Preface

One thing that distinguishes human beings from the other animals is our curiosity about nature. A wolf may look at the moon and howl at it, but only human beings want to know how big it is and how far away, what it is made of and why it changes its appearance. More generally, we want to know the way nature works, even if our knowledge brings no practical benefit. As history has turned out so far, some of the knowledge we have gained about nature has not helped us materially at all, but other knowledge has led to profound changes in our civilization. Unfortunately, not all these changes have been for the good.

Our senses let us perceive nature only at intermediate sizes, but not at the very small and the very large. We can look at a tree but we cannot see the atoms that make up the tree. We can look at a portion of the earth, but our vantage point does not let us see directly that the earth is a sphere.

In this book we shall be principally concerned with nature at both the smallest and the largest scales, from atomic and subatomic particles to the universe as a whole. We want to answer as well we can the questions: "What are we made of?" and "What is the nature of the universe in which we live?"

We are, of course, made of flesh and blood, bones and hair, and we live on the earth. But on a smaller scale our bodies are made of cells, and the cells are made of molecules. In turn, the molecules are made of atoms, and atoms are made of electrons and atomic nuclei. As far as we know, the electrons are elementary in the sense that they are not composed of smaller things. However, atomic nuclei are made of protons and neutrons, which in turn are made of quarks. That is where our present understanding of the nature of matter ends, although there are speculations about even deeper levels. On a larger scale, the earth is the third planet from the sun in our solar system, and the solar system is in our galaxy, the Milky Way, which is a system of more than a hundred billion stars plus dust and other kinds of matter held subject to their mutual gravitational attraction. The Milky Way in turn is only one galaxy (system of stars) of many billions of galaxies that exist in the visible universe. And there have been speculations about what lies beyond the visible universe and whether we can ever know anything about it.

We are about to take a journey into the world of the very small and the world of the very large. What we shall find will be so foreign to our senses and so much against our intuition as to be almost beyond belief. Mankind has long thought about what matter is made of and what the universe is like. However, it was not until the twentieth century that our knowledge has grown so much that today we have a largely coherent picture at what nature is like at both large and small scales.

In order to make sense out of the very large and the very small, we have to devote some of our effort to examining nature on a human

scale. In this way, we learn some of the laws of physics that we need, and we also learn of some laws that seem to satisfy common sense, but have only a limited range of validity. We often take a historical approach and discuss old ideas that seem either quaint or silly today, but it is beneficial to learn what went wrong with earlier scientific ideas.

Scientific knowledge is always provisional. Based on past experience, we can be confident that new discoveries will change the way we look at nature in many ways. However, many of our present ideas are rooted firmly in the results of a large number of observations and experiments, and so we can be confident that much of our present picture will endure.

The bibliography contains a number of books on the topics I treat here. I acknowledge freely consulting several of these books to obtain part of the material I used. I consulted other sources, especially on the web, as well. I have made decisions about what information to include, updated material when necessary, and put my own stamp on the presentation. I also acknowledge beneficial conversations with my good friends and colleages at Indiana University, Steven Gottlieb and Roger Newton. I am thankful to Bruce Carpenter of Indiana University for doing the drawings and to Andrew Chan Yeu Tong for his assistance with the editing and Alvin Chong of World Scientific for his cooperation in publishing this book.