the Earth. This book is not about evolution but is a religious work. The first part of the book documents the way in which the ideas of religious people have changed as knowledge of natural phenomena through observation has increased with time. The second part reviews the geological evidence for the age of the earth. The third part deals with Young's philosophical and "apologetic" considerations. Young argues that blindness to compelling observational data is a handicap to advancing religious good, yet at the same time he is reluctant to accept all types of observational data. As a professional geologist Young believes the evidence obtained from geology for the great age of the earth is convincing. He is concerned that conservative creationists are defeating themselves and their credibility with their continued advocacy of a young earth. Young states (p. 149), "The totality of evidence just does not point to the earth being only a few thousand years old, no matter how ardently creationists might wish that it did. No amount of juggling can change the overwhelming weight of evidence." And on p. 163 Young says, "May I plead with my brethren in Christ who are involved in the young-Earth movement to abandon the misleading writing they provide the Christian public. I urge them to study geology more thoroughly. Geology cannot be learned from a few elementary textbooks. There is far more to it than that." Young also acknowledges that religious concepts need interpretation. He even says (p. 163), "I also urge creationists to be less dogmatic about Scriptural texts over which there has been substantial diversity of interpretation within the historic Christian church."

But in Young's book we also meet the creationist-evolution dichotomy in its clearest form. Young is an admitted creationist (p. 10) as well as a professional geologist. Although he is willing to accept the evidence of the science he happens to practice and even advocates that scripture needs interpretation when it seems to conflict with the compelling evidence of geology, he is not willing to accept the evidence for evolution from biology and paleontology that Futuyma, Newell, Eldredge, and others regard as equally compelling. Because of his personal choice of scriptural interpretation he reaches the conclusion (p. 66) that "Without question a materialist evolutionary philosophy is hostile to Christianity and ought to be opposed by Christians. Likewise the doctrine of the evolution of man is unscriptural and should be opposed." On one hand Young admits that some observational data are compelling and religious interpretations should not attempt to deform or deny them and on the other hand he adopts the view that equivalent observational data must be opposed and denied because of religious interpretation. For judging the age of the earth Young requires evidence for his beliefs, for judging evolution he does not. Here is the issue in a nutshell.

I am afraid this is where the situation stands. Although evolution does not attack religion it does pose the problem of what to do when convincing scientific conclusions come into conflict with the beliefs people hold without evidence. The creationists are no more ready to deal with evolution than the Catholic church was prepared to deal with Copernican (heliocentric) astronomy in the time of Galileo.

Although they will probably not change very many minds among those who already have a conviction on the subject, these books should be of great utility in educating students in the sciences and in presenting the case for science, as separate from religion, to the uncommitted public. We should applaud the good efforts of all the authors of these generally excellent books. The choice of a book to read should be based on the flavor, style, or approach you are most attracted to—but every scientist should read at least one of these timely books. The political importance of the issue requires that we all be responsibly and reliably informed.

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Sex Ratios and Reversals

The Theory of Sex Allocation. ERIC L. CHARNOV. Princeton University Press, Princeton, N.J., 1982. x, 358 pp., illus. Cloth, $40; paper, $12.95.

As is well known, there are various ways to procreate. Certain shrimp, fish, and mollusks reproduce as males early in life but later reverse to the female sex. Other fish do the opposite, whereas most never change gender. Still others are male and female at the same time; so are many snails, earthworms, flukes, and tapeworms, to cite a few examples. Sex ratios of offspring are also diverse: some reptiles and invertebrates can produce almost anything from all male to all female progeny, depending on ecological circumstances, even temperature. Among plants, the forms of sexuality are even more varied.

Can all this variation be accommodated by a single theory? In this monograph Eric Charnov successfully demonstrates that it can. He provides a coherent evolutionary approach to an array of seemingly disparate problems of sex allocation: the allocation of time and energy by plants and animals to male versus female reproductive function. The book is based on "selection thinking" and asks "why" on a subject where "how" has been the traditional question. This focus on natural selection, the penetrating analysis of the problems, the balanced blend of theory and data, and the lucid, simple style make the book a delight to read.

It is organized in three main sections: on sex ratio in dioecious organisms (with the sexes separate and unchanged throughout life), on sex reversal, and on simultaneous hermaphroditism. Some of the problems treated are: What sex ratio among progeny is favored by selection? Should a sequential hermaphrodite be male or female first, and when is the best time to switch? In which proportions should a simultaneous hermaphrodite partition resources for male and female function? When will a mixture of sexual types be stable? And what are the ecological and social conditions favoring a certain sex ratio or sexual system? The unifying aspect of these questions is that answering them usually involves calculation of a population equilibrium (evolutionarily stable strategy) based on the genetic contributions through male and female function.

The theory is expounded in mathematical models. Charnov shows admirable skill in developing the simplest possible model that captures the essentials of a situation. Surprisingly, almost all the different problems can be treated by one main theoretical device: the "Shaw-Mohler equation." The resulting rule in words is that selection favors a mutant gene that entails a proportional gain in fitness through one sex function that

exceeds the proportional loss through the other sex function.

The author approaches the problems by developing the theoretical trade-off between male and female function in a fitness set, inserting this relationship in the appropriate form of the Shaw-Mohler equation, and solving for the equilibrium. The biological conditions that give rise to different trade-off relations are discussed, and the predictions are tested by taxonomic and geographic comparisons or experiments; if such information is not available, suitable test organisms are suggested.

How do the theoretical predictions stand up to reality? Qualitatively, quite well in most cases, and even the quantitative details are sometimes remarkably accurate. Some of the strongest evidence for sex ratio adaptation comes from ingenious experiments on parasitic wasps, in which females can control the gender of each offspring by laying fertilized (female) or unfertilized (male) eggs. As predicted, if females gain most from being large (for example because large size enhances egg production), the proportion of female eggs increases with host size; the size of the adult parasite increases with that of the host on which it was born. However, although it seems likely that females in these wasps benefit more than males from being large, this remains to be shown. Other important aspects of the theory are also untested. Moreover, as G. C. Williams has pointed out, the equilibrium sex ratio could be achieved in several different ways. For example, some females might have all sons, others all daughters; yet females usually produce mixed broods. Charnov describes two possible reasons, but the problem is not yet resolved.

Marked deviations from unit sex ratio are sometimes predicted where siblings compete for mates in a local breeding group, or over other resources: a female should produce most offspring of the sex with least sib competition. The quantitative predictions are fulfilled to an impressive degree in experiments on superparasitism by several wasps (*Nasonia vitripennis*) laying eggs on the same host.

With few exceptions, there is little evidence for marked short-term adaptations of the sex ratio in higher vertebrates; several observed deviations seem maladaptive. A remaining key problem is what favors the stability of the chromosomal sex determination, which apparently makes early sex ratio adaptation difficult in birds and mammals. But that question concerns the evolution of proximate mechanisms, which the book does not attempt to cover.

Under what conditions is sex reversal adaptive? The "size advantage hypothesis" predicts that it may evolve if reproductive success increases with body size more rapidly in, say, females, whereas small males can have higher success than small females. Starting as male and later changing to female sex may then be favored over dioecy. Any cost of changing sex promotes dioecy; Charnov suggests several such costs that may explain why sex reversal is limited to a minority of organisms.

Simultaneous hermaphroditism according to the "resource allocation model" may evolve if offspring production through male or female function follows a law of diminishing returns; sharing the reproductive effort between the two sex functions can then be better than concentrating it on one. Diminishing returns may occur for many reasons, such as limited capacity for parental care in females, or limitation of the number of mates that a male can fertilize in a small breeding group, as Charnov suggests for certain barnacles. Selfing and inbreeding depression are important for the optimal allocation of male versus female function and for the stability of hermaphroditism. If inbreeding depression is < 0.5, selfing may be adaptive; it will then enhance the stability of hermaphroditism. Evidence from many plants supports theory in that hermaphrodites spend less resources on male function as the selfing rate (and hence "local mate competition" among an individual's own pollen) increases.

Like most previous volumes in this series, the present one provides a stimulating theoretical perspective and review of its subject. The book has the additional merit of testing the theory with numerous critical experiments and observations, also considering alternative explanations. Many assumptions and predictions are still to be studied empirically, however, and the main task for some time may remain the gathering of data for further tests of the exciting ideas that Charnov develops and reviews. His monograph is an excellent guide and incentive to such efforts.

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Chronobiology and Neuroscience

Vertebrate Circadian Systems. Structure and Physiology. Papers from a symposium, Schloss Ringberg, Germany, Oct. 1980. J. ASCHOFF, S. DAAN, and G. A. GROOS, Eds. Springer-Verlag, New York, 1982. xiv, 364 pp., illus. \$56. Proceedings in Life Sciences.

Biological rhythmicity has been appreciated and exploited by humans since the dawn of recorded history. Earlier workers conceived of geophysical fluctuations as the proximate factors behind daily, lunar, and annual cycles in animal behavior. However, many cellular and behavioral rhythms of eukaryotic organisms are endogenous and under constant environmental conditions persist with periods that differ from those of the external cycles to which they are normally entrained. These rhythms have properties similar to those of self-sustained oscillators and provide evidence for the existence of biological clocks.

The book under review celebrates the recent marriage of chronobiology and neuroscience. It is yet another case of academics imitating life: the couple had been living together for some time before legitimizing their union; they are the parents of a four-year-old (*Biological Rhythms and Their Central Mechanisms*, M. Suda, O. Hayaishi, and H. Nakagawa, Eds., Elsevier/North-Holland, 1979) and from the look of things may require a lecture on contraception sometime in the near future.

The editors of this well-produced book, which is marred only by an excessive number of typographical errors, identify Maynard Johnson's 1939 report as the first in which the endogenous nature of animal rhythms was clearly demonstrated. Johnson's earlier work (1926) and several investigations summarized by J. H. Welsh in 1938 pointed to the same conclusion. Why then did we have to wait almost a half century for so much as a clue about the neural organization of vertebrate circadian rhythms? Many, if not all, cells in any complex metazoan organism are potential circadian clocks that can measure intervals of approximately 24 hours in the absence of periodic cues from the external environ-