uses "propagule mortality" to refer to the deaths of amphibian eggs and larvae, and Dominey and Blumer, noting that killing of eggs, larvae, and juveniles in fish is always accompanied by consumption, use "cannibalism" in preference to "infanticide." Dickemann proposes that, since the term "infanticide" is imbued with Western thought and societal values, "pedicide" may be a more biologically meaningful and broadly useful term. As with debates over such terms as "cuckoldry" and "rape," perhaps the essential issue is not what term is used but the need for researchers to define in detail what they mean by it and what evidence they consider imperative for establishing its occurrence.

The taxonomic groups receiving the most detailed treatment in this volume are rodents and primates. For rodents, field evidence of infanticide is sparse, in part because unweaned young are rarely seen and killers are likely to be quick and cryptic in their action. However, extensive laboratory data focusing on the effects of age, sex, strain, social status, reproductive status, copulatory experience, hormonal levels, and intrauterine environment for species such as house mice and Mongolian gerbils are reported in the five chapters covering rodents. All nine chapters on nonhuman primates discuss field evidence for infanticide, albeit circumstantial in many instances. Thus, even though primate infants are visible to observers from birth and infanticidal males appear not to be especially surreptitious in their behavior, observers rarely witness a complete infanticidal event. Human infanticide can also be difficult to document even in societies in which the behavior is not legally proscribed; authors of the four chapters on humans indicate how statistical evidence, such as sex differentials in mortality, provide an indirect indication of the occurrence of infanticide.

This book provides a valuable review of the evidence and ultimate explanations for infanticide across a spectrum of taxonomic groups. Two matters that I consider needed more treatment are the potential detrimental effects on lifetime reproductive success for males that kill female infants that might be future mates and the adaptive significance of female mammals' terminating investment in their own neonates by means of infanticide. No doubt other readers will find matters of interest to them that are neglected. However, overall such omissions are small compared with the wealth of information and ideas contained in the book. I consider this book essential reading for behavioral ecologists, sociologists, psychologists, demographers, and anthropologists interested in the evolutionary origins and proximate causation of infanticide in animals, including humans. It will enrich the reader's understanding of the types of infanticide that occur across a range of taxonomic groups and the contexts in which infanticide occurs; most of all it should convince even the most doubtful that, in most instances, infanticide is a natural behavior that can be interpreted in the context of modern evolutionary theory.

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De revolutionibus Analyzed

Mathematical Astronomy in Copernicus's De Revolutionibus. N. M. SWERDLOW and O. NEUGEBAUER. Springer-Verlag, New York, 1984. In two volumes. xxiv, 711 pp., illus. $78. Studies in the History of Mathematics and Physical Sciences, vol. 10.

The great work from which historians date the beginning of modern science, Copernicus's *De revolutionibus*, has been republished six times in its original Latin and translated more times than that into at least five modern languages. Yet for all this attention, nothing has been produced that can be termed a critical edition, or even a satisfactory translation, because none of the enterprises has been based upon the detailed technical understanding and extensive recomputation necessarily involved in comparing *De revolutionibus* with its great predecessor, Ptolemy's *Almagest*. Years ago, long before the appearance of the spate of new editions and translations in connection with the 500th anniversary of the birth of Copernicus in 1973, Otto Neugebauer envisioned an extensive commentary on Copernicus, as the final phase of a study of the entire tradition of Greek astronomy. The project proved too ambitious even for the venerable Neugebauer, however, and it has only now been completed by one of his disciples. The result is some 400 pages of analysis, accompanied by well over 200 diagrams and some 20 graphs, covering every aspect of Copernicus's mathematical astronomy.

This book is not for tyros. It is not that either the mathematics or the astronomy is severe; in fact, the closest I can come to criticizing Swerdlow's study is to express the opinion that many readers will wish for analytical expressions of some of the interminable geometry. But the historical discussion has to assume some background and sophistication in order to be useful to the professionals to whom it is directed, and most nonprofessionals will, accordingly, find a fair number of bewildering allusions and even apparent gaps in the presentation. For those who persevere, however, Swerdlow has a number of interesting general points to make, amid the mass of detail of individual calculations. What all of these points convey, in various ways, is that science was no easier to do in the 16th century than it is now. If the rules for doing science were so much looser as to allow Copernicus to indulge in shortcuts that will be viewed variously as tragic or comical, the methods available for coping with the task "legitimately" were correspondingly feebler. Four passages from Swerdlow's introductory summary should suffice to illustrate the problems:

> This [procedure] would be difficult enough if the parameters were correct, but mostly they were not, resulting as they did from very sensitive derivations from less-than-accurate observations [p. 74].
>
> Nevertheless, it is one of the most confusing sections of *De revolutionibus*, containing many errors and internal contradictions, due to an inconsistent revision of an originally flawed exposition [p. 75].
>
> The agreement between the observation and computation comes out perfectly, but only because Copernicus first altered the time of the observation by 40^m and the longitude of the star by $10'$ [p. 76].
>
> . . . the analysis required to discover these consequences was very difficult and required observations of a sort that it never even occurred to Copernicus to make [p. 77].

Inevitably, a commentary such as this is Monday morning quarterbacking. Yet Swerdlow never allows the reader to forget that Copernicus was not always even trying to do as much as modern readers might presume he was and that even what he was trying to do was very difficult. And, though Swerdlow's analysis is probably more pointed than what most historians of science indulge in, it is probably gentler than most people without historical training will find comfortable. Most controversial for scientists will probably be the fundamental chain of assumption underlying the analysis: (i) Copernicus truly seems to have assumed (more or less correctly) that Ptolemy's models were mathematically correct representations of the phenomena, but physically impossible ones; so (ii) all he (Copernicus) had to do was find physically reasonable models (without equants) that were mathematically equivalent to Ptolemy's; therefore (iii)

Copernicus "can hardly be blamed for not undertaking to investigate [the phenomena themselves, which] Ptolemy and Regiomontanus both considered to be settled" (p. 84); and so (iv) "comparison with modern computed positions (of the planets) is not really of interest . . . and give[s] a positively misleading idea of the contemporary judgment that is of real historical interest" (p. 457). Thus, though Swerdlow asserts that Copernicus's theories give better results than Ptolemy's did because the initial conditions were more accurate, some readers will be disappointed by his refusal to provide the comparisons with modern theory that have been traditional for this enterprise.

Although many readers will agree that this book contains "more [detail] than anyone wants to know," there can be little doubt that it will join Neugebauer's *History of Ancient Mathematical Astronomy* as one of the classics of the field.

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Earth History

Patterns of Change in Earth Evolution. H. D. HOLLAND and A. F. TRENDALL, Eds. Springer-Verlag, New York, 1984. x, 434 pp., illus. $22.50. Dahlem Workshop Reports. Physical, Chemical, and Earth Sciences Research Report 5. From a workshop, Berlin, May 1983.

This volume of results from an interdisciplinary conference amply documents the case that geological processes have changed significantly during the course of earth history and that the rates of change have fluctuated widely.

Though it is common knowledge that the earth's living inhabitants have changed with time, it is less well known, even among scientists, that the non-living world has changed also. In fact, life has had a significant effect on its physical and chemical environments. The most impressive example in earth history of organisms changing their environment is the oxygenation of the ocean and the atmosphere brought about by photosynthetic organisms approximately 2×10^9 years ago (during the Early Proterozoic). There is no longer much disagreement among earth scientists that the ocean and the atmosphere during the first half of earth history were anaerobic, in the sense that they contained too little oxygen to support aerobic metabolism. But the factors that made possible this significant impact of life on its environment are still subject to debate. The suggestion is made here by A. H. Knoll that the change was brought about by a great increase in the extent of stable, shallow-water, continental-shelf environments, which harbor particularly productive ecosystems. That the early earth probably lacked extensive continental land masses and the associated continental shelves is not yet well known, even to many earth scientists. Evidence for the growth in time of the extent of the continents is reviewed in several of the papers in this collection.

If the continents grew with time, did the masses of atmosphere and ocean grow also? Were the tectonic styles on the early earth markedly different from the now-familiar plate tectonics? What processes caused the growth and stabilization of continents? These questions are debated in the book. There is a consensus that earth accreted rapidly and therefore began its history with a hot, convecting interior. As a consequence, the volatiles of the ocean and the atmosphere were released from the interior of the earth at an early stage. The heat flow from the interior must also have been significantly higher when the earth was young, but how this high heat flow influenced global tectonics and the growth and development of the continents is not yet clear.

Other topics in earth history also receive attention. These include the impact on life, on the oceans and the atmosphere, and on climate of collisions with the earth by large extraterrestrial bodies, meteorites, or comets. Attention is given also to the accumulating evidence that significant and frequently rapid changes in the chemistry of the ocean (and presumably also of the atmosphere) took place during the most recent 600×10^6 years of earth history. Some of these changes may have been caused by biological innovation, but changing geography, a result of continental drift and plate tectonics, is the favored cause for most of the changes.

The book includes review papers, many of them exceptionally good, by individual authors, as well as four Group Reports presenting consensus views of current knowledge and questions for further study. The book presents a useful overview of recent advances in our understanding of earth history.

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Paleoclimatology

Milankovitch and Climate. Understanding the Response to Astronomical Forcing. A. BERGER, J. IMBRIE, J. HAYS, G. KUKLA, and B. SALTZMAN, Eds. Reidel, Boston, 1984 (distributor, Kluwer Boston, Hingham, Mass.). In two volumes. Vol. 1, xxxiv pp. + pp. 1–510, illus. Vol. 2, ix pp. + pp. 511–895, illus. The set, $117. NATO ASI Series C, vol. 126. From a workshop, Palisades, New York, Nov. 1982.

Palaeoclimatic Research and Models. A. GHAZI, Ed. Reidel, Boston, 1983 (distributor, Kluwer Boston, Hingham, Mass.). viii, 205 pp., illus. $34.50. From a workshop, Brussels, Dec. 1982.

Great strides have been made in quantitative paleoclimatology in the last 15 years. Every few years a book is published that summarizes another level in the development of the field. The most recent addition to this list is a two-volume set of about 50 papers from a conference on Milankovitch and climate.

The volumes address the role of orbitally induced insolation changes on the earth's past climates. The book is dedicated to an early champion of the theory—Serbian astronomer Milutin Milankovitch. Without explicitly saying so, the book is also a tribute to the most eloquent recent advocate of the Milankovitch effect—John Imbrie. As one of the leaders of the former CLIMAP project and the present SPECMAP project, and as a coauthor of a landmark paper, Imbrie has inspired a widespread search for evidence of an orbital effect on climate. The present book summarizes observational evidence and modeling results that bear on this relationship.

The observational part of the book mainly focuses on evidence of an orbital effect during the Pleistocene ice ages, although there is a valuable section on evidence of pre- Pleistocene cyclicity. In both cases, there seem to be cycles, cycles everywhere. There are several papers on rhythmic bedding in rocks spanning the last 200 million years. The sedimentary couplets have a characteristic time scale of tens of thousands of years, the same period as Milankovitch cycles. Further evidence from Pleistocene sections indicates that there was an orbital influence on lake levels, wind-blown dust variations, ocean currents, and the African-Asian monsoon. A contribution from the SPECMAP group (a consortium of scientists from Brown University, Lamont-Doherty Geological Observatory, and Oregon State University) indicates that orbital insolation changes account for as much as 85 percent of the variance in global ice volume