no mention of A. F. Fraser's 1968 book *Reproductive Behaviour in Ungulates.* Bad stippling of figure 44 makes it impossible to separate certain hypothesized sheep movements. It is occasionally difficult to determine in the text exactly which species the author is referring to. And Geist gives little information on his method of individual identification of animals, which is crucial in a behavioral study.

The book is very well illustrated by clear drawings and first-class photographs. There is a wealth of tabular and graphical data. To wildlife biolo-

gists this book provides an excellent basis for the management of wild sheep. There can be no doubt that *Mountain Sheep* will prove of considerable value to all those interested in mammalian behavior, ecology, and evolution. It will stand as the definitive text on wild sheep for many, many years.

R. M. F. S. SADLEIR
Department of Biological Sciences, Simon Fraser University, Burnaby, British Columbia

Atmospheric Modeling

Numerical Weather Prediction. GEORGE J. HALTINER. Wiley, New York, 1971. xviii, 318 pp., illus. $10.95.

Numerical weather prediction is the forecasting of a state of the atmosphere from a known initial state by solving the hydrodynamic equations governing atmospheric phenomena. The idea of such forecasting is old. However, although the basic principles of atmospheric dynamics have long been known, their successful application for the prediction of large-scale motion in the atmosphere awaited the construction in the last two decades of sophisticated numerical models of the atmosphere based on theoretical and observational studies of the characteristics of atmospheric motions. The development of electronic computers and the system of the meteorological observation have also contributed to the success.

In this book, the physical and mathematical considerations which have been and should be taken into account for successful development and integration of an atmospheric model are well described. In the atmosphere there are many modes of wave motions and oscillations. One should know the behavior of each mode of waves and its role in the prediction of the large-scale field of the atmosphere. In many models, the primitive equations are simplified so that only the factors that are primarily important for the change in the meteorologically significant waves are retained. Such an approximation can be made systematically by means of scale analysis. It may be desirable that the simplified system satisfy some integral constraints regarding vorticity and energy which are fulfilled by the primitive equation system. Understanding of the growth of large-scale waves as a result of the instability of the atmosphere is also important for proper modeling. Numerical integration schemes have to be formulated carefully so that both linear and nonlinear computational instabilities can be avoided. The aforementioned important subjects in this field have been discussed sporadically in various journals in many years. It is good that they are now treated in a single book. This book will be useful and handy for the numerical modelers in the field of dynamic meteorology in general, and the methodology summarized in it will be full of suggestions for scientists working with numerical models in other fields.

There are underdeveloped areas in numerical weather prediction. One problem concerns the atmospheric waves in the tropics. Another important problem is how to incorporate the ensemble effect of cumulus convection into a large-scale model. Those are briefly mentioned and some parameterization schemes of convections are explained, but the so-called convective adjustment method which is currently used with success in some big models is not introduced.

A question that may naturally arise is the limit of deterministic prediction—how far ahead and how accurately can one compute the future state of the atmosphere? An answer to this question cannot be found in this book. If the problem of predictability had been included I would have enjoyed reading the book more. At any rate, I welcome its publication.

YOSHIO KURIHARA
Geophysical Fluid Dynamics Laboratory/NOAA, Princeton University, Princeton, New Jersey

Chemical Exchanges

Bioinorganic Chemistry. A symposium, Blacksburg, Va., June 1970. RAYMOND DESSY, JOHN DILLARD, and LARRY TAYLOR, Eds. American Chemical Society, Washington, D.C., 1971. x, 436 pp., illus. $14. Advances in Chemistry Series, vol. 100.

These lectures on bioinorganic chemistry will be useful to chemists who seek examples of biological problems (nitrogen fixation, metal ion effects on nucleic acid structure, metalloenzymes, heme proteins, and other metalloproteins such as ferredoxins or ceruloplasmin) to which to apply knowledge of inorganic chemistry and techniques such as nuclear magnetic, electron paramagnetic, and proton magnetic resonance and complex kinetic analysis. Correspondingly, a biologist may find approaches that are more useful than the analyses usual in enzymology (enzyme isolations, cofactor and intermediate identification, and kinetic and inhibitor studies). These analyses are becoming analogous in value to the descriptive observations of anatomists or embryologists in a time when cellular and molecular approaches can be taken; though useful and important, they are not sufficient to open up new concepts.

One is impressed with the probable truth of what several of the authors imply: that inorganic chemistry is far more important to biology than has thus far been recognized in biological dogma and training, and may turn out to be as important as the organic side. Thus the curious political separations and territorial antagonisms of inorganic, organic, and physical chemists, biochemists, biological chemists, and biologists gradually have been diminished by the logic of the chemical and biological questions themselves. A chemist (Williams) now expresses his excitement at the reasonable way in which certain ions have been selected through evolution for special roles.

The volume reflects a continually increasing interest among protein chemists and enzyme mechanists in probing the mechanisms of inorganic ion catalytic groups and inorganic reactions, in contrast to a preoccupation with kinetics, protein structure, and mechanisms of reactions involving organic molecules. Chemists (some of whom may be in awe of enzymes or may not believe in them) may be stimulated by descriptions (such as that given by Breslow in this volume) of the development of model compounds for enzymes, not only for the inherent interest of enzymes but as they point the way toward the development of selective catalysts.

Some of the articles (Caughey's, for example) are fairly concise presentations largely of the authors' own work. Some (such as that by Williams) are rambling, enthusiastic, and speculative. Authors were motivated to spend more time in model building, speculation, commentary on the importance of problems, and prediction of useful approaches (as do, for example, Williams and Rabinowitz) than a scientist usually feels allowed to do in preparing a review.

The book will be a useful addition to biochemistry and chemistry libraries—more so to the latter, for much of the material in it is already available