of the previously accepted ideas about the rotation of the nucleus had been totally discarded by then. Papers being written in 1991 disagree with even the most recent papers available when Sekanina changed his chapter for the last time. By 1989, the "classical" 2.2-day periodicity, which had been derived in the early 1980s from images taken in 1910, was on its way out, and it was already clear that the motion was complex. Current papers suggest that the motion consists of 7.4-day and 3.7-day rotations around different axes, with a nodding motion about the third axis. Sekanina also reminds us of another puzzling aspect of the motion of Halley's nucleus: the images of the nucleus show strong jets of material ejected from the nucleus in such a way that they should produce significant torques. Simple calculations show that these torques could change the motion of the nucleus dramatically on the time scale of a month. Nevertheless, the variability in 1910 and the constancy of the rocket-like acceleration of Halley in its orbit (due to the outgassing over two millennia) strongly suggest that the torques have no significant effect on the rotation vector. This phenomenon is not understood.

Whereas Sekanina's chapter really brings home to the reader the way in which our fundamental ideas have changed and are still changing, other chapters are much less illuminating, and some are highly redundant. On the whole, the second volume is much better than the first, if for no other reason than that it contains some chapters devoted largely to theoretical work that provide a context for the experimental and observational results. Even the primarily observational chapters in this volume typically provide a certain amount of theoretical background, whereas in volume 1 a significant fraction of the chapters do not provide that context.

Some of the better chapters in volume 1 are the chapter on jets by Kömle and the chapter on chemical composition by Krankowsky and Eberhardt. Kömle discusses the theory of hydrodynamic flow from a nozzle and then discusses many different observations (both ground-based and from Giotto) of jets in Halley. He clearly illustrates the difficulty of reaching firm conclusions about the nature of the jet-like features observed. Krankowsky and Eberhardt have written a particularly valuable chapter in that they not only present their own data, which so dramatically show the existence of a distributed source of the carbon monoxide gas but also bring together many other measurements of the composition of the gas in the coma. They then put these pieces together to try to infer the composition of the nucleus. This chapter is fundamental to our basic understanding of comets and their origin, and I only wish that the authors had included more of their own results from the mass spectrometer on Giotto.

The work as a whole fails in its goal of presenting a clear comprehensive picture of our knowledge of comets, but it is valuable as a resource if read selectively and critically. Workers in the field will have other sources for even more details of the experiments and observations and will be able to go immediately to the chapters that bring together data from diverse sources. People outside the field may have to struggle to separate the wheat from the chaff.

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Planetary Adventures

Uranus. The Planet, Rings and Satellites. ELLIS D. MINER. Horwood (Prentice Hall), Englewood Cliffs, NJ, 1990. 334 pp., illus. $59.95. Ellis Horwood Library of Space Sciences and Space Technology, Series in Astronomy.

"Much has been written about the Voyager missions, generally by authors far more eloquent and experienced in writing than I." So states Ellis Miner in the preface to his new and welcome book on NASA's highly successful Voyager mission to the outer planets. The statement, however, as the reader will quickly learn, is much more a reflection of the author's modesty than of the style and distinction of his writing.

The Voyager odyssey began with the launch of two robotic spacecraft, Voyagers 1 and 2, to the outer planets of our solar system in 1977. Voyager 1 flew past Jupiter in 1979 and Saturn in 1980 before leaving on a trajectory that is now taking it out of our solar system. Voyager 2 followed its predecessor both to Jupiter and to Saturn, then continued on to Uranus in 1986 and ended its planetary exploration at Neptune in 1989. Like its twin, Voyager 2 is now heading out of the solar system, while continuing to collect data on interplanetary and interstellar physics as it travels. The principal subject of Miner's book is the Voyager encounter with the planet Uranus, its rings, and its satellites, but the Voyager discoveries at Jupiter and Saturn are also well reviewed. Much of the effort committed to the preparation of this book apparently occurred at a time when Miner, the Voyager Assistant Project Scientist, was also deeply involved in preparing science activities for the upcoming encounter with Neptune, from which, regrettably, no results are included in the book.

The book begins with a well-documented history of both the discovery of Uranus and its discoverer, Sir William Herschel. This is followed by several chapters that summarize the more significant scientific knowledge of the Uranus system acquired by ground-based and airborne telescopes from the time of its discovery up to the end of the pre-Voyager era. Uranus is discussed in context with its outer solar system neighbors, giant planetary bodies with Earth-size cores of rock and ice, surrounded by deep atmospheres of hydrogen and helium. The next chapters are devoted to a history of the Voyager project, including key personnel, descriptions of the spacecraft themselves, in-flight problems, and a review of some of the more important discoveries made by both spacecraft at Jupiter and Saturn.

The second half of the book discusses in detail the many and exciting scientific accomplishments of Voyager at Uranus. Miner leads us through the preparation for the Uranus encounter, recounting the anticipated engineering problems involved in operating a spacecraft nearly 3 billion kilometers distant and reviewing the scientific objectives and the observational sequences that could best achieve them. He reviews the Voyager results, which include data on the planet itself, including internal mass distribution, thermal properties, atmospheric structure, and wind profiles; the magnetic field and magnetosphere, along with plasma and high-energy charged particle environments; the physical and photometric properties of the ring system, including several previously unknown features; the physical and geological properties of the five major Uranian satellites and the ten new moons discovered by Voyager. Uranus is found to be a distinctly individual planet, with many of its characteristics uniquely different from its giant planet neighbors.

Each chapter of *Uranus* is complete with thorough notes and references and bibliography. Illustrations and diagrams are of high quality and have been well chosen to complement the text. Errors are few, but Miner's continued use of somewhat obscure names for certain stars, such as Rigel Kentaurus for α Centauri, brought back humorous memories of us astronomers scurrying for our handbooks whenever Miner and his engineering colleagues would update the current stars being recommended as targets for spacecraft stability guidance.

The Voyager discoveries have completely revised our scientific understanding of the outer solar system, a vast, remote region that includes more than 99 percent of all known planetary mass. As an effective and key player in the scientific planning of a highly complex and demanding mission, Miner has continued to contribute to the accomplishments of Voyager through this authoritative amalgamation of the more noteworthy scientific, technical, and human elements that have characterized this great adventure.

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A Paradox for Biology

Evolutionary Biology of Aging. MICHAEL R. ROSE. Oxford University Press, New York, 1991. xiv, 221 pp., illus. $35.

The existence of aging presents something of a paradox for evolutionary biologists. If natural selection favors high reproductive success and high survival to the next opportunity to reproduce, then why do both traits show such widespread decline in old age? Why cannot organisms continue to achieve late in life biological feats of which they were capable in youth? These are the questions Michael Rose sets out to answer. "Why" questions in general can be answered at varying levels of proximity. Building on Dobzhansky's famous dictum that "nothing in biology makes sense except in the light of evolution," Rose's thesis is that to understand aging we must understand its evolution. Only then do its taxonomic distribution and its genetic and physiological mechanisms become intelligible. Gerontologists may require some persuading of this point of view, but Rose is the advocate to do it.

An evolutionary account of aging would be unnecessary if the process were inevitable; it could be that organisms are simply incapable of overcoming the effects of damage, wear, and tear they encounter. However, there is variation in the extent to which damage is combated. The life forms of today are the progeny of a line of descent unbroken for at least a billion years; germ lines do not die out.

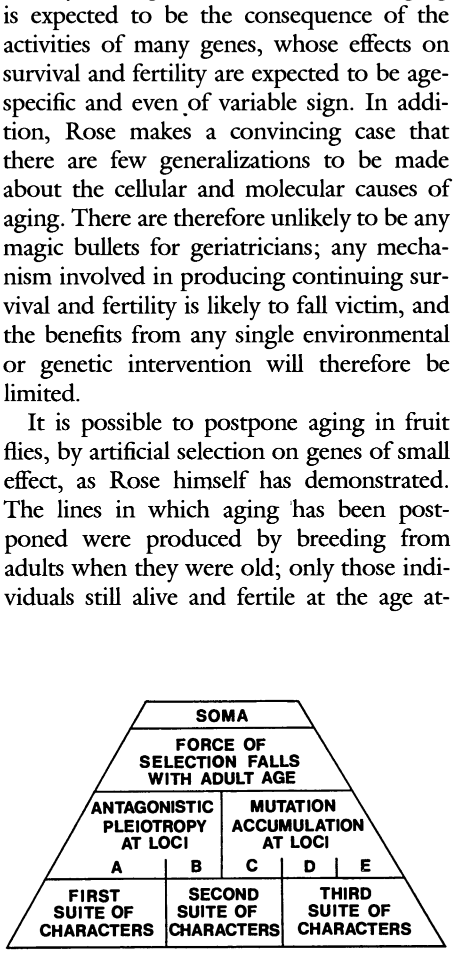
In evolutionary terms, what matters is the frequency at which a gene is represented in future generations. A compelling evolutionary reason for the occurrence of aging is the declining intensity of natural selection on mutant genes with effects late in the normal life-span. New mutations occur at a low rate during the copying of genes, and most lower either survival or reproductive success. Rose makes a compelling case that many are also age-specific; their effects are not equally apparent at all times of life, Huntington's chorea being an unwelcome human instance. Late-acting mutations of this kind are more difficult for natural selection to eliminate because by the time their effects are expressed many of their original carriers will already have died of something else, at a rate no different from that in non-carriers of the mutation. These mutations will therefore reach a higher frequency in the population than ones with an equivalent effect earlier in the life-span, and they will lead to a drop in fertility and survival later in life.

In addition, many mutations may affect survival and fertility at more than one age. For instance, a mutation leading to high rates of reproduction in young adults may do so by diverting resources away from repair or growth of the parent, and may thereby cause lower fertility or survival later in life. The evolutionary fate of such mutations will depend upon the magnitude of their early and late effects, and in general natural selection will act more intensely on the early positive effect than on the late negative one, so that aging will evolve as a side-effect of earlier benefits. A verbal account cannot do justice to the demographic and population genetic work that has led to these conclusions. Rose gives a fascinating historical account of the contributions of the major players on this field: Weismann, Medawar, Hamilton, and Charlesworth.

Theoretical population genetics is sometimes (wrongly) viewed as an arcane abstraction even by workers in nearby disciplines. One beauty of the evolutionary theory of aging is its testability; it stands or falls on the pattern of age-specificity of genetic effects on survival and fertility, and these are open to empirical investigation. Rose himself is a leader in this field, his work on genetics of aging in *Drosophila* having become a classic demonstration both of age-specific gene effects on survival and fertility and of genes with opposing effects on fitness at different ages. He produces an excellent review of the current state of knowledge on this point, not only for the classic animal models for work on aging, "the" nematode, fruit fly, and mouse, but also for lesser-known breeds including plants.

An evolutionary view of aging has some not altogether welcome messages for gerontologists and geriatricians. One is that the human progeroid syndromes, which give the appearance of greatly accelerated senescence, may be poor models for normal aging. They are caused by defects in single genes and are present at frequencies so low that they can be explained as the product of the balance between the input of the new mutations that cause the diseases and their subsequent elimination through premature death and impaired fertility of their carriers. The mechanisms of gene action in progeroid syndromes are not known, but what is clear is that they involve single mutations of drastic negative effect on both survival and fertility at all ages. In contrast, normal aging is expected to be the consequence of the activities of many genes, whose effects on survival and fertility are expected to be age-specific and even of variable sign. In addition, Rose makes a convincing case that there are few generalizations to be made about the cellular and molecular causes of aging. There are therefore unlikely to be any magic bullets for geriatricians; any mechanism involved in producing continuing survival and fertility is likely to fall victim, and the benefits from any single environmental or genetic intervention will therefore be limited.

It is possible to postpone aging in fruit flies, by artificial selection on genes of small effect, as Rose himself has demonstrated. The lines in which aging has been postponed were produced by breeding from adults when they were old; only those individuals still alive and fertile at the age at-



"Hierarchy of causation of aging. At the top of the pyramid is the ultimate determinant of whether or not an organism senesces: the possession of a soma distinct from its germ line. This gives rise to a fall in the force of selection with adult age, in all cases where survivorship is concerned and in most cases where fecundity is concerned. There are then two subsidiary population-genetic mechanisms for the evolution of aging: antagonistic pleiotropy and mutation accumulation. Specific suites of characters may be subject to either or both of these mechanisms. In any case, multiple suites of interconnected physiological mechanisms are expected to determine the pattern of aging in any one species, with even greater diversity among species." [From *Evolutionary Biology of Aging*]