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Foreword

The notion of *symmetry* has manifestations that are widespread in human culture. Symmetry also exhibits itself in a great many features of the operation of the Natural world. It is a notion that is simple enough to be understood and made use of by a young child; yet it is subtle enough to be central to our deepest and most successful physical theories describing the inner workings of Nature. Symmetry is thus a concept that is simultaneously obvious and profound.

Symmetry has many areas of application. Some are basically practical, such as those made use of in engineering—for example, with the bilateral symmetry of most aeroplane designs or in the symmetry in bridge construction—or, at a more mundane level, in the satisfactory creation of furniture. But other uses of symmetry are more evidently purely aesthetic, and can be central to many artistic creations, where it may provide a key ingredient underlying the sublime beauty of various great works of art. Moreover, this is true over a considerable range of disciplines, such as in painting or sculpture, or in music or literature. In mathematics, the notion of symmetry is the starting point of vast areas of deep theory, providing much penetrating insight of enormous scope. In the science of crystallography it is crucial, as it is also in many aspects of chemistry. It is evident to the eye that symmetry is also important to biological function. There is great symmetry to be found throughout the plant and animal kingdoms, and this symmetry can contribute in many different ways to the efficient functioning of an organism. Bilateral symmetry, for example, is almost universal among animals. Yet it is occasionally grossly violated, such as in the twisting spiral shape of a snail's shell. But with such a shell, we find that there emerges a deeper type of symmetry, not evident at first: a symmetry

under rotational motion, provided that this is accompanied by uniform expansion or contraction.

It is in modern fundamental physics, though, that we find the most subtle interplay between symmetry and asymmetry, for, as twentieth-century physics has revealed, there is a special role for symmetry in Nature's basic forces that is both central and sometimes enigmatically violated. Some of the underlying ideas are quite simple to grasp, but others, distinctly sophisticated. However, I believe that this undoubted sophistication should not be held as a reason for denying the lay public an opportunity to access some of these ideas, which often exhibit a kind of sublime beauty. Yet, it is not so easy to present such ideas in a way accessible to a lay reader, while at the same time holding the reader's interest and conveying some nontrivial understanding. Tony Zee, however, achieves this in a masterful way in his classic, here reprinted, *Fearful Symmetry: The Search for Beauty in Modern Physics*.

Fundamental physics is genuinely difficult, and the crucial role of symmetry is often a subtle one. For this good reason it is not often satisfactorily explained to a lay audience at length or in significant depth. In the arts, on the other hand, it is usually not hard to produce accessible works fully extolling the use of various qualities of symmetry, often merely by use of a good picture, as is the case also in architecture and engineering. This seems to be true as well in biological descriptions and in books depicting the natural beauty of crystalline substances. There are even many popular works in which the symmetrical forms of pure geometry, or of other areas of pure mathematics, can be made very accessible even to the mathematically unsophisticated reader. But there is something especially hard to communicate about the roles of symmetry in basic physics, particularly because these roles are often very abstract and they frequently depend upon the highly nonintuitive and confusing fundamental principles of *quantum mechanics*. The demands of quantum physics are themselves not easy to comprehend. They are often subtle, and have a special importance to the workings of Nature at the deepest levels that human understanding has yet been able to penetrate. It is when the ideas of symmetry and quantum mechanics come together that we find the special subtleties that are crucial to our modern understanding of the basic forces of Nature.

All this serves to emphasize the difficulties that confronted Zee's task, and to enhance our admiration for his superb achievement. But there is one thing to his advantage that he was able to ex-

plot: the fact that symmetry and *beauty* are closely linked. By emphasizing the beauty in the use of symmetry that lies behind our modern theories of the forces of Nature, rather than dwelling on the mathematical details, he is able to side-step most of the technicality and many of the deep remaining difficulties that presently confound further progress. This is a story that, indeed, has not reached its end, as it is still beset with enigmas and apparent inconsistencies. Of course, this makes it all the more fascinating to study the progress that has been made so far, and perhaps to entice more readers to enter, in a serious way, this wonderful world—a world that they may not have considered before.

And for this, Tony Zee here serves as a superb guide!

Roger Penrose
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