But even if the pendulum has now definitely swung in the opposite direction, only confusion could result if we failed to recognize the factors which have created this attitude and which justify it in its proper sphere.

There were three main obstacles to the advance of modern Science against which it has struggled ever since its birth during the Renaissance; and much of the history of its progress could be written in terms of its gradual overcoming of these difficulties. The first, although not the most important, was that for various reasons scholars had grown used to devoting most of their effort to analyzing other people's opinions: this was so not only because in the disciplines most developed at that time, like theology and law, this was the actual object, but even more because, during the decline of Science in the Middle Ages, there seemed to be no better way of arriving at the truth about nature than to study the work of the great men of the past. More important was the second fact, the belief that the "ideas" of the things possessed some transcendental

*züge der Psychologie* (1909), vol. 1, p. 137; E. Bernheim, *Lehrbuch der historischen Methode und Geschichtsphilosophie,* 5th ed. (1908), p. 144; and L. v. Mises, *Nationalökonomie* (1940), p. 24. The phenomenon that we tend to overstrain a new principle of explanation is, perhaps, more familiar with respect to particular scientific doctrines than with respect to Science as such. Gravitation and evolution, relativity and psychoanalysis, all have for certain periods been strained far beyond their capacity. That for Science as a whole the phenomenon has lasted even longer and had still more far-reaching effects is not surprising in the light of this experience.



reality, and that by analyzing ideas we could learn something or everything about the attributes of the real things. The third and perhaps most important fact was that man had begun everywhere to interpret the events in the external world after his own image, as animated by a mind like his own, and that the natural sciences therefore met everywhere explanations by analogy with the working of the human mind, with "anthropomorphic" or "animistic" theories which searched for a purposive design and were satisfied if they had found in it the proof of the operation of a designing mind.

Against all this the persistent effort of modern Science has been to get down to "objective facts," to cease studying what men thought about nature or regarding the given concepts as true images of the real world, and, above all, to discard all theories which pretended to explain phenomena by imputing to them a directing mind like our own. Instead, its main task became to revise and reconstruct the concepts formed from ordinary experience on the basis of a systematic testing of the phenomena, so as to be better able to recognize the particular as an instance of a general rule. In the course of this process not only the provisional classification which the commonly used concepts provided, but also the first distinctions between the different perceptions which our senses convey to us, had to give way to a completely new and different way in which we learned to order or classify the events of the external world.

The tendency to abandon all anthropomorphic ele-

ments in the discussion of the external world has in its most extreme development even led to the belief that the demand for "explanation" itself is based on an anthropomorphic interpretation of events and that all Science ought to aim at is a complete description of nature.[2] There is, as we shall see, that element of truth in the first part of this contention that we can understand and explain human action in a way we cannot with physical phenomena, and that consequently the term *explain* tends to remain charged with a meaning not applicable to physical phenomena.[3] The actions of other men were probably the first experiences which made man ask the question why, and it took him a long time to learn, and he has not yet fully learned,[4] that with events other than human actions he could not expect the same kind of "explanation" as he can hope to obtain in the case of human behavior.

[2] This view was, I believe, first explicitly formulated by the German physicist G. Kirchhoff in his *Vorlesungen über die mathematische, Physik; Mechanik* (1874), p. 1, and later made widely known through the philosophy of Ernst Mach.

[3] The word *explain* is only one of many important instances where the natural sciences were forced to use concepts originally formed to describe human phenomena. *Law* and *cause, function* and *order, organism* and *organization* are others of similar importance where Science has more or less succeeded in freeing them from their anthropomorphic connotations, while in other instances, particularly, as we shall see, in the case of *purpose,* though it cannot entirely dispense with them, it has not yet succeeded in doing so and is therefore with some justification afraid of using these terms.

[4] See T. Percy Nunn, *Proceedings of the British Academy,* vol. 13, *Anthropomorphism and Physics* (1926).



That the ordinary concepts of the kind of things that surround us do not provide an adequate classification which enables us to state general rules about their behavior in different circumstances, and that in order to do so we have to replace them by a different classification of events is familiar. It may, however, still sound surprising that what is true of these provisional abstractions should also be true of the very sense qualities which most of us are inclined to regard as the ultimate reality. But although it is less familiar that science breaks up and replaces the system of classification which our sense qualities represent, yet this is precisely what Science does. It begins with the realization that things which appear to us the same do not always behave in the same manner, and that things which appear different to us sometimes prove in all other respects to behave in the same way; and it proceeds from this experience to substitute for the classification of events which our senses provide a new one which groups together not what appears alike but what proves to behave in the same manner in similar circumstances.

While the naive mind tends to assume that external events which our senses register in the same or in a different manner must be similar or different in more respects than merely in the way in which they affect our senses, the systematic testing of Science shows that this is frequently not true. It constantly shows that the "facts" are different from "appearances." We learn to regard as alike or unlike not simply what by itself looks,

feels, smells, etc., alike or unlike, but what regularly appears in the same spatial and temporal context. And we learn that the same constellation of simultaneous sense perceptions may prove to proceed from different "facts," or that different combinations of sense qualities may stand for the same "fact." A white powder with a certain weight and "feel" and without taste or smell may prove to be any one of a number of different things according as it appears in different circumstances or after different combinations of other phenomena, or as it produces different results if combined in certain ways with other things. The systematic testing of behavior in different circumstances will thus often show that things which to our senses appear different behave in the same or at least a very similar manner. We not only may find that, for example, a blue thing which we see in a certain light or after eating a certain drug is the same thing as the green thing which we see in different circumstances, or that what appears to have an elliptical shape may prove to be identical with what at a different angle appears to be circular, but also may find that phenomena which appear as different as ice and water are "really" the same "thing."

This process of reclassifying "objects" which our senses have already classified in one way, of substituting for the "secondary" qualities in which our senses arrange external stimuli a new classification based on consciously established relations between classes of



events is, perhaps, the most characteristic aspect of the procedure of the natural sciences. The whole history of modern Science proves to be a process of progressive emancipation from our innate classification of the external stimuli till in the end they completely disappear so that "physical science has now reached a stage of development that renders it impossible to express observable occurrences in language appropriate to what is perceived by our senses. The only appropriate language is that of mathematics,"[5] that is, the discipline developed to describe complexes of relationships between elements which have no attributes except these relations. While at first the new elements into which the physical world was "analyzed" were still endowed with "qualities," that is, conceived as in principle visible or touchable, neither electrons nor waves, neither the atomic structure nor electromagnetic fields can be adequately represented by mechanical models.

The new world which man thus creates in his mind, and which consists entirely of entities which cannot be perceived by our senses, is yet in a definite way related to the world of our senses. It serves, indeed, to explain the world of our senses. The world of Science might in fact be described as no more than a set of rules which enables us to trace the connections between different

[5] L. S. Stebbing, *Thinking to Some Purpose* (Pelican Books, 1939), p. 107. See also B. Russell, *Scientific Outlook*, 1931, p. 85.

complexes of sense perceptions. But the point is that the attempts to establish such uniform rules which the perceptible phenomena obey have been unsuccessful so long as we accepted as natural units, given entities, such constant complexes of sense qualities as we can simultaneously perceive. In their place new entities, "constructs," are created which can be defined only in terms of sense perceptions obtained of the "same" thing in different circumstances and at different times—a procedure which implies the postulate that the thing has in some sense remained the same although all its perceptible attributes may have changed.

In other words, although the theories of physical science at the stage which has now been reached can no longer be stated in terms of sense qualities, their significance is due to the fact that we possess rules, a "key," which enables us to translate them into statements about perceptible phenomena. One might compare the relation of modern physical theory to the world of our senses to that between the different ways in which one might "know" a dead language existing only in inscriptions in peculiar characters. The combinations of different characters of which these inscriptions are composed and which are the only form in which the language occurs correspond to the different combinations of sense qualities. As we come to know the language we gradually learn that different combinations of these characters may mean the same thing and that in different contexts the same group of characters may mean



different things.[6] As we learn to recognize these new entities we penetrate into a new world where the units are different from the letters and obey in their relations definite laws not recognizable in the sequence of the individual letters. We can describe the laws of these new units, the laws of grammar, and all that can be expressed by combining the words according to these laws, without ever referring to the individual letters or the principle on which they are combined to make up the signs for whole words. It would be possible, for example, to know all about the grammar of Chinese or Greek and the meaning of all the words in these languages without knowing Chinese or Greek characters (or the sounds of the Chinese or Greek words). Yet if Chinese or Greek occurred only written in their respective characters, all this knowledge would be of as little use as knowledge of the laws of nature in terms of abstract entities or constructs without knowledge of the rules by which these can be translated into statements about phenomena perceptible by our senses.

As in our description of the structure of the language there is no need for a description of the way in which the different units are made up from various combinations of letters (or sounds), so in our theoretical description of nature the different sense qualities through

[6] The comparison becomes more adequate if we conceive that only small groups of characters, say words, appear to us simultaneously, while the groups as such appear to us only in a definite time sequence, as the words (or phrases) actually do when we read.