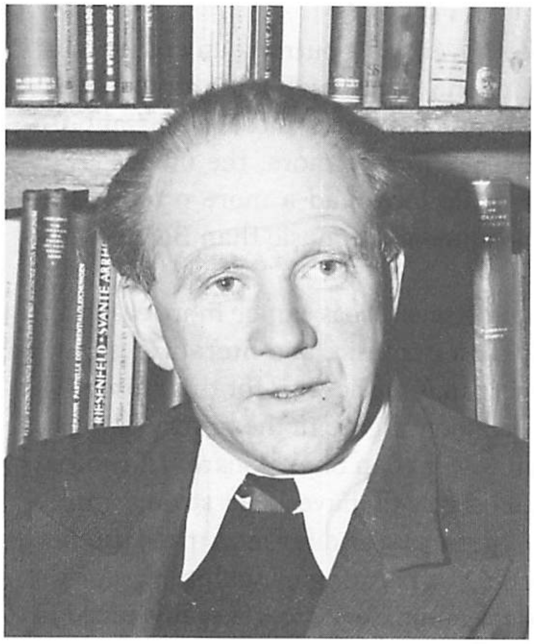

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WERNER HEISENBERG

1901-1976

In 1932, the Nobel Prize in physics was awarded to Werner Karl Heisenberg, a German physicist, for his role in the creation of quantum mechanics, one of the most important achievements in the entire history of science.

Mechanics is that branch of physics which deals with the general laws governing the motion of material objects. It is the most fundamental branch of physics, which in turn is the most fundamental of the sciences. In the early years of the twentieth century, it gradually became apparent that the accepted laws of mechanics were unable to describe the behavior of extremely minute objects, such as atoms and subatomic particles. This was both distressing and puzzling, since the accepted laws worked superbly when applied to macroscopic objects (that is, to objects which were much larger than individual atoms).

In 1925, Werner Heisenberg proposed a new formulation of physics, one that was radically different in its basic concepts from the classical formulation of Newton. This new theory—after some modification by Heisenberg's successors—has been brilliantly successful, and is today accepted as being applicable to *all* physical systems, of whatever type or size.

It can be demonstrated mathematically that where only macroscopic systems are involved, the predictions of quantum mechanics differ from those of classical mechanics by amounts which are far too small to measure. (For this reason, classical mechanics—which is mathematically much simpler than quantum mechanics—can still be used for most scientific computations.) However, where systems of atomic dimensions are involved, the predictions of quantum mechanics differ substantially from those of classical mechanics; experiments have shown that in such cases the predictions of quantum mechanics are correct.

One of the consequences of Heisenberg's theory is the famous "uncertainty principle," which he himself formulated in 1927. That principle is generally considered to be one of the most profound and far-reaching principles in all of science. What the uncertainty principle does is to specify certain theoretical limits on our ability to make scientific measurements. The implications of this principle are enormous. If the basic laws of physics prevent a scientist, *even in the most ideal circumstances*, from obtaining accurate knowledge of the system that he is attempting to investigate, it is obvious that the future behavior of that system cannot be completely predicted. According to the uncertainty principle, no improvements in our measuring apparatus will ever permit us to surmount this difficulty!

The uncertainty principle insures that physics, in the very nature of things, is unable to make more than statistical predictions. (A scientist studying radioactivity, for example, might be able to predict that out of a trillion radium atoms, two million will emit gamma rays during the next day. He is, however, unable to predict whether any *particular* radium atom will do so.) In many practical circumstances, this is not a grave restriction. Where very large numbers are involved, statistical methods can often provide a very reliable basis for action; but where small numbers are involved, statistical predictions are unreliable indeed. In fact, where small systems are involved, the uncertainty principle forces us to abandon our ideas of strict physical causality. This represents a most profound change in the basic philosophy of science; so profound, indeed, that a great scientist like Einstein was never willing to accept it. "I cannot believe," Einstein once said, "that God plays dice with the universe." That, however, is essentially the view that most modern physicists have felt it necessary to adopt.

It is clear that from a theoretical point of view the quantum theory, to a greater extent perhaps than even the theory of relativity, has altered our basic conception of the physical world. However, the theory's consequences are not only philosophical.

Among its practical applications are such modern devices as electron microscopes, lasers, and transistors. Quantum theory also has wide applications in nuclear physics and atomic energy. It forms the basis of our knowledge of spectroscopy, and is employed extensively in astronomy and chemistry. It is also used in theoretical investigations of such diverse topics as the properties of liquid helium, the internal constitution of the stars, ferromagnetism, and radioactivity.

Werner Heisenberg was born in Germany, in 1901. He received a doctorate in theoretical physics from the University of Munich in 1923. From 1924 to 1927, he worked in Copenhagen with the great Danish physicist, Niels Bohr. His first important paper on quantum mechanics was published in 1925, and his formulation of the uncertainty principle appeared in 1927. Heisenberg died in 1976, at the age of seventy-four. He was survived by his wife and seven children.

In view of the importance of quantum mechanics, the reader may wonder why Heisenberg has not been ranked even higher on this list. However, Heisenberg was not the only important scientist involved in the development of quantum mechanics. Significant contributions had been made by his predecessors, Max Planck, Albert Einstein, Niels Bohr, and the French scientist, Louis de Broglie. In addition, many other scientists, including the Austrian, Erwin Schrödinger, and the Englishman, P.A.M. Dirac, made major contributions to quantum theory in the years immediately following the publication of Heisenberg's seminal paper. Nevertheless, I think that Heisenberg was the principal figure in the development of quantum mechanics, and that—even when the credit is distributed—his contributions entitle him to a high spot on this list.