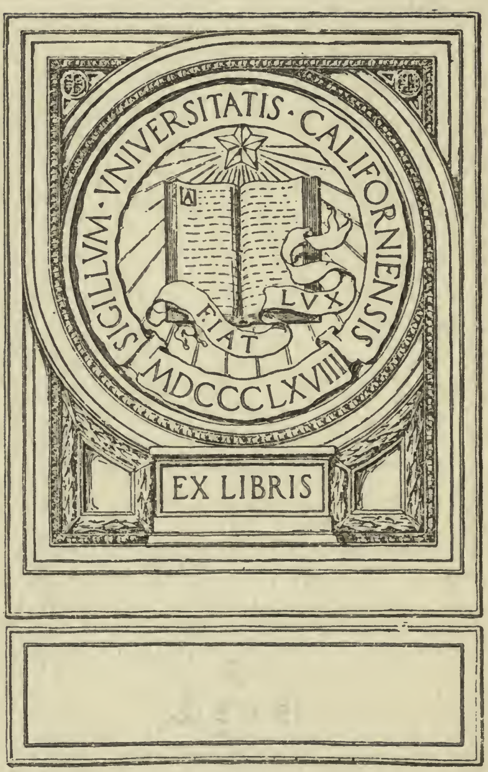
THE EVOLUTION OF KNOWLEDGE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BY

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PREFACE

The following essay is intended to call attention to an aspect of knowledge which has been very generally overlooked. Its importance was not evident until the theory of evolution came into prominence and, although that theory has now been expounded in regard to a great variety of subjects, I have not yet found any statement of its application to epistemology.

Viewed as a product of the evolution of nervous function, knowledge is seen to have grown from the need of the organism to forecast the consequences of voluntary action, and throughout its development from its most elementary forms to the latest achievements of science it is found to subserve this requirement. It is built up from sensory reactions woven into a system by means of certain hypotheses: elements which may be compared to the warp and woof of a textile fabric. One of the basic hypotheses is that sensory reactions have a fairly constant relation to changes, other than themselves, which are supposed to take place in an external world.

It is a common assumption that by scientific knowledge we can get behind our senses and picture the nature of the (hypothetical) external world as it exists independent of sensation. It may be so, but there is nothing to indicate this, either in the nature of the process of acquiring knowledge, or in the history of its development.

What we do find from experience is that the acquisition of knowledge gives increasing control of the environment, making it possible for the organism to surmount obstacles and to escape dangers to which ignorance would succumb.

This being so, it would seem that, as a necessary part of their education, learners should be trained to use for themselves the well-tried method by which knowledge is advanced: namely (1) the observation of recurring sequences of sensation; (2) the comparison of these sequences with previously known series; (3) the forecasting of the course of the new sequences by analogies drawn from the known series; and (4) verification by the comparison of the forecasts with further experience.

G. S.

Savile Club,
June 1922.

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CHAPTER I

ORIGINS

THE ability to acquire knowledge is here considered, not as a mysterious power inherent only in mankind, but as a nervous function, originating at a very early stage in the evolution of the nervous organism and, thereafter, progressively developed in the same way as other functions which enure to the survival and the well-being of the species exercising them. So great are the advantages conferred by it that the species in which it is best developed become dominant, even though they may be physically weak; by virtue of it man is everywhere raised above other animals, and, among human beings, those communities in which the function is most used have the greatest control over their environment.

An account of the evolution of knowledge might logically start from the origin of the nervous system; for the present purpose, however, there is no need to deal with organisms at an earlier stage than mammals.

The knowledge to be discussed is obtained through the senses, but depends upon nervous modifications which are not directly parts of sensation. First there must be the supposition that the nervous process known to us as *memory* is not entirely independent of the past, but is in some degree a record of previous sensation; and, secondly, there must be an expectation that feelings which are remembered as having followed one another in a certain sequence may afterwards be *repeated* in a similar sequence.

The words *supposition* and *expectation* in their strict sense refer to conscious processes, but must here be accepted as suggesting analogous processes in parts of the nervous system to which we do not attribute consciousness. When a dog's flank is irritated, its leg acts in a way that tends to remove any adherent source of irritation, so that a recurrent sequence of sensations [i.e. (1) irritation, (2) movement, (3) relief] would appear to be expected. Normally, such a sequence would emerge into consciousness in the dog's brain; but it is found that the movement is performed as a reflex action even after the connection between the afferent nerve and the brain has been severed, when therefore no sense of the irritation can reach the dog's consciousness. Thus the action which, when consciously performed, was followed by relief, is imitated without conscious guidance: as though the disconnected nerves had, in themselves, the memory of relief and the expectation of a similar feeling as part of a recurrent sequence. From such phenomena it appears that those conditions of knowledge which (for want of better names) I have called supposition and expectation, are not confined to the brain, but are functions of the whole nervous system, and may have been developed at a very early stage of its history.

In conscious thought a third supposition (no more forming part of sensation than the two others) plays an important part in the process of knowing. It is the hypothesis that sensations arise from changes in an external world independent of the senses: changes which stimulate the nerves to sensory reactions whose relation to the stimuli is, under normal conditions, approximately constant.

Put into a more concrete form, this means that on feeling certain visual and tactile sensations, a man supposes them to be caused by stimuli due to his having come into sight of, and touch with, some external object, say a chair, which would still exist whether it were seen and felt by him or not. Also that sensations, recognisably similar, would be felt whenever the nerves were again stimulated in the same way, either by that chair or by another closely resembling it.

Each of the aforesaid suppositions is frequently found to be misleading; the records of memory, always incomplete, may become confused; actual experience may disappoint the expectation of the recurrence of particular sequences; and the theory that the stimuli felt on a given occasion result from a certain hypothetical process in the external world may be rendered untenable by the non-fulfilment of the forecasts framed on that basis.

These are among the obstacles to the acquisition of knowledge; we have to inquire by what method and to what extent they can be overcome. It will be convenient, in the first place, to classify knowledge under three heads, and to call them respectively Empirical, Abstract, and Systematic knowledge.

The Empirical is the original form of knowledge and is the basis of the other two. It involves nothing more than the memory that certain sequences of sensation have occurred in the past, together with the expectation that they will recur in the future; it is capable of no other confirmation than that of actual recurrence.

Sequences of sensations could hardly be mentally arranged in series unless there were some idea of a connection between them; the connection supplied by continuity in time, when the sensations follow closely one after the other, is naturally the one that is most obvious. Sequences connected in this way are noticed, and their recurrence expected, by animals. Very early in their lives they may be seen trying, by repetition, to learn what changes in the position of their limbs follow upon changes in their muscular sensations; while the play of young animals is, in part, a succession of further experiments tending to confirm this knowledge and to give it greater precision. There are plenty of well-known examples showing how, in later life, animals expect the recurrence of series of consecutive sensations; thus a dog will show signs that he expects a walk when he sees his master with a hat on; a carriage-horse, that he expects to halt at places where he has been pulled-up once or twice previously. Children learn how to use their limbs and to speak their mother-tongue by a process of a similar kind.

The reactions which are continually taking place in a nervous organism give rise to a crowd of sensations so large and miscellaneous that no increase of knowledge can be gained by trying to arrange them all in a single mental series; some distinct group of sensations must be selected from the crowd and its elements considered in relation to one another before any question of recurrence can be investigated. The hypothesis that sensation is due to changes in external objects, independent of the senses, greatly simplifies the selection by providing centres around which sensations can be grouped. So strongly does this influence our mental processes that few sensations are ever thought of apart from their grouping, and language is constructed almost entirely in terms of an external world. Even the small number of words denoting particular sensations (pain, warmth, cold and the like) are seldom used without reference either to their objective source or to the part of the body affected.

Consider the watching of a falling body. What is felt is a visual sensation combined perhaps with the muscular sensations of eye-movement; yet the thoughts are always directed, not to these sensations, but to the changes in the relative positions of the (hypothetical) body and the earth.

Owing to this attitude of mind, it is easy to conceive the fall of bodies as a recurrent series of changes; had the attention been fixed upon the sensations as subjective processes only, it would have been difficult to disentangle them from the great number of other sensations that might be felt during the period of the fall.

It seems fairly certain that the hypothesis of an external world is not an idea peculiar to mankind, but is shared also by many animals.

This hypothesis, though very helpful, does not by any means provide the complete answer to an inquiry as to what sensations are relevant to any particular recurrent series. In the case of a falling body, for example, experience quickly shows that some sensations associated with the body, such as colour and smell, do not affect the series, and careful experiment has shown that differences of size, shape and weight, which at first sight seem important, make no difference to the motion unless the fall takes place through air. On the other hand, while the relation of the body to the earth appears, superficially, to be the same in every place, it is known from exact observation that the greater the distance of the place from the equator, the higher is the velocity of the motion.

The idea that a body without visible support may be expected to fall rapidly toward the earth, is one that rests upon frequently repeated experience—it is empirical knowledge. That the sequence is subject to conditions becomes at once evident when feathers are seen to flutter down slowly, or leaves in a wind to fly upwards. The determination of the rate of fall, and the conditions which affect it, may be termed, for distinction, systematic knowledge.

It is a serious defect of knowledge which is not systematised, but remains merely empirical, that since the circumstances conditioning the recurrence of a series have not been investigated there are no means of forecasting when the repetition may unexpectedly fail. Thus suction-pumps had long been known to draw water, and it was expected that they would always do so; yet it was found at Florence that a pump would not raise the water from a depth greater than about thirty feet, and hence Torricelli was led to recognise the condition that water will rise in a pump only so far as its weight is balanced by the pressure of the surrounding atmosphere.

Again, purely empirical knowledge cannot point to a way of avoiding an unwelcome sequence by modifying its conditions, since these are not yet discovered. It had been known for centuries that a sojourn in certain marshy districts was often followed by an attack of malarial fever. No effective steps could be taken to prevent the recurrence of this malificent sequence until its conditions were known; but when it was found that the fever was due to the presence of certain parasites, introduced into the blood by the bite of an infected mosquito, it became plain that the frequency of the sequence might be reduced by destroying the breeding places of the mosquito.

The hypothesis of the recurrence of every sequence is, however, universally accepted, subject to the proviso that all the conditions under which it took place should also be repeated. No failure of this has been experienced, or is even imagined.

Unfortunately, when the sequences are concrete, it is never possible to exclude entirely the possibility of their being affected by unknown conditions which may interfere with the recurrence, and therefore any forecast of this must remain doubtful until repetitions have been observed on many occasions and under varying circumstances.

But, on the other hand, when a sequence is of a nature so abstract that all the conditions affecting it can be defined and every deviation from them excluded, valid forecasts of its recurrence may be drawn from a single experience of its having taken place. Thus the words 'a plane, rectilinear triangle' describe an ideal figure; an approximation sufficiently close to illustrate the idea can easily be made (e.g. by cutting a piece of paper to shape), but it cannot be ensured that this, or any other construction, should, with absolute accuracy, be either plane or rectilinear. The statement that where two angles of one plane, rectilinear triangle and the side between them are respectively equal to those of another such triangle the two figures are similar in all geometrical respects, is an abstract proposition referring, not to any imperfect representations, but to perfect, ideal figures. On making the experiment of fitting one approximate representation of the figure upon another, the similarity is at once seen to be as close as their approximation, and the single example of the truth of the statement is held to give a knowledge of the general proposition, because any variation from the relevant conditions of the abstract sequence is excluded by the terms of the enunciation.

The appeal thus made to experience depends for its force upon the universal assumption that every sequence will recur if all the relevant conditions be repeated. It is put in this form by

Euclid, and although some find it unconvincing, it has sufficed for numbers of learners in many countries and during several centuries. There is, therefore, historical warrant for thinking that it accords with the normal mental process of the acquisition of knowledge.

Take another example. Three parallel rows, of four dots each, can be arranged in a parallelogram, and it becomes at once evident that the diagram represents equally well a system of four rows of three dots each; so that in this instance the multiplier and the multiplicand can be interchanged without changing the number of dots which is the product. Now the dots merely serve to represent abstract unit integers, while the particular numbers 3 and 4 are no more essential to the sequence than the particular shape of the triangles in the former example; hence the universal assumption applies here also, and it is possible, from the single experience, to forecast that multiplier and multiplicand will always be interchangeable provided that they be abstract unit integers. This gives no guarantee of recurrence where the elements are other than numerical units; in quaternions, for instance, factors are introduced which have a different relation.

While empirical knowledge does not point to any forecast beyond that of the repetition of past sequences in an identical form, abstract knowledge does lead to the expectation that experiences differing from, though analogous with, those of the past will occur in the future, provided that the sequences involved are subject to certain definite conditions; these conditions being mentally abstracted, as far as is possible, from any qualities, or properties, of the external material world. But forecasts of abstractions cannot serve as immediate guides of action; their function is to assist calculation, and the results must ultimately be connected with the concrete by the re-inclusion of those properties of the external world which, for the convenience of calculation, had been mentally excluded during the process. Indeed, the hypothesis of the existence of an external world would have no practical value were it not supplemented by hypotheses attributing definite properties to its various components. These being taken as bases of calculation, they and the sum total of the forecasts resulting from them constitute that body of concrete knowledge which is here called *Systematic.*

The attributions are themselves forecasts drawn from experience, and are, in fact, made for the very purpose of assisting the formation of other forecasts; in order that they may the better fulfil this purpose, changes have been (and are still being) made in the hypotheses concerning their nature.

Most properties are assigned to special kinds of matter, or to matter in some special state, but a few are attributed to matter in general. From constant experience of its obstruction of free movement, all matter is held to have the property of resistance; which implies that the presence of one material body prevents any other such body from being in the same place at the same time. The limits at which the resistance of a body can be felt determine the extension, i.e. the size and shape of the body. In the same way, from experience of the uniform tendency of bodies to move towards the earth, the property of weight was attributed to all terrestrial matter.

When the need for measurement was first felt, the dimensions of bodies were estimated by comparison with the lengths of men's limbs; and weights, by comparison with what a man, or a beast of burden, could carry. The fixing of the units of length and weight by reference to standard bodies was an important step toward systematising knowledge in many of its branches.

Chaldean astronomy, the earliest systematic knowledge on record, introduced another unit, the degree, which remains in use for the measurement of angles to the present day.

The whole history of astronomy illustrates the usual course of systematic knowledge, and may be taken as its type. The idea first suggested by observation was naturally that of a circular motion of the heavenly bodies, and the familiar process of the turning of a ball round an axis through its centre afforded an obvious analogy. Based upon this, the theory was framed that the fixed Stars were attached to the inner surface of a large hollow sphere turning uniformly about an axis through the centre of the Earth, while the Sun, Moon and Planets were attached to smaller transparent spheres, one within another, turning independently about axes inclined to the main axis. Step by step the theory was modified to bring its forecasts into closer agreement with observation, till in the time of Ptolemy, the second century A.D., it was supposed that the Moon and Planets were each attached, not directly to the surface of its sphere, but to the end of a revolving arm pivoted on the sphere, so as to produce an epicyclic motion, while the axes of some of the spheres were excentric—that is to say, they did not pass through the centre of the Earth.

In the middle of the sixteenth century Copernicus improved astronomical theory by taking the Sun, instead of the Earth, as the centre about which the circular motions of the planetary system are performed. The simplification thus introduced made it possible for Kepler, some sixty years later, to show that more accurate forecasts may be made when the idea of circular motion is abandoned and the paths of the planetary bodies are compared with another well-known curve, the ellipse; the Sun being supposed to occupy the position of a focus.

On this theory the analogy of the rotating sphere would no longer serve as the ideal for planetary motion; nor was there any other mechanical analogy available at the time.

About the same period, however, Galileo laid the foundation of the science of dynamics, besides introducing a more minutely accurate measurement of time by means of the pendulum. Both of these were valuable aids to Newton, who, toward the end of the seventeenth century, propounded the three so-called 'laws of motion' and the theory of universal gravitation; thus giving to astronomy a new mechanical analogy for the planetary motions, in place of the discarded one of a rotating sphere.

The 'laws of motion' are abstractions derived from observed sequences and are most helpful in making forecasts, but they are ideals incapable of actual realisation; the first law, for instance, is that 'Every body continues in its state of rest, or of uniform motion in a straight line, except in so far as it is compelled by force to change that state.' Yet we have no experience either of rest, or of motion in a straight line, since the whole Earth revolves both about its own axis and round the Sun.

Again, since no planet actually moves in an ellipse, it is evident that when Kepler propounded his theory of elliptic motion he only indicated the ideal curve which corresponded to his observations more closely than any other with which he was acquainted. The idea of gravitation as a force varying inversely as the square of the distance, appears to have been originally suggested to Newton by his study of this ideal motion, though he delayed its publication for many years, pending the demonstration that, when applied to the motion of the Moon, it gave results agreeing approximately with those from the fall of heavy bodies to the Earth. The astronomical forecasts made on the basis of the gravitation theory, agree with observation much more closely than those which could be made on the hypothesis of simple elliptic motion, but Newton's theory, no less than Kepler's, was an ideal construction.

Forecasts made in accordance with Newton's laws of motion are confirmed by experience, not only in astronomy, but in every department of physical investigation concerning the movements of bodies. For example, the laws are employed in the finding of a relation between the effective length of a pendulum and its period of oscillation; this is shown to depend upon the acceleration of a body toward the Earth at the place where the pendulum is hung, and observations agree, as closely as possible, with the theoretical results.

In physics, therefore, the method of bringing observed sequences within the domain of systematic knowledge has been as follows: Each new sequence was compared with some process already familiar; the experiences of the known process were arranged in an ideal mental series; forecasts were made that if the new sequence should follow the analogy of this ideal series, not only in the instances already observed, but also in other respects, then such-and-such consequences might be looked for; and, lastly, these forecasts were compared with actual experience.

On examining the records of the progress of systematic knowledge it will be found that, in every department, the method employed has invariably been the same as that which has been described above, and traced throughout the history of astronomy. This generalisation could be proved only by a review of the whole range of science; all that can here be offered in support of the proposition is an illustration from some entirely different branch of science.

Consider, then, the introduction of aseptic surgery. Pasteur had observed that certain germs always grew among organic substances which were undergoing decomposition; that in the absence of these living germs no decomposition took place; and that when the organic substance was isolated from every external source whence it could be reached by the germs, they did not appear. In the normal course of systematic thought these experiences were arranged in series and mentally incorporated into a process; it was held that germs are produced only from parent organisms of their own species, not originally present in the substances among which they flourish, and that when the living germs have been introduced from external sources, their growth determines the chemical breaking down of the organic substances affected. From the analogy of this process Lister drew the hypothesis that suppuration is a decomposition of the blood due to germs introduced into a wound. His theory pointed to the forecast that no suppuration would take place if the access of living germs from any source external to the wound were prevented. Ample verification has been obtained by the success of this forecast, and a complete revolution in the practice of surgery has been the result.

The foregoing example brings into prominence that essential function of knowledge which has ensured its continuous development throughout the evolution of those species whose nervous systems were most highly organised—I mean its use as a guide of action. Whenever a voluntary act is the antecedent in a sequence where knowledge supplies the power of forecasting the consequence, that act can be controlled with a view to the promotion, or prevention, of the sequence according as the consequence foreseen is, or is not, desired. It is evident, also, that when the outcome of the sequence can be compared with experience, each performance of the antecedent action gives a fresh opportunity for the verification of the hypothesis upon which the forecast was based.

Knowledge is an indispensable element of purpose, and its value as a factor therein depends upon the power of forecasting, with sufficient accuracy, the consequences of doing, or refraining from, certain voluntary acts. The many suppositions which are made in the construction of knowledge are framed for the sake of such forecasting, and are verified solely by its results; they may be of any nature whatever, provided only that they yield the best available forecasts with the least possible difficulty.

Among the suppositions found to be most helpful is the hypothesis that changes of sensation are the reaction of the organism to the stimulus of changes in an external world. The mental constructions founded on it afford what passes with most men for a sufficient knowledge of that world. Knowledge of this kind is disparaged by some philosophers, who refuse to be satisfied with less than a knowledge of external changes, not only as they hypothetically affect sensation, but also as they may occur behind sensation, in a world metaphysically denominated 'real.' There is, however, no trace of an evolution of knowledge tending in this direction; nor does it appear that such knowledge, if acquired, could have been of use to any organism for the guidance of its actions.

The word *real* in its ordinary sense refers, like the word *verification*, to the fulfilment of forecast. When experiences concerning objects of a definite kind have been summed up and symbolised by a name, the forecast made is that these experiences will be repeated in respect to any object rightly called by the same name. If the forecast be fulfilled in the case of any particular object, it is then held to belong to the class named, and in that sense is said to be *real*. Thus a material is real gold if its properties correspond with the forecasts drawn from past experiences of the metal called gold. When a traveller in the desert sees what appears to be water he will, very likely, expect it to quench his thirst; if it does so, it is real water. The appearance may, however, be a mirage, and, if so, what he sees is not real water; but in that case it is a real mirage.

Experience can offer no other criterion of reality, as must be plain when it has been recognised that sensation is directly concerned only with changes, that these changes are what we project into the external world as the properties of things, and that the things themselves are, for us, no more than a substratum, supplied by hypothesis to connect the sum-total of the properties in a manner suitable for making forecasts.

Knowledge in the early form, the empirical, does not, except in special cases, rise to the definite idea of a *process*, or series in which the change from the initial state is mentally followed through continuous, imperceptible gradations till it reaches the final state. Visible bodies moving from place to place are open to continuous observation, and their motion through every intermediate position is the original type of a process; but the intermediate stages of a change can seldom be directly observed whilst the sequence is in progress, and thus the steps which do come under observation are associated, empirically, merely as changes occurring one after the other.

The first advance toward systematic knowledge is the replacement of this empirical association by the idea of a process, for which purpose an hypothesis must be framed upon analogies drawn from processes already supposed to be known. In the physical sciences this usually involves measurement and numerical calculation. The next step is the use of the hypothesis for making forecasts of consequences hitherto unobserved, and its verification by comparison of the forecasts with experience.

This mode of verification is more convincing than that which is commonly available for empirical knowledge—namely, a limited number of repetitions of the sequence as originally observed. Thus in addition to its vastly wider scope, systematic knowledge has the advantage that it can be more surely verified than empirical knowledge. This is a characteristic of the highest value, for in the advance of knowledge verification is the decisive operation, and usually the most difficult. In its absence, hypotheses of great importance have remained unusable for years, or even centuries.

Epicurus recommended the method of analogy for the investigation of phenomena, but since he despised verification his followers became the most unscientific of philosophers. Pythagoras is said to have taught that the Earth is a planet revolving about the Sun, but the theory was unfruitful till it was verified by Copernicus. Lucretius imagined that matter was atomic; it remained a useless and unverified speculation till the time of Dalton. The Romans, in classical times, appear to have supposed that mosquitoes caused malaria, yet the verification by Ross was needful before the idea could be used in combating the disease. So, too, Francis Bacon's theory that heat is motion required verification by Joule; and Newton himself delayed the publication of the theory of gravitation for years until he was able to verify it to his own satisfaction.

The systematic practice of verification is the latest development in the search for knowledge, and is the characteristic which distinguishes modern science from everything that went before.

CHAPTER II

PHYSIOLOGY

For the better understanding of the development of knowledge as a nervous function it will be well to have some idea of the nervous system itself. The following outline, so far as I have been able to learn, is in accordance with modern researches on the subject.

Two kinds of nerves, the afferent and the efferent, communicate with the brain and the central nervous system; for present purposes it is convenient to call them respectively sensory and motor nerves. The nervous functions of the organism are roused to action by stimulation of the sensory nerves, the reaction to which involves nerves of the other kind and generally affects external movement. Stimuli reach the sensory nerves through end-organs, each of which is adapted to receive its own particular kind of stimulus and no other. Thus at certain spots on the surface of the body there are end-organs for the feeling of cold; at others, for the feeling of heat; and at others, again, for the feeling of pain. Hence the message transmitted along a nerve has, from the start, a definite character of its own; the stimulation of a cold-spot would, if it reached consciousness, produce a feeling of cold; that of a heat-spot, a feeling of heat; that of a pain-spot, a feeling of pain.

But of the innumerable responses made by the nerves to stimulus, comparatively few do reach the level of consciousness; there is a kind of competition among them, and some do not advance beyond the level at which inevitable reflex action is their appropriate outcome. Many others, advancing farther, produce the sub-conscious co-ordination of movements of the body and limbs. Only those which have been strong enough to overcome the resistance of their nervous path, and to win their way through the competition, do ultimately arouse consciousness.

This assorting of nervous reactions takes place in the central nervous system, which includes the spinal cord, the medulla oblongata, and the cerebellum. The process is carried on, without the intervention of consciousness, by means of a series of receptors which guard certain synaptic junctions in the centripetal paths. They serve as inner end-organs to receive, not the direct external stimuli, but the nervous discharges liberated when those stimuli act upon the exterior end-organs. Both these kinds of end-organs transmit the excitations for which they are adapted, and refuse all others.

Those responses which surmount the selective process in the central nervous system reach a certain nerve-junction, whence they can act upon two sensory centres, viz. the essential organ of the optic-thalamus and the cerebral cortex. The former responds to stimuli so far as they evoke the massive feelings of well-being and the reverse, and it gives the 'feeling-tone' of somatic, or visceral sensations; while discrimination, which leads to all that is generally classed as knowledge, is the function of the cerebral cortex. The reactions of the optic-thalamus, when freed from the control of the cortex, are an almost perfect expression of the non-discriminative aspects of sensation, and are the origin of those vague generalised feelings, those 'thoughts too deep for words' which from time to time pervade the organism.

The necessity of the above-described sorting process may be shown by a simple example. Among the end-organs dotted over most of the exterior surface of the body are the three kinds already mentioned—pain-spots, heat-spots, and cold-spots. All three may be stimulated at once by contact with a body at a temperature between 40° and 45° Cent. (104° and 113° F.); were the nervous discharges from all three to reach consciousness together, mental activity would be chaotic and discrimination impossible.

The struggle between them takes place, therefore, on the physiological level, and the victor alone appears in consciousness as a sensation. The normal result in this example would be a pleasant sensation of warmth; but that depends upon the condition of the nervous system at the moment. Should the resistance to heat-discharge be exceptionally high, the sensation may be one of cold; if the resistance to this be also high, and that to pain-discharge be low, the feeling may be painful.

Again, reactions which determine the posture of the body, and co-ordinate the movements of the limbs, are nervous discharges which have advanced so far as to affect the cerebellum; they may also excite consciousness by continuing their course and reaching the cortex of the brain, but if they be prevented from doing so, and thus have their sensory aspect suppressed, this does not annul their unconscious activity; the movements of the limbs may still be co-ordinated just as well as if they had been consciously directed. Thus movements which, under conscious direction, have been learnt with some difficulty during infancy, or early life, are afterwards executed easily and well without any conscious attention; sometimes, indeed, when consciousness is evoked, it appears to have a disturbing influence.

Although so many nervous disturbances are sorted out and intercepted on the physiological levels, great numbers make their way to the cortex of the brain, and these have still to contend one against another for the predominance which is known as *attention*. Since this is, to some extent, decided by volition, the organism must be supposed to possess the power of reducing the resistance of particular nerve-tracks in the cortex, and thus giving predominance to the discharge of energy through them, unless it be overborne and repressed by an exceptionally strong discharge in some other direction.

Every nervous reaction gives signs of having been affected by previous reactions which have left traces along the path by changes in its condition. Now energy is necessary for the propagation of disturbance, and the only source of energy available for nervous disturbance is a chemical change in which a portion of the nervous tissue is reduced to a more stable composition; this must, therefore, be one of the changes originally made in the path of a nervous reaction. But one single reaction does not render the nerve incapable of a second reaction immediately afterwards, hence it would appear that only a part of the nerve-tissue can have become stabilised in the first discharge of energy. The power of the nerve to respond to stimulus does, however, temporarily diminish when a number of discharges have followed one another in rapid succession. The bio-chemical instability of the nerve-tissue is quickly restored by the vital functions of the organism, but traces of the nervous disturbances remain; and our experience of memory suggests that the process of recuperation leaves the track of a disturbance more unstable than it had been previously, since the reactions which we call reminiscences follow such tracks in preference to any others. These pathways of lessened resistance form a complex of memory-tracks which affect, not only conscious reminiscence, but also the subconscious nervous reactions determining habits of mind and body.

What, then, are the inter-relations among nerve-tracks new and old? We know that reactions to simultaneous stimuli do not reach consciousness in isolation, but in associated groups which include reminiscences of previous reactions; thus the sight of a friend brings immediate recognition but very little idea of the details of his appearance unless some of them should be unusual. We are also aware that reminiscences are so linked together in series that one leads to another in definite succession. It will be found that the thoughts associated in memory are such as have been previously connected in experience, either directly or through their symbols, and that the usual link of connection is that of a close sequence in time. As a rule the order of mental association follows the order of succession in experience; thus it is easier to remember the spelling of a word than to recall the letters in a reverse order.

The physiological aspect of these mental phenomena is still uncertain, but provisionally it may be supposed that while a nervous path is undergoing a disturbance there is a diminution of resistance to the passage of other disturbances along the same path; that in virtue of this lessened resistance it becomes possible for the track to receive and transmit some of the energy liberated by disturbances affecting other tracks at the same time; that connections thus established produce an association in consciousness; and, lastly, that the pathway of communication between the different tracks will serve thereafter as a memory-track.

There is no way of verifying such a theory, but it presents a mental picture of a possible nervous process whereby reactions to stimuli which are simultaneous could be grouped together in consciousness, and reactions to stimuli which have followed one another in close sequence could be associated in memory, provided that each has taken place during the period of lessened resistance due to its predecessor.

Memory-tracks are apparently formed at all levels of nervous response; those above the reflex level must be under the same voluntary control as other sensory nerve pathways.

The motor-nerves regulate the contraction of the muscles, and thus determine all our movements both reflex and voluntary. The latter term can have no other meaning than that the resistance along the paths of the motor-nerves regulating the muscular contractions, which produce certain movements, is controlled by the reactions of the organism as a whole.

CHAPTER III

ABSTRACTIONS

Most of what has gone before applies equally to the nervous organisation of any mammal; a distinctively human function is now to be considered—namely, Abstraction.

Every experience may be looked at under an indefinitely large number of aspects which cannot all occupy the attention at the same time. This is doubtless the case with animals as well as men; when a savoury smell reaches the nose of a hungry dog his attention will be occupied with the aspect, *food*; but there can be little doubt that the idea in the dog's mind remains merely an aspect of the particular olfactory experience, and is inseparable from the notion of something which he himself desires to eat. A man, on the other hand, can regard the idea of food as an aspect common to many substances, and so can dissociate it from any particular edible and from his own personal appetite. He may think of it as a necessity of life in general; as a source of energy; as being scarce or plentiful in some other country, or at some other time. The abstract idea of food can thus be used for purposes of calculation in combination with other abstractions, as if it had an independent existence.

This is partly due to our possession of a language which enables us to name an abstraction and thus to stamp it with a distinctive mark, like the impress on a coin. This naming of a particular aspect common to a group of experiences makes its mental isolation easier and thereby vastly simplifies calculation, for the process of arranging and rearranging ideas involving such an aspect would be inextricably confused if it were not possible to leave out of consideration the other miscellaneous and irrelevant aspects of the members of the group.

In using the names of abstractions, variation of meaning due to differences of experience is unavoidable, and besides this there is also a risk that, when an abstraction is not very clearly defined in the mind of a thinker, he may inadvertently change its meaning in the course of a continuous calculation, and thereby totally invalidate the result. The complex abstractions of ethics and æsthetics—such as justice, happiness, beauty and the like—are very liable to changes of this kind.

It has sometimes been supposed that abstractions are more real than the experiences from which they are derived, because an experience is fleeting and individual, whereas an abstraction seems to be lasting and shared by everybody, and hence to belong to an objective, external world. As to permanence, if this were made the test of reality, then a memory would be more real than the experience of which it is a record. Moreover, the idea of an abstraction is shared only by those to whom the particular aspect of a group of experiences has become familiar, and, as we have seen, it is often the name rather than the nature of the idea which is common to different minds. There are, nevertheless, certain comparatively simple abstractions, derived from aspects of familiar experiences, whose meaning as used in science is, for the present, fairly generally agreed upon. Some of these are germane to our subject and will now be considered.

Number.—From experiences which are repeated twice, thrice, four times and so on, the aspect of repetition is isolated and its frequency denoted by the ordinal numbers. A further abstraction is indicated by the series of the cardinal numbers which are used in connection with every kind of physical measurement. They have so prominent a place in calculation that the word itself is derived from the pebbles (calculi) which formerly served as numerical symbols.

Motion.—Every experience of change involves Motion as one of its aspects; yet in the calculations of physical science it is, paradoxically, found convenient to regard Motion itself, not as a change, but as a state of matter, subject to changes which are technically called accelerations. To the ordinary observer these are most conspicuous when Motion is beginning or ending.

Matter.—This name is given to more than one abstraction. It is often used to denote that hypothetical substratum which, under all superficial change, is supposed to remain unaltered. Originally Matter seems to have been an abstraction from experiences of pressure, and it still has much the same character in physical science, where it may be defined as that which can be moved, but resists change of motion. When the aspect of resistance is to be emphasised, the word 'Mass' is usually employed.

Space.—This word also is used in two senses. First, it is an abstraction from the experience that different portions of matter mutually exclude one another, and hence it is said that bodies occupy, or fill, Space. In the case of solids and liquids, the limits or dimensions within which the exclusion obtains can be compared with the dimensions of certain standard solids used as measures. The second meaning of Space is abstracted from experiences of the movement of Matter, and the word indicates the possibility of its being moved without being obstructed by the pressure of other matter. In this connection the presence of gaseous matter is often ignored, since the resistance offered by it, under normal conditions, is very small.

The so-called measurement of Space (in its second meaning) is the forecast that a certain number of solids of standard size could be inserted between some given terminal limits; this link with the first meaning of the abstraction has given rise to the idea that Space, in its second meaning, has dimensions like Matter.

Time.—This is an abstraction from experiences of change under their aspect of succession. If one change or part of a change, A, can be remembered when another, B, is perceived, then, as far as consciousness is concerned, B has followed A. When nervous disturbances are nearly simultaneous, the periods of reaction may overlap, and it becomes very difficult to determine the order of their succession.

When the attention is focused upon the flow of the successive changes in consciousness, rather than upon the nature of those changes, we get the abstraction Time; which is naturally thought of as continuous because the flow of change is felt to be continuous. It is convenient for calculation that Time should also be regarded as uniform. This convention having been established, Time can be divided into equal periods, and thus measured, by the progress of certain regular recurrences, the diurnal revolution of the Earth being the most important.

Force.—Experiences of pressure, like other experiences, have many aspects: the isolation of one aspect gives the abstraction Matter; of another, the abstraction Force. The only experience by which Force can be known directly is that of muscular pressure, but this is closely associated with experiences of change of motion, and it is found convenient to suppose that every change of motion has a correlative analogous to pressure, even when no human agency is involved.

It is this hypothetical correlative which is usually spoken of as a force; there are no signs of its existence other than the changes of motion which are supposed to have been produced by it, though some of the changes leave lasting traces in the form of fracture. In mechanical calculations, forces are always expressed simply as being the equivalents of the acceleration of the masses under consideration. When continuous pressure is exerted it very frequently happens that no resulting continuous acceleration is experienced: in such cases an equal force is imagined to be producing an equal acceleration in the opposite direction; consequently no actual change of motion occurs, and the state is said to be one of equilibrium in respect of those forces. It follows that since pairs of equal and opposite forces produce no sensible effect, they may be supposed to be in action at any point whatever.

Such imaginary pairs are often introduced into mechanical calculations without in any way altering the conditions of a problem.

When any unbalanced force causes a disturbance of equilibrium, the consequences take one of three forms: either the disturbed system of bodies may tend to return to its previous state, in which case the equilibrium is said to be stable; or the tendency may be toward further change, when equilibrium is said to be unstable; or there may be no tendency either way, and equilibrium is neutral. For example, an egg on a level surface is in unstable equilibrium when standing on its end, but when lying on its side its equilibrium is stable with regard to movements of tilting toward either end, neutral with regard to rolling.

Work.—In physical science the word has a technical meaning: it is the distance through which a given mass moves with a given acceleration.

Energy, or the power of doing work.—This abstraction is singular in that, although it is based upon experience, yet the particular aspect isolated is one taken, not directly from what has been, but from a forecast of what will be, experienced. It is of two kinds: Kinetic energy, in which the power of doing work is derived from the movement of matter; and Potential energy, where the power depends upon some condition of a body, or a system of bodies, independent of their movement.

The work which a body of given mass can do in virtue of its motion—its Kinetic energy—is half the square of its velocity. Its Potential energy may depend upon its position among other bodies, or upon its electrical relations, or upon something in its chemical constitution. Thus Kinetic energy is in a form appreciable by the senses, but Potential energy is nothing more than a forecast drawn from previous experience. Thermal energy must be partly kinetic and partly potential, seeing that heat is attributed to vibratory motion.

As the result of experiment it is held that the sum total of the energy in a self-contained system of bodies remains constant under all changes of condition; the energy liberated in one part being transferred to other parts. Thus the energy liberated in the muscles of an arm and expended upon the winding of a clock is (mostly) changed into the potential energy which reappears as kinetic energy while the clock is going. The rest of the muscular energy liberated during winding, and all the energy liberated in the going of the clock, takes the form of heat, which in a self-contained system would be distributed among the parts of the system.

Since energy is the power of doing work, and, like matter, is regarded as constant in amount (the quantity liberated in doing the work re-appearing simultaneously in another form); it follows that the doing of a definite quantity of work is, under another aspect, a change in the form of an equivalent quantity of energy.

It must not, however, be supposed that all forms of energy are equally available for transformation into massive mechanical movement; of the vibratory energy of heat, only a limited proportion can be converted into that form by our present appliances.

In physical science the transformation of energy is regarded as an aspect of every change. The reason for considering that unaltered motion is a state, not a change, is because, in theory, no transformation of energy is necessary for its continuance.

Causation is an abstract term denoting the process of the transformation of energy. Every process has two correlative aspects: the change out of a precedent condition, and the change into a subsequent condition. In relation to one another, the former aspect is called a *Cause*, the latter, an *Effect*. The causal nexus is supplied by the energy transformed, and both correlatives are included under the term Causation.

For example, the fall of a heavy body is said to be an effect, of which gravity is the cause. But this gravity is nothing else than the acceleration of the mass of the body toward the mass of the Earth. The dynamical theory is that a body, whilst it is supported, is in equilibrium under the acceleration of gravity balanced by an equal and opposite acceleration applied by its support; that the mutual influence of the body and the Earth is a form of potential energy; that this energy is liberated when the support is withdrawn, and that it becomes kinetic in the course of the body's fall. Thus the acceleration of the body, regarded as change from the state of equilibrium, is called the cause, while its acceleration toward a lower position of equilibrium is called the effect. At the end of the fall the energy is usually allowed to pass off in the form of heat; the amount, in ordinary cases, being inappreciable.

If the heavy body in question be a clock-weight, it may be wound up by the application of sufficient muscular energy to produce an acceleration opposite to, and greater than, gravity. In that case the process of winding up, regarded as an expenditure of muscular energy, is called the cause; regarded as the providing of potential energy for the clock, it is called the effect.

When the clock goes the escapement liberates some of the potential energy at each swing of the pendulum, so that the process resolves itself into a modification of the previous example.

These instances are mechanical, but chemical causation follows the same lines. For example, Carbon in the presence of Oxygen is chemically unstable, and their collocation is a source of potential energy. Their instability in relation to one another is often called *Chemical Affinity*. The combination between them, usually called the burning of the Carbon, liberates the potential energy, which passes off in the form of heat; at the same time both the Carbon and a corresponding weight of Oxygen disappear and a compound gas is produced in a quantity whose weight is equal to the sum of the weights of the vanished Carbon and Oxygen. Here again the process of burning, i.e. the transformation of energy, presents the two aspects; regarded as a change out of the unstable state of uncombined Carbon and Oxygen, it is called the cause; regarded as a change into the more stable state of a compound gas, with evolution of heat, it is called the effect.

Now Carbon and Oxygen may remain together, uncombined, for any length of time, unless the chemical equilibrium be disturbed by a sufficient rise of temperature, or, in other words, unless the Carbon be set on fire. Similarly, a heavy body does not fall unless its support be removed. It will be seen then, that, in many cases, energy may retain the potential form for an indefinite period unless it be liberated by some external disturbance. Hence we get a modified meaning of the word Cause, for it is often applied to the liberating process of external disturbance; while, in reference to this, the entire process of the transformation of the liberated energy is called the Effect.

Cause and Effect, in the sense of two aspects of the same process, must begin, continue, and end together; while a cause, in the sense of a disturbance, must be complete before the effect, in the sense of the transformation of liberated energy, can begin. The most important difference between the two meanings is, however, that cause (in the former sense) refers to no other energy than that transformed in the process which, under its correlative aspect, is called the effect; whereas a cause (in the latter sense) is a process which liberates potential energy due to the unstable equilibrium of a distinct system, and thus initiates a new process of cause and effect. For instance, the pulling of a trigger is a cause which, through various intermediate processes, may have the effect of discharging a gun and liberating a quantity of energy vastly greater than that employed in the pull upon the trigger.

Where cause and effect are held to be merely different aspects of the same process they cannot be regarded as separable; hence arises the idea of necessary connection. If the combination of Carbon and Oxygen could be supposed to be a separate process from the formation of the compound gas, there would no longer be the same feeling that the expectation of their recurrence together is an inevitable mental attitude. The feeling is not quite the same when cause and effect are used in the modified sense; thus it is understood that a gun may possibly 'misfire.'

The word 'occasion' may be used instead of cause in the modified sense, when a distinction is to be made between the two meanings.

In dealing with abstractions attention should always be paid to the purpose for which the special aspects of experience are isolated, named and defined; this is that the experiences under their most valuable aspects may be put into a form convenient for use in those arrangements and rearrangements of ideas that are called calculations.

For the fulfilment of this purpose, the best definition of any particular abstraction is the one which, under the circumstances of the case, is found most helpful toward framing successful forecasts. In different calculations, therefore, it may be advisable to use different definitions of the same abstraction; but the most appropriate definition should be chosen, and care must be taken that the abstraction shall retain its definite meaning unaltered throughout the course of any one continuous calculation.

If it had been kept in mind that an abstraction is an artifice of calculation, not a separate entity, many difficulties and much fruitless discussion would have been avoided.

The abstractions noticed above are such as can be more strictly defined than most others, yet the development of knowledge has imposed on them various changes of meaning in the course of times past, and they may, of course, undergo still further changes in the future.

Few abstractions could appear less subject to change than that of number, yet for some purposes this has been altered to include 'imaginary numbers,' the square roots of negative quantities.

Motion is naturally regarded as a change; the idea that this abstraction should be taken to denote a state, rather than a change, was introduced in connection with Galileo's theory of dynamics.

Early notions about Matter were grotesquely different from modern ideas. It was thought that Matter moved of itself in one direction only—namely, down toward the flat disc of the Earth. One objection to the theory of a globular Earth was that everything on the 'under' side of it would fall off. In all directions, except downwards, Matter was sluggish, reluctant to move, and inclined to stop as soon as the moving force ceased. Air was identified with spirit, and was not recognised as a form of Matter. The two were contrasted and opposed in an ethical sense; air, or spirit, represented everything that was considered praiseworthy, while Matter was the source of all evil.

To this day 'materialistic' is a term of opprobrium; it is usually thrown at those who confessedly regard verifiable knowledge as a guide of action, and who prefer to use, in their calculations, definite abstractions rather than those which have no fixed meaning.

Space, in the sense of the limits or dimensions of bodies, and Time, are defined mainly by systems of measurement which have considerably altered since the periods when distance was measured only by the 'day's journey' or by the variable dimensions of the human body, and Time was reckoned by the unequal intervals between successive sunsets, or successive full moons. There is a proposal, at the moment, to introduce further changes into the definitions of Space and Time, but it is still doubtful whether calculation will be facilitated thereby.

Force and Work could only be defined originally as being aspects of muscular effort; the definitions which connect them with acceleration, and thus with movements other than those due to living muscle, are results of the development of dynamical theory.

The same theory introduced the new conception of Energy, which corresponds in some respects to the older abstraction, Power. Energy was at first regarded only as an aspect of movements unattended by friction; afterwards, when friction was found to produce definite quantities of heat, and these were measured in terms of energy, it came to be regarded as an aspect of every change. It is of great value in calculation because, like the abstraction Matter, it can be treated as a constant whose quantity remains unaltered under every change of form.

The idea of Causation was originally derived from sequences in which the movement of the limbs followed the will to move them; associated with which were sequences of action following the issue of orders. Volition, regarded as a nervous function, is the cause, only in the modified sense of being the occasion of organic movement, since the nerve does not supply the energy of movement, but only liberates what is required from the potential energy of the contractile muscles.

In primitive times, however, no distinction was made between organic or inorganic movement;

the Sun was believed to rise and set, winds to blow and rivers to run according to the volition of spirits inhabiting and informing them. Everywhere, Will was regarded as the cause and movement as the effect.

Even when animistic notions had been displaced by the ideas of physical science there remained vestiges of primitive thought, according to which cause and effect not only served as the mental connection between the phenomena of recurrent series, but in some way controlled them. How vague the idea was in the seventeenth and eighteenth centuries, may be seen from the Essays of Locke and Hume. The former wrote:

> We see animals are generated, nourished and move; the loadstone draws iron; and the parts of a candle, successively melting, turn into flame and give us both light and heat. These and the like effects we see and know, but the causes that operate and the manner they are produced in, we can only guess and probably conjecture. For these and the like coming not within the scrutiny of human senses, cannot be examined by them, or be attested by anybody, and therefore can appear more or less probable only as they more or less agree to truths that are established in our minds, and as they hold proportion to other parts of our knowledge and observation. Analogy in these matters is the only help we have, and it is from that alone we draw all our grounds of probability (Book IV, xvi, § 12).

Hume, in his turn, stated that we cannot attain any definition

> which may point out that circumstance is the cause which gives it a connection with its effect. We have no idea of this connection, nor even any distinct notion what it is we desire to know when we endeavour at a conception of it (*Essays*, 39, § 7).

The theory of Energy, as developed in the middle of the nineteenth century, gives to the mental connection between cause and effect the definite meaning which was unattainable in Hume's time. It can now be seen that causation is an artifice of calculation, mentally constructed, like other abstractions, from experience. Provided that the forecasts made with its help be successful, we need not inquire whether it does or does not correspond to relations among the entities of an external world.

CHAPTER IV

PROBABILITY

Probability is often regarded as something distinct from, and even opposed to, knowledge; it should rather be considered as an aspect of all knowledge, since this depends ultimately on the belief that memories of the past are not wholly untrustworthy, and on the expectation of the recurrence of sequences in the future; both of which might be counted among probabilities. If these were taken for granted, some abstract knowledge might then be called certain, but elements of probability would still be found in all other knowledge, and these elements become conspicuous when the knowledge is to be put into a precise form.

In order to show clearly the nature of probability we will first consider cases in which it can be expressed by a numerical ratio. In calculations dealing with these ratios, certainty is always denoted by unity, and probabilities by fractions; thus where the probability is as 2 to 1, the fractions used in calculation would be $\frac{2}{3}$ and $\frac{1}{3}$, and similarly for the probability 100 to 3 the fractions would be $\frac{100}{103}$ and $\frac{3}{103}$.

Take as an example the very simple case where two sequences are equally likely, so that the ratio of the chances will be as $\frac{1}{2}$ to $\frac{1}{2}$. This occurs when a coin is spun and allowed to fall upon some firm, flat surface, so that either a 'head' or a 'tail' must be shown on the exposed face. Here much of the sequence is supposed to be known; e.g. the stamping of the coin with the usual marks, its gravitational fall, and its coming to rest upon one face or the other. The unknown part of the sequence is the exact motion of the coin; it is assumed, however, that this will not be so similar in each spin as to bring the same face always uppermost, but that the variations may tend one way as often as the other. This assumption having been confirmed by much experience it follows that in a number of spins the frequency of 'heads' and 'tails' may be expected to be equal *on the average*; an expectation which is denoted by saying that the probabilities are as $\frac{1}{2}$ to $\frac{1}{2}$.

Another example of this kind of probability is the chance that the total number of pips shown in the throw of a pair of dice shall be 7; which works out as follows: Suppose the dice to be thrown separately and one of them to show that side uppermost which is marked with a single pip. When the other is thrown it may show any number from 1 to 6, but of these only one (the number 6) added to the 1 on the other of the pair of dice will give the total 7; the other 5 sides would give a different total. Hence the chances against this total are 5 out of 6 and the chances for it 1 out of 6; say, $\frac{5}{6}$ to $\frac{1}{6}$ against it.

The calculation is similar when the first of the pair shows any of the other 5 faces, so that of the 36 possible throws, only 6 give the total number of pips 7, while 30 give different totals. The chances against it are therefore $\frac{30}{36}$ to $\frac{6}{36}$, which, reduced to lowest terms, are again $\frac{5}{6}$ to $\frac{1}{6}$. Here, as before, most of the elements of the sequence are supposed to be known, and it is assumed that in a number of throws any one of the 6 faces may be uppermost as often as any other, on the average.

Again, since the faces of dice are marked from 1 to 6, it follows that the highest total which can be shown in any one throw of the pair is 12, and this can be done in only one way, namely, by a throw of 6 on each. The chances against this are therefore $\frac{35}{36}$ to $\frac{1}{36}$. Similarly the lowest throw, 2, can be got only by a throw of 1 on both dice, and the chances against this are also $\frac{35}{36}$ to $\frac{1}{36}$. For numbers intermediate between 12 and 7, or between 2 and 7, the ratios of the chances are intermediate between $\frac{35}{36}$ to $\frac{1}{36}$ and $\frac{30}{36}$ to $\frac{6}{36}$.

Probability then appears as a modified form of the expectation of recurrence when most, but not all, of the elements of a sequence are determinate, and when the sequence is found, by repeated trials, to vary within certain limits.

Expressed as a ratio, the probability of the occurrence of a particular variation of the sequence in a number of trials is the average number of its recurrences compared with the total number of trials. If a number of different variations be possible, then each will have its own ratio of probability, but there is usually one particular form which has a probability greater than any of the others.

Since the concrete sequences from which our knowledge is derived are not absolutely identical at each repetition, but include indeterminate elements which produce variation within limits, our ideas concerning them cannot be absolute; they must be adapted to the variation of the experiences. The only known way in which this can be done is by means of probabilities calculated from averages; the validity of this procedure, like that of other developments of knowledge, has been tested and proved by the success of the forecasts to which it leads.

For the ordinary purposes of knowledge it is sufficient to find which of the possible forms of a sequence has the highest probability, and to adopt this as the standard form, from which the others are deviations. In certain cases, however, it is desirable to find also the quantity by which it is probable that the average result may differ, one way or the other, from the best possible result; this is a calculable quantity, depending upon the amount of divergence between the observed sequences.

When knowledge is indefinite the need for taking averages may easily be overlooked, but it is seen to be imperative where precision is required; thus when it is stated that an unsupported body falls, this means no more than that it has some undefined acceleration towards the Earth; in which all observations seem to agree. But when the value of the acceleration at any place is to be determined, indirect methods must be employed and a probable approximation made by averaging the results obtained from the sequences observed. In the case of an actual body falling through the air, the acceleration would be influenced by unknown elements of resistance depending on the condition of the air and the dimensions of the body itself.

Since the verification of hypotheses depends upon comparisons between forecast and experience, all possible precision in both members of the comparison is a desideratum in science. It is sought first by devising sequences which will be affected as little as possible by unknown elements, then by careful and frequently repeated observation of these sequences, and lastly by estimates of the most probable result, calculated from the average of the observations.

In many branches of science a necessary condition for accurate observation is the correctness of the instruments used in measurement. Even this is not absolute, but is a careful approximation made from the average of a large number of experiences. Thus when the Prussian *toise* of about 76·735 inches was compared with the English standard yard, the operations extended over 25 days and involved 2340 micrometer readings and 520 thermometer readings; yet in the end there remained a 'probable error' in the determination of the length of the *toise*, such that this might be greater or less than the equivalent fixed, by a difference of 0·0000015 yard.

The smallness of the residual error shows an accuracy in the determination of a concrete quantity which could hardly be required for any but scientific purposes, yet it is denoted by no more than 7 places of decimals. Abstract relations, being independent of concrete measurement, can be calculated to any desired degree of accuracy; the relation between the circumference and the diameter of a circle has been worked out (uselessly) to more than 500 places of decimals from the properties of the ideal circle, but no concrete measurement of it could be made nearly as accurate as that of the relation of the *toise* to the yard. This will give some idea of the limits of accuracy in determining the values of concrete quantities.

In Astronomy, the oldest and most exact of the applied sciences, approximation by probability is the recognised procedure. The unknown quantities in astronomical sequences are mostly due to imperfections in the instruments, including clocks, used in observation. The irregularities have been reduced by the ingenuity of successive generations, yet cannot be entirely eliminated, though the greatest care is taken to watch and correct them.

Another unknown quantity is introduced owing to the necessity of combining the work of different observers. It appears that when stimuli are very nearly simultaneous the exact time of coincidence is differently judged by the different observers, and that men working with the same instruments show a systematic difference in their records of the times when a star passes the 'spider-lines' fixed in the telescope. Recourse must therefore be had to the method of averages; a mean value is found from the records of the several observers, and, when results are to be combined, some fraction of time is added to, or subtracted from, the records made by the individual observer, in order to reduce them to correspondence with this mean value. The fraction is called his 'personal equation.'

After all precautions have been taken, there still remain discrepancies between corresponding observations; the value of a quantity such as the position of a planet must therefore be determined as a probability by taking a mean of the observed values. This is done by the 'method of least squares,' which is based upon the proposition that if a number be divided into two parts and each of these be squared, the sum of the squares is least when the two parts are equal. Taking the number 10, for instance, we find $5 \times 5 + 5 \times 5 = 50$ is less than $9 \times 9 + 1 \times 1 = 82$; or, algebraically, starting with 2A we have $A^2 + A^2$ always less than $(A + X)^2 + (A - X)^2$. Hence if a value be found such that the sum of the squares of the differences between it and the observed values is the least possible, this will be the mean value required.

The nature of the problem to be solved can be illustrated by an imaginary example. Suppose that a mark were placed as a bull's-eye upon a target, a number of shots fired at it and the bull's-eye then removed, leaving the question of its probable position to be determined from the positions of the shot-marks. In calculating this it is assumed that the marks are not more likely to diverge on one side of the truth than on another. The result would be misleading if the shooting had been affected by something unknown which tended to divert all the shots in one particular direction; if, for instance, the same gun were used by all the marksmen, and this had an undiscovered defect. Such errors are called 'systematic'; to correct them it is necessary to vary the conditions under which observations are made and to compare the results.

Probability is, then, an aspect of knowledge in the exact sciences; it is still more prominent in their practical application. For instance, the stresses and strains on the different parts of a machine, or a fabric, are calculated by engineers from the theories of mechanics, and the strength of materials from the average results of careful tests; yet in the planning of a structure each part is usually designed to be from 3 to 6 times the strength indicated by calculation. This large margin is called 'the factor of safety,' and is introduced to allow for the probable occurrence of unknown elements beside those recognised as parts of the sequences on the recurrence of which the calculation was based. The theories of mechanical science are, nevertheless, most important to engineers as guides to action.

In sciences outside the domain of physics, probabilities can seldom be calculated numerically, but the theories are equally dependent upon data drawn from average experiences. Take the science of Economics for example. Here calculations are based on the hypothesis that under normal conditions business affairs will be carried on under the direction of men whose purpose is to make a satisfactory profit from them, and that those who, for any reason, fail to do so, will tend to lose control of capital and to drop out of business. This is equivalent to making economic forecasts in terms of an abstraction which leaves out of account individual deviations from the business average; it does not represent any one actual person, but is an artifice of calculation, like other abstractions, and is sometimes designated 'the economic man.'

Since this abstraction represents an average of those who must either make profits, or cease to control business affairs, it does not include public officials who, whether they be competent or incompetent, retain their posts so long as the routine of their department is duly performed.

The data of Economics cannot be obtained by experiment, since the phenomena are too widely spread to be within the control of students; for the most part also, their developments occupy such considerable periods of time that no one sequence is likely to be repeated many times during the life of a single observer. Hence data must be sought among the records of past history which, in respect to this subject, are neither copious nor entirely trustworthy. Moreover, economic sequences, being manifestations of human nature under one of its aspects, are more complex than the sequences met with in physical science, and the abstract 'Economic Man' leaves out of consideration many more elements, relevant though incalculable, than a physical abstraction such as the engineer's 'rigid body.' In spite of the difficulties, however, many valuable results have been formulated, and verified, from the average data of economic science; they afford guidance in the same way as mechanical theories guide engineers, but in practical applications economists should allow a large 'factor of safety' in view of the probable intrusion of so many unknown elements into the theoretical sequences.

As in the study of economics so in most other subjects, it is necessary to supplement personal experience from the accounts given by other observers, and to estimate the probability that these are accurate. In this connection the rules concerning evidence in courts of law are worthy of study; they are based on experience of human nature, and are intended to assist in extracting from the evidence the most probable story of what has taken place, guarding especially against perversions due to personal bias, whether these be unconscious or wilful.

When a statement is unsupported the weight given to it depends partly on its nature, but chiefly upon what is known about the source from which it comes, since this may indicate whether there be a likelihood of bias, carelessness, ignorance, or forgetfulness.

When there are several different accounts, not in complete agreement, the greatest probability attaches to those most nearly in accord; as in the case of shots on a target. The exception, when the agreement is due to derivation from a common source which may be untrustworthy, corresponds to the supposed case of shots from a single defective gun.

As to the probability of hypotheses, seeing that their validity cannot be accepted until they have been verified by repeated experience, they must evidently pass through a trial stage of great uncertainty, and then through stages of increasing probability, if they are in the end to rank as parts of systematic knowledge.

At what point in the process verification shall be considered adequate, depends on the frame of mind in which the question is approached; it varies for different people, and even for the same person at different times.

The estimates of probability are often deflected by prejudice, especially during the earlier stages of verification. Most men appear to find some difficulty in readjusting mental associations after these have once been established among their ideas; the effort required is displeasing, and resentment against the call to make it is apt to create an emotional bias against any novelty by which the association of ideas would be disturbed. Additional bias may be caused by men's natural reluctance to confess that they have allowed themselves to be misled, if the subject be one which has occupied their attention.

In consequence of this prejudice there is often strong opposition when it is proposed that some hypothesis, which had been generally accepted, should be superseded by another more completely satisfying the test of verification. Many to whom neither of the hypotheses are more than a mere form of words, are moved by sheer dislike of change; while those who have understood and acted upon the older hypothesis, feel as if its displacement deprived them of something which had seemed to give a solid foothold upon the external world. Thus both complete ignorance and imperfect knowledge are arrayed against the advance, and the further development of knowledge is retarded.

At one time the opposition was powerful enough to use physical force; Galileo was imprisoned for promulgating the hypothesis that the

Earth moves round the Sun. In later days it has been confined to abuse and ridicule, such as was showered upon Darwin.

Ignorant obstruction has little reference to rational considerations, but the opposition of intelligent men may have been due in part to the older view of knowledge, according to which it was supposed to give an exact account of changes going on in the external universe. On that theory the displacement of an accepted hypothesis by a new one was a serious matter, since it involved a denial that certain external changes really took place as they were believed to have done, and thus threw doubt on the reality of all the other processes of change in which people had believed upon similar grounds. There should not, I think, be the same feeling of disturbance when it is recognised that knowledge is a mental arrangement of experiences for which it is claimed only that it gives the best available forecasts of future experience, on the hypothesis that sequences approximately repeated in the past, will show similar recurrence hereafter. It surely need not be very distressing to admit that in the course of the development of knowledge, new mental associations may be formed, the forecasts from which will, on the average, show an agreement with further experience closer than those calculated by means of the previously accepted associations.

The conscious search for knowledge along the lines of a probability calculated from the average results of repeated observations, is a comparatively recent method of investigation and is not often followed except for scientific purposes. The primitive attitude is that of the child, who expects the continual recurrence of any sequence which has once or twice attracted his attention. Thus the reputation of a popular remedy may be established because some invalid has recovered health after using it; no inquiry being made as to how many invalids have used it without deriving any benefit. So, too, the experience of occasional success apparently leads the habitual frequenter of the roulette tables to expect continued gain, although the fixed advantage in favour of the 'table' gives it a probability of winning which approaches always nearer to certainty the oftener money is staked upon the game.

In public affairs, where guidance is to be sought from history, records are so imperfect and the importance of the unknown elements in every sequence so great, that it is impossible to rely upon inferences drawn from solitary examples;

yet, even here, on the analogy of averages, the approximate repetition of sequences resembling one another in their salient features will afford data from which forecasts may be derived having a very high degree of probability.

The ornamental side of history narrates picturesque episodes, and biographical details of the lives of prominent individuals which cannot be regarded as recurrent and do not therefore supply material for forecasting the future. History written for use would record great national movements; alterations in the distribution and the relations of different strata of the population; economic changes; those due to the development and application of knowledge, and similar subjects. Concerning none of these is it easy to get full information; they were not subjects which, in former days, engaged the attention of contemporary writers, and what we can learn about them must, for the most part, be gathered from accounts originally intended to serve some other purpose. In spite of the difficulties, however, much valuable guidance may be obtained from history by the skilful and unbiassed examination of probabilities.

CHAPTER V

LANGUAGE

All knowledge depends for its verification upon the success of the resulting forecasts; but no forecast can be made which does not rest on some hypothesis of the truth of memory and some expectation of the recurrence of remembered sequences; while few could be utilised without the further hypothesis of a material externality. Moreover, each individual has a great number of experiences which can be arranged in recurrent series only by means of the additional hypothesis that the external world contains organisms more or less closely resembling himself, not alone in form, but also in mental function. In earlier ages the hypothesis of mentality was applied very promiscuously; for instance, to such objects as the Sun and Moon. It has since been found that this hypothesis does not lead to satisfactory forecasts when applied otherwise than to nervous organisms; nor does it greatly help us in making forecasts unless the nervous functions of these organisms can be supposed to have a generic likeness to our own.

It is, indeed, generally supposed that, for other organisms as well as for ourselves, the response to stimulus has an internal, or subjective, aspect which, like our own consciousness, influences action; but what that internal aspect may be like in organisms differing much from mankind, we have no means of knowing. Many actions of insects are so unlike any conduct resulting from human nerve-reactions that they are classed apart as being 'instinctive.' For instance, certain insects make provision for the wants of a succeeding generation, although no one of their generations ever lives to see its successor; there seems to be nothing in human mentality to correspond with the feeling that prompts such action. Instinct is thought by some to be due to inherited memory, but this leaves it still outside the range of our mental experience, as we are not conscious in ourselves of any such inheritance.

When we come to species of birds and mammals whose nervous systems more nearly resemble our own, we find that although some of their conduct is still 'instinctive,' yet most of their actions are such as might be supposed to result from nervous reactions on lines similar to those of human beings; hence we have grounds for applying the analogy of our own mental experience in dealing with such actions.

All our forecasts of changes, whether organic or inorganic, are made on the supposition that what has occurred under certain conditions in the past will recur under similar conditions in the future. The man who supposes that the actions of others are determined by a mentality somewhat resembling his own, does not supersede the hypothesis of recurrence, but merely attempts to include in his calculations the internal or subjective factors along with the more obvious external circumstances.

In making this attempt each individual has to rely solely upon the recollection of his own subjective experiences; he may be able to understand different combinations of these experiences, but cannot possibly imagine the internal aspect of a nervous reaction in another organism unless he can remember some reaction of his own similar in kind if not alike in degree. This is obvious when applied to perceptions; one blind from birth cannot be supposed to know how the sensations of colour affect others; it must be equally cogent when applied to other subjective experiences, though this is sometimes overlooked.

Now, organisms of many different species, during some part at least of their lives, consort with others of their own kind in groups which can survive and prosper only by combined action on the part of their constituent members. It is possible that the requisite combination may, in some cases, be secured by a community of 'instinct,' which will on occasion lead all the members of the group to react in the appropriate way to a common stimulus; but for mankind and other organisms whose nervous systems are analogous, it seems necessary that some kind of communication by signal should be employed to facilitate co-operation. These signals are mostly made by sound; for example, a hen calls to her chickens by clucking, and has a special note to warn them of danger; the young chicks keep in touch with her and with one another by continual cheeping. Since human beings are, to an exceptional degree, dependent upon the co-operation of the individual members of the communities in which they dwell, they must have felt the need of sound-signals at a very early stage of their history, and such signals, when developed into a code, would be the natural foundation upon which the different communities might build up languages to meet the growing complexity of their several needs.

Whether language is to be used for the purpose of facilitating simple physical co-operation, or to enable an individual to indicate to others more complex associations of ideas, it is necessary to prepare the way by some convention about words, directly or indirectly, preconcerted between the speaker and the hearer, since the relation between sounds and the ideas they are to represent is not intrinsic, but depends upon common usage among those who speak the language. Before any such convention can be arranged, both minds must have entertained the ideas denoted by the separate words, since no one could agree that a particular sound should symbolise for him a particular idea without knowing what that idea was; thus the only possible order of procedure is first to acquire the idea through experience, and afterwards to be instructed in the convention by which a certain word is assigned to that idea as its symbol.

Consider how a normal child does learn this convention. Before it knows anything about words it has abundant experience of visual and tactile sensations, and these, which under one aspect are perceptions, are not deprived of their other aspect, that of ideas, merely because the ideas are not yet associated with verbal symbols.

I take it to be a sign that ideation is present among the functions of an infant's nerves when it learns that the slightly different sensations from its two eyes can be referred to the same objective, and accordingly begins to converge the two visual axes. The signs are quite definite when the child has begun to associate a group of visual sensations with the existence of a tangible object, and to estimate its distance, so that he learns to lay his hand upon toys, and ceases to reach out for the moon. In acquiring such fundamental ideas the child has to rely upon his own experience without help from others, but he could not acquire the knowledge of the appropriate symbols for his ideas unless he were taught by those around him.

The method of teaching is by pointing out concrete objects, together with such of their properties and changes as are easily perceptible, and naming them when they are affecting the senses of both teacher and learner. The stimuli are so much alike for both of them that there need be no confusion about the application of the names, although they may have more associations for the mind of the teacher than for the child. Thus, for the latter, the sounds 'dad' and 'mam' symbolise the ideas of definite objects without connoting any relation between them. When the symbols for a number of familiar ideas have been taught in this way, they can be employed to suggest the combinations and arrangements of which the ideas are capable. A language developed to this stage would probably suffice for purposes of physical co-operation; but human thought reaches out beyond these limits, and it is in the attempt to adapt language to symbolise more elaborate ideation that its difficulties become prominent.

One of the first requisites of wider thought is the use of abstraction, that is to say, the isolation by mental analysis, of some aspect common to a number of diverse experiences. But such abstraction is a subjective function of the individual; another person having similar experiences might not perceive that they did present any common aspect. The abstraction cannot be pointed out in physical isolation, and when a name has been assigned to it, there seems to be no way of defining the meaning of the word except by indicating the class of experiences in which the particular aspect may be found. Even if this be supplemented by a reference to experiences from which the aspect is conspicuously absent, the definition will often fail to convey to others a correct idea of the signification of the symbol.

The method, being rather cumbrous, is apt to be either carelessly used, or altogether neglected, so that people are, for the most part, left to pick up the meaning of abstract terms haphazard, and consequently the same word may be used with extremely different meanings by different people, and by some without any definite meaning at all. Animadverting on this imperfection of language when used for anything beyond ordinary speech, Locke wrote:

It is true, common use (that is, the rule of propriety) may be supposed here to afford some aid to settle the signification of language; and it cannot be denied that in some measure it does. Common use regulates the meaning of words pretty well for common conversation, but nobody having an authority to establish the precise signification of words, nor determine to what ideas anyone shall annex them, common use is not sufficient to adjust them to philosophical discourses; there being scarce any name of any very complex idea (to say nothing of others) which in common use has not a great latitude, and which, keeping within the bounds of propriety, may not be made the sign of far different ideas. Besides, the rule and measure of propriety itself being nowhere established, it is often matter of dispute whether this or that way of using a word be propriety of speech or no.

(*Essay concerning Human Understanding*, Book III., Chap. II., par. 2.)

Words then, in so far as they are not mere sounds but symbols of ideas, must be related to the experience of the speaker; and they will not be understood in the sense in which they are uttered unless the ideas denoted by the separate words have already been framed by the hearer as a result of his own experience.

The communicative function of language is that which enables the speaker to suggest to others mental associations formed by him from the combination and arrangement of these ideas. It has been found, however, that when a man puts his mental associations into language carefully adapted to convey the suggestion to others, he is using the best method of defining the associations clearly to himself. Words serve as counters to aid the calculation of more generalised results, much in the same way as figures, or the beads on an abacus, aid arithmetical calculations. The arrangements and re-arrangements of ideas which constitute our mental deliberations are practically all made by the help of verbal symbols, and this reflexive function of language has become as indispensable as the communicative function.

When words are used in this way there is not the same possibility of misunderstanding as there is when they are used for the purpose of communication, but mental confusion is often caused by the ambiguity of words, especially of abstract terms whose meanings have been left indeterminate; one meaning being substituted for another during the course of a single, continuous train of reasoning. This invalidates the conclusion as completely as the substitution of one digit for another would falsify an arithmetical result.

Another cause of trouble is that words denoting relationship have the same form as other substantives. Those who use language without much reference to its foundation in experience, are apt to be misled by the form, and to regard the relationship, not simply as a link between the things related, but as something having an existence independent of them. In certain cases the state of knowledge makes this unavoidable; for example, *Weight*, which is a relation between different masses of matter, was in past times naturally regarded as a property inherent in any single mass. More commonly, however, there is a deliberate ignoring of the known elements of the relationship; thus the ancient Greeks gravely discussed *Beauty* as though it were a property of particular objects, or even existed independently; whereas it can be known by experience only as a relation between an object and its admirer. Again, it has been found by the experience of untold generations that human communities benefit by the maintenance of certain relations among their members, and a rather indefinite group of these beneficial relations has been distinguished by the name *Justice*; one constantly hears the word used as though it were the name of an independent entity; both the community and its members, the elements of the relationship, being totally disregarded. Lastly, a group of the reactions of some nervous organisms to stimulus has been denominated *Mind*; this also is commonly spoken of as an entity, separate both from stimulus and from nervous reaction, although it is known by experience only in relation to these processes.

Words which cannot be ultimately referred to experience are a hindrance rather than a help to knowledge; they are misleading because they purport to be symbols, yet have nothing behind them for the symbols to represent. In this respect a verbal symbol is comparable with a monetary cheque, which may be passed from hand to hand on the faith that it represents money, but is worthless if, in the end, there be no funds to meet it on demand. The corresponding test for a word is that there should be behind it the sterling coin of experience, capable of being produced when required.

Language has, so far, been discussed only as an aid to co-operation, or as a vehicle for communicating associations of ideas in the vernacular of any one community; for although the words are put to other uses, these do not belong to the present subject. There is, however, a whole department of knowledge concerned with the various languages which are, or have been, spoken by different communities, and this must be considered in its relation to other kinds of knowledge.

When a man wishes to have free intercourse with the members of a community which does not speak his mother-tongue, he must learn their language in addition to his own. Such knowledge is indispensable for many commercial purposes, and might sometimes be useful in scientific research, when the works of foreign investigators have not been made available in translations. But there is a prevalent opinion that, besides its possible utility, the learning of more than one language has a unique value as a means of mental development. This does not seem to be borne out by experience, for certain small populations learn, and habitually speak, two languages, one for domestic use, the other for communication with the outer world; there is no reason to think that their minds are, on this account, more highly developed than those of their neighbours who speak only the latter language.

Those who advocate the study of foreign languages for reasons other than their commercial utility mainly argue:

1st, that it puts the learner in touch with the best thoughts which have been expressed in the language learnt; 2nd, that the learning of the sound of so many unfamiliar words strengthens the memory; and 3rd, that the steady concentration demanded for the performance of a task which must, at first, be uninteresting and apparently profitless to the learner is a valuable mental gymnastic.

But, 1st, it is a rare accomplishment to become so immersed in a foreign language as to be able to think in it, and until he has attained this the student can do no more than translate the foreign thought into words of his own language. If a translation were required, a single expert could make it better than ordinary students could do it for themselves, and by such a version they would be put in closer touch with the substance of the thought, than by acquaintance with the language, unless they became themselves experts.

2nd. The notion of strengthening 'the memory' in general, is a mistake in psychology, for memory is not one and indivisible; a verbal memory is not found to have any connection with a memory for other things, such as visual impressions. The verbal memory is chiefly useful as a help in passing examinations.

3rd. It is a still greater mistake to suppose that work in which no interest is taken for its own sake is the best exercise for the mental powers; it would be as reasonable to fancy that the treadmill is the best exercise for the body. Such mental exercise would be better than none at all, but in these days when so many branches of knowledge are available for study, there are plenty of alternatives, and among them it should be possible to find one or more which would arouse interest in a normal mind and at the same time exercise the mental functions in a wider sense and in a more natural manner than the learning of a language. As a mental training the latter has the disadvantage that, by reason of its arbitrary character, it gives little scope for the use of hypothesis and verification, so essential to the growth of other knowledge. Indeed the only linguistic study to which it appears to be applicable is the philological comparison of allied languages.

A plea sometimes urged in favour of linguistics is that some who had this training, subsequently showed themselves men of ability. This is futile as an argument since, during many generations, no other system of mental training was practised, and if it is to be credited with the ability of one student, it should equally be debited with the stupidity of others. There is no conclusion to be deduced from the premises except that the system is not invariably fatal to all mental power.

CHAPTER VI

REMARKS

Knowledge and the External World

It seems to be generally presumed that scientific knowledge must either make us acquainted with the actual conditions of the external world, or, failing this, can have no appreciable value; according to the theory here propounded this would not necessarily follow. If knowledge be the outcome of functions which have been developed in nervous organisms through their need to foresee the consequences of voluntary action, then the nature of its relation to the external world will not affect its value to the organism, provided that this need be satisfied.

Now there are no sufficient grounds for denying (or proving) that modern science may be able to trace natural processes through the actual stages by which they occur; but it must be remembered that, in past times, valuable forecasts have been drawn from hypotheses which are not in accordance with modern ideas.

A calendar of great use for practical purposes was constructed on the basis of pre-Copernican astronomy. Moreover, some parts of our present scientific knowledge could not have been obtained otherwise than by development from hypotheses which formed the science of an earlier period, but are now found to be inadequate. Kepler and his immediate successors thought that the planets moved in ellipses about the Sun; Newton's theory of gravitation would have been impossible in the absence of this approximation, which still plays a part in astronomical calculations, although it does not correspond accurately with observation.

It appears, then, to be possible for an hypothesis, even if it should not correspond with any natural process, to have, nevertheless, both practical and theoretical value. Such a possibility may be illustrated by a parable. Suppose a sheet of paper to be marked with dots belonging to a great number of superposed patterns whose original connecting lines have disappeared. A succession of these dots is found to lie approximately along some curve of a kind whose form is calculable, and when this curve is produced, the succession of dots along it is found to recur in regular series. The calculated curve may not correspond with any of the original connecting lines; indeed, the dots along it need not have all belonged to the same pattern; yet if the patterns were recurrent, dots belonging to them might continue, indefinitely, to lie along that curve. Now if the dots be taken to represent experiences, the curve will represent an hypothesis of recurrence, the series of dots first noticed will represent the observations upon which the hypothesis was based, and the series of dots lying along the produced curve will represent the observations by which the hypothesis was verified. The object being to forecast the positions where dots would be found, the curve is of use solely because it is calculable. There is nothing to indicate its relation to lines in any of the original patterns, nor need such relationship concern those whose only object is attained when their forecasts of position are successful.

Knowledge and Emotion

An investigation of emotion in general is beyond the scope of our subject, but something must be said concerning the relation between knowledge and those emotional responses of the organism which instigate action, namely, desire and its converse. Acts are not considered to be voluntary unless the reactions of which they are the outcome include some emotional factor of this kind.

Voluntary acts are hardly ever performed for their own sake; they are almost always looked on as parts of a series, and performed with a view to the consequences expected from the series. But emotion, in itself, gives no indication of the nature or consequences of any series; infants evidently have desires, but have no notion of any action by which these may be satisfied. Before a definite course can be pursued for the satisfaction of a desire, a forecast must be framed concerning the result of some series that can be set in motion by voluntary action. The development of knowledge has been a continual endeavour to bring such forecasts into more uniform correspondence with experience.

We may take, as an imaginary sequence of organic changes, first, a stimulus producing a reaction whose emotional factor urges toward something desirable in the future; next, the use of knowledge to guide the discharge of nervous energy along tracks in the brain whereby a forecast is made that certain actions will initiate a series of external changes leading to the desired result; and, lastly, a discharge of energy along the motor nerves determining the contraction of the muscles by which the calculated action is produced.

In experience, however, the relation between emotion and action is more complex. Emotion and knowledge must be concurrent throughout the conscious reaction, since no definite emotion of desire would be felt without a co-existing knowledge of something to be desired: thus, if voluntary action is to result from a nervous disturbance, the factor represented by knowledge must affect the form under which the emotional factor emerges into consciousness, beside controlling the method by which it is to be satisfied. Apparently, therefore, the emotional and intellectual factors of a reaction are not really separable, but are different aspects of a single response of the organism, although considered separately for convenience of mental analysis.

In so far as the emotional factor of a reaction is distinguishable from the intellectual factor its nature is massive and undifferentiated; hence it would have a place among the functions of the thalamus rather than among those of the cortex.

When the emotional side of a reaction is greatly predominant it sometimes impels to action before the consequences of the resulting series of external changes have been sufficiently calculated; and the action performed, though guided to a certain extent by knowledge, is not so well adapted to its purpose as it would have been after greater deliberation.

Emotional reactions, like other discharges of nervous energy, are subject in some degree to voluntary control when they emerge into consciousness.

It should be noted that emotion does not always impel toward immediate action; when very violent, it may overpower and suppress the other nervous functions: thus we hear of people who are dumb with astonishment, blind with rage, or paralysed with fear.

Knowledge and Education

Seeing that knowledge is the guide of action, and that the aim of education is preparation for the work of life, one of its main functions should be the training of the learner in the method of acquiring and testing knowledge for himself. The range of modern knowledge is very wide and is continually being extended; no one can have experience in every department, but for most men there is some special subject with which they come into practical contact. In such a subject it is well to learn all that can be gathered from symbols as arranged by others, but each man should be trained to test the symbolic knowledge by comparing it with his own experience, and to make corrections and extensions as occasion serves. In subjects with which his occupations do not bring him into practical touch, a man is largely dependent upon experts, but even so he may have opportunities for testing the dicta of those who are reputed to be experts. Education should help him to note such opportunities and familiarise him with the method of utilising them.

In the first place it is necessary that the nature of proof (i.e. verification) should be thoroughly understood. No progress will be made so long as the erroneous idea is entertained that a proposition can be proved by words. Verbal symbols are useful in recalling experiences and in suggesting relationships among them, but it is the experiences, not the words, which constitute the proof.

In questions of evidence the ostensible grounds of proof may be words alone; but in such cases it is the value of the evidence which is all-important, and this is what must be subjected to the tests of experience.

Education is very far from complete unless it include the explanation of the nature of such tests, together with some practice in their application.

The Acquisition of Knowledge

In respect to the motive for the acquisition of knowledge it may be thought that to dwell upon the close connection persisting between knowledge and the original need for forecasting the consequences of action is to take a base utilitarian view, and that knowledge ought now to be regarded as an object to be pursued for its own sake, or in other words, for the sake of the emotional satisfaction accompanying the pursuit. The kind of pleasure often found therein is not, however, peculiar to the search for knowledge, but is associated with the free exercise of many other faculties. Healthy animals enjoy using their limbs; poets and musicians delight in the production of their compositions; and artists follow art for art's sake. Moreover, although emotional satisfaction has been an incentive to the search for knowledge and has thus aided progress, it is not an essential element in the acquisition of knowledge, which may sometimes be learnt by painful experience. Verification, on the other hand, is essential, and thought can hardly take on the character of knowledge until it has been tested by being applied, in some way or other, to the guidance of action.

SUMMARY

Chapter I. Origins. Page 1

Knowing is a nervous function, not peculiar to mankind; its elementary stages may be observed among animals, and its presence in various degrees among human beings is the result of development from the animal function. This development is due to the need of forecasting the consequences of voluntary action, and the more varied the possibilities of action, the greater is the need to foresee its outcome.

It is found that before knowledge can be used to satisfy this need there must be a supposition that memory is, to some extent, a record of past sensation, and an expectation that sequences of sensation will repeat themselves in the order in which they are remembered. Another supposition which appears to be equally necessary is that experiences refer to something beyond themselves, which may be called the external world.

The expectation that sequences will repeat themselves is found to be misleading when it is applied indiscriminately; hence in the development of knowledge the problem arose, how to distinguish between the recurrent and the non-recurrent.

In the case of abstract mental series there is no difficulty; they may be regarded as invariably recurrent because all the conditions affecting them can be predetermined. What is required is a way of distinguishing among sequences from which none of the elements of actual experience are excluded arbitrarily. This has been, to a certain extent, effected by the method of systematic knowledge, which is as follows:

Each newly observed sequence is compared with some process already familiar; the experiences of the known process are arranged mentally in an ideal series; forecasts are made that, if the new sequence should follow the analogy of this ideal series both in the portion of its course already observed and in its further progress, then such and such consequences would follow; and, lastly, these forecasts are compared with experience.

This last operation is usually the most difficult; it is known as Verification; its methodical employment is the distinguishing feature of modern science.

Chapter II. Physiology. Page 25

Organisms have two kinds of nerves, which may be called Sensory and Motor respectively. An organism responds to stimulation of the sensory nerves by reactions which affect the central nervous system and, through it, the motor nerves.

Some of these reactions are reflex, some are subconscious; but a certain number reach the brain and thus evoke consciousness. The massive feelings of well-being, or the reverse, result from discharges of nervous energy which reach the deep-seated optic-thalamus; the discriminative senses, from discharges which reach the convolutions of the outer cortex of the brain. The latter is therefore the organ most concerned in all that is usually included under the head of knowledge.

The path of a discharge of nervous energy is determined by the difference of the resistances encountered in different directions. Our experience that a reminiscent disturbance follows the pathway of previous disturbance, indicates that a discharge of energy along any path leaves a track whose resistance to subsequent discharge is diminished.

The impression from an isolated stimulus never reaches consciousness uncombined, but is always associated with groups of impressions from other simultaneous stimuli and from memories of past experiences. I can only suppose that this results from some intercommunication between the nerve-paths by which these separate elements of the reaction reach the centres of consciousness.

When nervous discharges reach consciousness, we are able to pay attention to particular groups of disturbances, either primary or reminiscent, and thus to give them predominance over disturbances belonging to any different group, which might otherwise compete with, or even suppress them. Evidently, therefore, the centres of consciousness exercise a limited amount of control over the resistances along the pathways of the sensory nerves; their control over the resistance of certain motor nerves is what distinguishes voluntary from reflex action.

Chapter III. Abstractions. Page 33

An abstraction is essentially a human production; it is obtained by considering some special aspect in which certain experiences resemble one another, as mentally isolated from the aspects in which they differ. The utility of an abstraction greatly depends upon its having a name, a symbol which can be employed as a counter in calculation. The drawback to the use of abstractions lies in the risk that the counter may not always represent one constant value, but may have different meanings for different people, or even for the same person at different times.

It is a common mistake to suppose that an abstraction is more real than the experiences from which it is derived. An abstract idea may certainly be shared by others, and may be mentally retained as a memory; whereas an experience is the fleeting reaction of a single individual; but the idea can be shared only by those who have recognised it as exemplified in their own experience, while the mere permanence of an idea does not give it reality; a memory is not more real than that which is remembered. Moreover the use of the same abstract term by different people by no means always ensures the identity of the idea denoted thereby.

Certain abstract terms employed in physics refer to very familiar aspects of experience and are taken in the same sense wherever they are used scientifically.

Those most important for our present purpose are Energy and Causation. The term Energy denotes the amount of Work which would be expected to result from certain changes in a material system. It has two forms, Kinetic and Potential. The kinetic energy of a mass is half the square of its velocity, and can therefore be found whenever the velocity is measurable; but the potential energy in a system is known only by forecasts based on experience of the course of previous changes in similar systems. The sum of the kinetic and potential energies in any self-contained system is constant in amount, whatever changes of form it may undergo.

Causation is an abstract term connoting the process of the transformation of energy. Every process has two correlative aspects—the change out of a state previous to the transformation of energy, and the change into a state succeeding the transformation. These are spoken of as Cause and Effect respectively. The transformation itself is what supplies the mental connection between the two states, which are often very different in appearance.

The terms Cause and Effect are applied also, in a somewhat modified sense, to the earlier and later changes of a series wherein each successive change is initiated by energy liberated in the previous change.

Since the value of abstractions consists chiefly in their utility as counters in calculation, they should take the meanings which will best adapt them for this purpose. From time to time it has been found convenient to alter the meanings of many abstract terms, and those employed in physics have not been exempt from change.

Chapter IV. Probability. Page 52

If it be taken for granted that when all the relevant conditions of a sequence are repeated the sequence itself will recur, then some abstract propositions may be regarded as absolutely certain, since every variation from their conditions is excluded by the terms of their enunciation. But since we cannot exclude every unknown factor which might possibly affect the conditions of the sequences met with in concrete experience, it follows that all forecasts respecting them are subject to probability.

Now the probability of the result of a sequence can be estimated only as an average calculated from a comparison of a number of experiences, a basis which implies that the main elements of the series are already known. Hence probability is not opposed to knowledge, but is the form which knowledge takes when its data are incomplete.

Averages of experience are utilised in various ways; sometimes to forecast the number of occurrences of a particular event in proportion to the number of times that event would be possible; sometimes to determine the most likely value of a quantity from several observations whose results are not in exact agreement; and sometimes to reconstruct the most probable story of past events from a variety of discrepant accounts.

The probable validity of hypotheses must be tested by the process of verification already described; it requires time, but pending complete verification, every hypothesis should be examined without prejudice; it should neither be prematurely accepted, nor hastily rejected merely on the ground of novelty.

In many subjects it is very difficult to collect the data from which to obtain the averages needful for calculating probability. Sociology is a notable instance, and here the data are of the utmost importance, since through them alone can we discover a trustworthy guide of conduct affecting the community.

Chapter V. Language. Page 69

Birds and mammals, when living in communities of their own species, use sound-signals to help them to act together for various purposes. It seems probable that primitive man used a similar set of signals and that language was gradually developed from this in response to the growing complexity of human needs.

In its present development language not only serves to assist co-operation, but enables any one member of a community to indicate to others the order and connection of his ideas. This cannot be done, however, without some convention, preconcerted between the speaker and his audience, concerning the meaning of words; a condition which is more or less adequately fulfilled when the children of a community learn to speak their mother-tongue.

The connection between a concrete idea and its verbal symbol is easily taught, but it is more difficult to arrange that an abstract term should have the same meaning whenever it is used. Evidently an abstraction cannot be pointed out in physical isolation; apparently all that can be done is to point out the class of experiences which show the particular aspect denoted by the abstract term. This, again, will serve its purpose only for those who have had similar experiences and can see that they do present a common aspect.

In the end, therefore, we find that an abstract term will not convey a definite meaning except to one who is already prepared to form the idea as a result of his own experience. Although this is conspicuous in the more difficult case of abstractions, yet it is, in fact, equally true of concrete terms, for the meaning of any word depends upon the common agreement that it shall denote a particular idea, and no one can join in such an agreement until he knows the nature of the idea concerning which it is made.

Words are employed, not only for communication with others, but also as counters to help us in the arrangement of our own ideas. When thus used, there is no danger of a term being misunderstood, but there are still ways in which words may prove misleading. For instance, it often happens that some unnoticed change is made in the meaning of an abstract term during the course of a calculation, and that the result is thereby vitiated. And again, many are misled into supposing that a mere relationship has an existence independent of the things related, simply because the relationship is called by an independent name.

During many generations great stress was laid upon the learning of foreign languages, which was regarded as the best, if not the only, form of education. Such studies may sometimes have a commercial value, but are defective as a mental training because of their arbitrary character. This affords little scope for the practice of hypothesis and verification, which is the only method of enlarging the knowledge requisite for the guidance of conduct.

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Knowledge and the External World

It is possible that scientific knowledge may, in some cases, trace the connection between changes in the external world through the very stages by which they come to pass, but there is no proof of this, and knowledge has, in times past, led to useful forecasts in cases where it is now known that the calculations followed mental, not physical, lines of connection.

Knowledge and Emotion

These seem to be inextricably blended in the reactions of the nervous organism, but, in so far as they are ideally separable, it is knowledge, not emotion, which affords guidance in action. Strong emotion sometimes has a paralysing effect on other nervous functions.

Knowledge and Education

If education is to be a preparation for the work of life, it should train the learner in the method of acquiring and testing knowledge for himself. The training will fail in this respect unless it brings the learner to realise that no proposition can be proved by words, that experience alone constitutes proof, and that words are helpful only as counters for recalling and arranging experiences.

The Acquisition of Knowledge

It was from the advantage gained by forecasting the consequences of action that the development of the faculty of acquiring knowledge first originated. Its exercise, like that of many other faculties, often affords high emotional satisfaction; but this, though an incentive to the activity of the function, is not a necessary concomitant of its performance. The one thing needful is verification, since hypothesis does not take on the character of knowledge till it has been verified by means of successful forecasts.

The measure of the value of knowledge is not the satisfaction given by its acquisition, but the service it can render in the guidance of action.

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