Book Reviews

Tactics in Reproduction

Sperm Competition and the Evolution of Animal Mating Systems. ROBERT L. SMITH, Ed. Academic Press, Orlando, Fla., 1984. xxii, 687 pp., illus. $41.

The presence of ejaculates from more than one male in the vicinity of ova sets the stage for sperm competition, according to a ground-breaking paper by Geoffrey Parker (1970). Parker developed the idea of gametic competitive techniques and counter-techniques specifically for insects, females of which often mate multiply and store viable sperm for days or years. The competitive techniques he proposed included displacement or dilution of a rival's sperm, post-copulatory mating plugs, and guarding of a female until oviposition. Fifteen years later the question of sperm competition has grown in importance and generality. The present volume documents areas of progress and points the way to future work.

Not that it has been easy to gain insight into subtle events that occur within a reproductive tract and slow processes that unfold over evolutionary time. The first five papers, on general topics, illustrate the main methods used to explore the challenging subject of sperm competition: studies of relative fertilization success of successive male mates, speculation about morphological, physiological, and behavioral traits that may influence sperm competition, experimental and comparative studies to test hypotheses generated, and mathematical modeling to explore proposed relationships among relevant traits of males and females.

The remainder of the book is organized phylogenetically. There are six review papers on arthropod groups ranging in inclusivity from the genus *Drosophila* to the class Arachnida. These make stimulating reading, for patterns are emerging, but it is noted that much remains to be done both conceptually and empirically. There are eight chapters on vertebrates—on the Poeciliidae, representing fish, and on the amphibians, the reptiles, the monogamous birds, and rodents, bats, primates, and humans. The main purpose of several of these chapters is to identify vertebrates in which sperm competition may be occurring. Good candidates include salamanders, snakes, and bats. Other chapters, however, have more progress to report. Dewsbury not only demonstrates multiple paternity of rodent litters but is able to discuss the influence of mating order, interval between matings, and number of ejaculations on paternity in several rodent species.

A recurring theme in these works, not developed in Parker's original exposition of sperm competition, is the influence of female traits on the outcome of sperm competition. The female is viewed not merely as a selective environment influencing sperm competitive traits but as a significant player in the evolutionary game. According to Knowlton and Greenwell, the female role has been overlooked because it was expected that selection on traits affecting sperm competition would be very much more intense for males than for females, given that a potentially successful male can leave many times the number of descendants that a female of his species can. Knowlton and Greenwell make the important point, however, that a female is preadapted to manipulate. She controls the body which rival sperm must enter and in which they compete. By means of a model the authors explore the conditions under which mechanisms of sperm competition can evolve, assuming sperm competitive techniques costly to and detectable by females and ability of females to terminate copulation if deployment of the techniques is detected. Knowlton and Greenwell and other authors, furthermore, have found it important to consider which strategies are opposed in the evolutionary game. If it is in the female interest to mate multiply, her opponent is the first male and his devices to prevent subsequent mating or sperm preemption. If it is in her interest to mate but once, her opponents are the persistent, later-arriving males.

Because mating with more than one male is a precondition for sperm competition, many of the authors carefully consider the possible reasons a female might mate multiply. The possible advantages of multiple mating are clearly related to the biology of the species in question. For example, Austad suggests that multiple mating may be widespread in web-building spiders because rejection is more costly than acceptance. In his view, males may be unusually persistent in their efforts to mate with one female because of the high predation they suffer traveling between female webs; on the other hand, mating does not reduce a female's food intake by much, given that her web entangles prey whether or not she is copulating.

Two of the papers give especially interesting perspectives on the relationship between female traits and sperm competition. Gromko, Gilbert, and Richmond review the complexities that affect the fate of sperm in the reproductive tract of a single species, *Drosophila melanogaster*. Temperature in the female tract and location of sperm storage affect the probability of usage of the sperm. Male influence arises through chemical substances transferred to the female during copulation, including ones that affect oviposition, courtship, and courtship rejection. However, the predominance of fertilization by the second male's sperm in a remated female may not be a selected response to sperm competition between males but may instead be the incidental result of complex interactions between sperm of the respective males and characteristics of the female. In a paper on the haplodiploid aculeate Hymenoptera, Starr reveals how the outcome of male-female interactions, sperm competition, and the environment of the female tract color colony dynamics; the implications of colony dynamics for the success of ant, bee, and wasp queens feed back on the female traits that are selected. For example, single or multiple mating by queens and the degree of mixing or clumping of ejaculates is expected to influence the harmony or disunity of workers within a nest and their propensity to interfere with the production of male eggs by fellow workers.

Those who think that humans have bypassed gametic strife will enjoy Smith's concluding paper. Given that sperm are motile for seven to nine days in the human female tract and that females may copulate with two or more males during the space of a week, it becomes possible for sperm competition to influence the evolution of human sexual attributes. Smith considers a number of traits in this light. Relative to most apes man has a long penis and large testes for his body size, and sperm competition may have selected for the voluminous, deep ejaculations made possible by these structures. Masturbation and nocturnal emission in males may be a way of discarding old sperm in favor of

younger, more competitive sperm. Smith hypothesizes that the prostaglandins in the semen, known to produce contractions of uterine smooth muscle, may enable the sperm to be conveyed closer to the ovum. In a similar way female orgasm and accompanying uterine contractions may be a way for a woman to differentially aid the sperm of a man she likes, trusts, and feels attracted to. Among prostitutes, Smith finds it significant that call girls, whose customers are better-paying, more considerate, and higher in status, experience orgasm considerably more often than streetwalkers. The chemistry of female secretions may also act selectively on the ejaculates of preferred and less preferred males.

The last, unabashedly speculative, section in Smith's paper picks up the theme of the interplay of male and female strategies. Using fossil and archeological data to speculate about the food resource base of the hominoid lineage, he constructs a series of scenarios from *Australopithecus* to *Homo sapiens sapiens* that portray the changing importance of sperm competition, the changing strategies of males and females, the changes in the mating system that would result, and a timetable for the emergence of traits we see today.

As a whole the book is broad, ambitious, stimulating, and well referenced. I recommend it for young investigators in search of research ideas, as well as for old investigators looking for new directions and fresh perspectives.

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Gaseous Nebulae

Physics of Thermal Gaseous Nebulae. (Physical Processes in Gaseous Nebulae.) LAWRENCE H. ALLER. Reidel, Boston, 1984 (distributor, Kluwer, Hingham, Mass.). x, 350 pp., illus. $49.50. Astrophysics and Space Science Library, vol. 112.

Ionized gaseous nebulae comprise such objects as diffuse nebulae, planetary nebulae, and supernova remnants. They emit a spectrum composed of emission lines and continuum corresponding to an ionized low-density plasma with typical densities in the range of 1 to 10^5 particles per cubic centimeter, densities many orders of magnitude smaller than those attained in terrestrial laboratories.

The study of gaseous nebulae has been of paramount importance for our understanding of the universe. Diffuse nebulae, or HII regions, are conglomerates of gas and dust in which stars are being formed at present. Planetary nebulae are shells of gas ejected from, and expanding about, extremely hot low-mass stars. Supernova remnants are shells of gas violently ejected during supernova explosions by massive stars. In addition to their intrinsic importance, gaseous nebulae give us important clues for the study of the dynamics of the interstellar medium, stellar evolution, galactic chemical evolution, and pregalactic conditions.

The study of gaseous nebulae combines atomic physics with astrophysics through the computation and use of atomic parameters. These parameters permit one to derive such physical conditions in the nebulae as the radiation field, the source of energy input, and the temperature, density, and chemical composition of the ionized gas.

Lawrence H. Aller has been one of the leading astronomers in this field for almost five decades. The book under review is based on lectures he has given over the course of his career.

The first part of the book deals with the study of physical processes in gaseous nebulae. It discusses the early development of the physical concepts, key papers on the subject, and the latest results as of 1983. It presents many tables and the relevant references needed to interpret mainly the optical and ultraviolet spectra of gaseous nebulae. It also presents several exercises at the end of each chapter.

The second part deals with models of photoionized nebulae, like HII regions and planetary nebulae, and models of shock-excited nebulae, like supernova remnants. Special emphasis is given to the effects produced by interstellar dust on the observed spectra, mainly through extinction in the ultraviolet and optical regions and through radiation in the infrared regions, but almost nothing is mentioned of the physics of dust grains.

The third part deals with applications to specific objects like the Orion nebula, which is the most observed HII region due to its apparent size, low reddening, and high surface brightness; the Gum nebula, which is the galactic HII region with the largest apparent size; and 30 Doradus, which is the most important HII region in the Large Magellanic Cloud. The section also includes an account of recent developments concerning the chemical composition of gaseous nebulae and the relationship of gaseous nebulae and stellar evolution, enrichment of the interstellar medium with elements heavier than hydrogen, and chemical evolution of galaxies. The book ends with an appendix by C. Mendoza, which is an excellent compilation, complete up to August 1982, of transition probabilities, electron excitation rate coefficients, and photoionization cross sections.

The book is directed to astronomy graduate students, physicists interested in astrophysics, and astrophysicists interested in the interpretation of the spectra of gaseous nebulae. It could be used in a graduate course on physical processes in gaseous nebulae.

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Cosmology

The Big Bang and Georges Lemaître. A. BERGER, Ed. Reidel, Boston, 1984 (distributor, Kluwer, Hingham, Mass.). xxii, 420 pp., illus. $59. From a symposium, Louvain-la-Neuve, Belgium, Oct. 1983.

This volume is the proceedings of a symposium held in honor of the Belgian-born scientist and priest Georges Lemaître 50 years after his initiation of big-bang cosmology in 1933, the year of his famous paper on the "primeval atom." It is fitting that Lemaître should be considered the father of the big bang. He was not alone in the formulation of a theory of an expanding universe, but he was the first to take the bold leap of considering a universe that began a finite time in the past. The subject is alive and vigorous to this day, as is here attested. The book is divided according to Lemaître's principal scientific interests into sections entitled Cosmology, Celestial Mechanics, and Structure of the Universe and Cosmic Rays. Lemaître was interested in cosmic rays because he thought they were remnants of the primeval atom; today we recognize this to be impossible although we still do not understand the details of the origin of cosmic rays. The true remnant of the primeval atom is the microwave background radiation, an isotrophic blackbody remnant of the hot big bang, which was discovered in 1965, a year before Lemaître's death. A final section, entitled Georges Lemaître: The Man and His Work, contains delightful papers by Deprit and Godart.

Reviews of fundamental cosmology emphasizing Lemaître's contributions are presented in papers by McCrea and Peebles. Lemaître favored a class of