

DEAR READER

The purpose of this book is to present our understanding of the basic building blocks of nature and their fundamental interactions. The underlying ideas have a beauty and power worthy of the attention of all those who are curious about the world. These concepts, along with the experimental investigations associated with them, are among the greatest achievements of human thought. Although they are usually written in the language of mathematics, I have presented their essences without its use. This should make the ideas accessible to interested readers whose backgrounds may not include advanced mathematics.

In this book, the reader is taken along the path of knowledge that leads from our basic physical concepts to our understanding of the fundamental interactions of the underlying building blocks of nature. That understanding was developed in the second half of the twentieth century and is incorporated in the theory known as the Standard Model, which has been verified in many different high-precision experiments. The magnificent power of the particle-type symmetries that surreptitiously govern the fundamental interactions will be revealed here. Thereafter, the reader will be introduced to the dreams that contain even broader, more fundamental conjectures. Along the way, we will be exploring the fundamental building blocks of matter (quarks and leptons), and the concepts of relativity, quantum theory, symmetry, gauge theories (and their associated particles), the Standard Model (theory) and even beyond — the theoretical ideas and their experimental foundations and verifications. The last part of the book provides a brief introduction to the experimental enterprise of particle (otherwise known as “high-energy”) physicists, and the connections of experimental studies to the theories we have met on our journey. The reader should feel free to read that part whenever curiosity demands, without feeling that all of the first three parts must be read first.

If you haven't traveled this way before, you are entering a new country with an unfamiliar culture, so you may not understand everything you encounter. Nevertheless, I hope you find your trip intriguing. If so, you may even enjoy retracing your steps or following other paths to these fundamental concepts. Note that there is a Glossary at the end of the book to help you along the way, by reminding you of those concepts and definitions already read.

Some readers of a *preliminary* version of this book, from the arts, literature, humanities and business world, found the initial flow of unfamiliar words somewhat

disconcerting. I ask those readers who have a similar initial reaction to bear with me; all the important words will be repeated along with reminders of their meanings. Furthermore the Glossary should be useful in this regard.

If you listen to National Public Radio or watch Jim Lehrer's News Hour, you should recall that a short musical interlude is used at the end of each story. I have adapted this technique by inserting poems after intense discussions. These verses serve several useful purposes. They provide some respite and hopefully some amusement, as well as reinforce your grasp of the concepts just explained.

The book begins with a poem that sets the stage for all that follows, much like an overture to an opera. It dramatizes the "grand unified" origin of the particles of our universe, believed to have occurred very shortly after its emergence from the Big Bang. The particular names of the particles involved can be accepted just as we would accept unfamiliar names of characters in a play. By the end of the book, you will be familiar with them and their corresponding properties. That is *my* obligation to you and not *vice versa*.

Our knowledge of the thought of people in ancient times has been culled from their writings, as well as their oral traditions. In those contemplations, we see a mixture of philosophy, science, history, and theology. During the Renaissance, scientific contemplation separated itself from the others. Its scope was restricted to those concepts that can be tested by directly measurable observations of nature. These included both passive observation and experimental investigations. (This restrictive demand upon scientific inquiry was succinctly expressed in the writings of Francis Bacon.*) Since that time, so many centuries ago, a widening gulf has developed between the realm of scientific thought and the so-called "humanities." (The existence and width of that gulf was brought to public consciousness by the incisive lectures of C.P. Snow, which are available in book form.) There have been several very fine books and articles written, as well as public lectures given, to acquaint those not conversant with the concepts of science with their power and beauty. It is my hope that this book will serve as another span across that gulf between the "two cultures," making the magnificent concepts that have been developed in our pursuit of the *underlying* structure and workings of nature accessible to those who do not have the time or inclination to master the mathematics involved.

I have not named the creators of the various concepts described here, because there are many people who deserve credit and the historical record is not the subject of this book. I do hold those brilliant, insightful people in high regard and am truly amazed at the beautiful structure of nature that their fertile imaginations have uncovered. (The poems that humorously portray Sherlock Holmes' and Hercule Poirot's imagined involvement should not be seen as in any way detracting from the true creators of the ideas discussed.) I strongly recommend the book "Inward Bound" by A. Pais (as well as his earlier books about Einstein, etc.) as an

*in *Novum Organum*; the relevant sections are reprinted in *The World of Physics*, Simon & Schuster (1987).

excellent, accurate and beautiful historical account of the development of the ideas of particle physics during the first eighty odd years of the twentieth century. “The Second Creation” by R.P. Crease and C.C. Mann and “Constructing Quarks” by A. Pickering include the developments in the early 1990s. There are several more recent books that cover the developments in the 1990s. I have led the reader to the threshold of the unifying theory of superstrings, and recommend the celebrated book that explains those ideas and their incorporation of gravitation into a *fully* unified theory: “The Elegant Universe” by Brian Greene. The books I have cited here have many excellent references as well.

It is my pleasure to acknowledge the people, from many different walks of life, who read parts of various drafts of this book and gave me both their reactions and their support. A hearty thank you goes to Lynne Hirschelman, Ray Greene, Al Varone, J. Will Campbell, Rita Winters, Francine Nightingale, Trevor Nightingale as well as my wife Ellen. I also wish to thank my fellow physicists for their advice. Thanks goes to Alexey Petrov, Dave Cinabro, J.J. Chang, Jim M. Johnson, and Bert Stein.