changes in egg cell membranes. Sperm can initiate a potential change that somehow blocks polyspermy. That this is essentially an electrical phenomenon in certain invertebrate eggs can be shown by inducing polysperms with repolarization. Phylogenetically fertilization potentials seem to be generally similar, but not identical. During the subsequent maturation of the cells, marked changes in the electrical properties are observed that are due to changes both in the relative numbers of channels and in the properties of the channels themselves.

In short, here is a brief, readable introduction to the diversity of the ontogeny and phylogeny of membrane physiology.

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Relativity

The Mathematical Theory of Black Holes. S. CHANDRASEKHAR. Clarendon (Oxford University Press), New York, 1983. xxii, 646 pp., illus. $110.

In the early 1930's Chandrasekhar investigated the fate of stars that have reached the endpoint of nuclear burning. At that time the only fate known for such stars was as white dwarfs. Chandrasekhar made the momentous discovery that white dwarfs have a maximum mass, which is a little more than the mass of the sun. Since stars much more massive than this were known to exist, the question of their ultimate fate arose. We now know of two further endpoints of stellar evolution: neutron stars and black holes.

The astrophysical community did not readily accept Chandrasekhar's work, partly because it did not wish to confront the existence of objects so far removed from everyday reality. Chandrasekhar wrote a monograph on his work and moved on to other fields. There is a certain fittingness in Chandrasekhar's receiving the Nobel Prize for his work on white dwarfs some 50 years later, at the same time that his sixth book, on the subject of black holes, is published.

Chandrasekhar's books have a distinctive style. He pursues research on a topic for a period of years, until he has achieved a coherent understanding of it. He is then able to give a complete exposition of the material from a unified point of view. This book begins with some mathematical preliminaries on differential geometry, including the Newman-Penrose formalism. Though this material is essentially self-contained, the reader will benefit from some previous knowledge of tensors.

The discussion then moves on to the metrics (gravitational fields) of black holes. A remarkable fact is that the most general metric for an isolated black hole is completely known analytically and is specified uniquely by the mass and angular momentum of the black hole. Chandrasekhar gives the proof of this important result and describes in detail the properties of such isolated black holes.

A large part of the book deals with perturbation theory for black holes, which is concerned with how a black hole interacts with its environment. The problem can be reduced to understanding how the black hole scatters and absorbs incident waves of various kinds. Mathematically, the problem is analogous to the familiar quantum-mechanical problem of finding reflection and transmission coefficients for potential barriers. At this point the reason for the fascination of the subject for all those who have worked on it becomes evident. At each stage of the investigation, starting with the simplest nonrotating case (Schwarzschild black hole), one uncovers unexpected interconnections and miraculous simplicity. For example, the potential barriers for scattering of the two different polarization states of a gravitational wave by a Schwarzschild black hole are different, yet the reflection and transmission coefficients are the same. Chandrasekhar dextrously weaves the threads of the connections to inverse scattering theory and to the Newman-Penrose formalism. One is left with a sense of wonder that all the pieces fit together the way they do.

Rotating black holes present even more surprises. Although there is no longer spherical symmetry, a "miracle" allows one to separate variables and reduce the problem to simple barrier penetration again. This separation requires one to introduce a new set of "special functions," which generalize the well-known spherical harmonics. Certain consistency requirements of Einstein's theory lead one to discover mathematical identities satisfied by these functions, identities virtually impossible to discover otherwise. The list goes on: How does a potential barrier "know" how to allow energy extraction from the black hole for certain frequencies? How is this "superradiance" turned off for spin-1/2 particles?

This book will certainly be read by professionals and graduate students in relativity. I am afraid that others will be deterred by its apparent complexity. Though some of the calculations are lengthy, most involve only upper-level calculus and could in principle be reproduced by the reader with a conventional "mathematics for physicists" background. Those readers who do venture into the book will have the opportunity to ponder the two quotations in its epilogue: "There is no excellent beauty that hath not some strangeness in the proportion" and "Beauty is the proper conformity of the parts to one another and to the whole."

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Cosmology

The Big Bang and Element Creation. D. LYNDEN-BELL, Ed. The Royal Society, London, 1982. vi, 148 pp., illus. £20.20. First published in *Philosophical Transactions of the Royal Society of London*, series A, vol. 307. From a meeting, March 1982.

Remarkable recent advances in theories of elementary particle physics have greatly increased our ability to study the very earliest stages of the big bang. These theoretical advances have come at a time of equally remarkable advances in observational cosmology. We have gathered improved information about the primordial abundance of the elements, the spectrum and distortions of the microwave background radiation, and the distribution of galaxies in the universe in recent years.

The Big Bang and Element Creation is a collection of 12 papers almost unique in its balance of theory and observation. Such a mix is particularly useful for understanding the significance of the observational work reported in the book. For instance, a theoretical paper by Hogan, Kaiser, and Rees on the interpretation of anisotropy in the cosmic background radiation is crucial to an understanding of importance of the measurements.

The book does an excellent job of reviewing the observational and theoretical status of primordial nucleosynthesis (the production of light elements in the primeval bang) and the spectrum and anisotropy of the cosmic microwave background radiation (the remnant of the big bang discovered by Penzias and Wilson in 1965).

A paper by Ellis on grand unified theories and cosmology is an excellent introduction to a subject that is often difficult for the nonspecialist to under-

stand. The paper describes what grand unified theories have to offer and why cosmologists are so excited about them. I recommend it to anyone curious about the subject.

There is only one brief paper on galaxy formation, although particle physicists have been generous in providing candidates (massive neutrinos, axions, gravitinos, and so on) to act as the dark matter in galaxies and several surveys of galaxies have recently been completed.

The few graduate-level textbooks with a thorough discussion of the big bang are by now a decade old. Although the foundation of the big-bang model has not changed, the standard textbooks seem dated, given the observational and theoretical advances of the past five years. Although *The Big Bang and Element Creation* does not cover all recent developments in cosmology, it is an excellent book for someone who has read the standard textbooks and still wants more information about primordial nucleosynthesis and the microwave background radiation.

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