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Lecture Two

OBJECTIVITY

In the Ptolemaic system and in the cosmogony of the Bible man was assigned a central position in the universe from which he was ousted by Copernicus. Ever since, writers eager to drive the lesson home, have urged us resolutely to abandon all lingering claims of our anthropocentrism and to see ourselves objectively in the true perspective of time and space. However, in a full "main feature" film recapitulating in two hours the history of the universe, the rise of human beings from the first beginnings of man to the achievements of the twentieth century, would be covered by a single second. In fact it would seem that any attempt really to see ourselves objectively as parts of the universe would result in a lifelong preoccupation with interstellar dust, relieved only at brief intervals by a survey of incandescent masses of hydrogen. Not in a thousand million lifetimes would the turn come for giving even a second's notice to man.

If such are the requirements of objectivity then the objective picture of the universe is totally misleading. Nor should this surprise us. For we human beings must inevitably see the universe from a centre lying within ourselves and speak about it in terms of a human language shaped by the exigencies of human intercourse, so that any attempt rigorously to eliminate our human evaluation from our picture of the world must lead to absurdity. In what follows I shall try to acknowledge the claims of objectivity in a manner which takes into account these essential limitiations of objectivity.

What is the true lesson of the Copernican revolution? Why did Copernicus exchange his actual terrestial station for an imaginary solar ~~stand~~point of view. The only justification for this lay at his time in the greater intellectual pleasure derived from the celestial panorama as seen from the sun instead of the earth.

Copernicus gave preference to man's theoretic delight at the price of rejecting the evidence of our senses which present us with the irresistible fact of the sun, the moon and the stars rising daily in the east to travel across the sky towards their setting in the west. In a literal sense therefore the new Copernican system was as anthropocentric as the old Ptolemeic view, the difference was merely that it preferred to satisfy a different human affection.

But it becomes legitimate to regard the Copernican system as more objective than the Ptolmeic if we accept this very shift in the nature of intellectual satisfaction as the criterion of greater objectivity. This would imply that of two forms of knowledge we should consider as more objective that which relies to a greater measure on theory instead of on more immediate sensory evidence. So that the theory being placed like a screen between our senses and the things of which our senses otherwise would gain more immediate impressions, we would increasingly rely on theoretical guidance for the interpretation of our experience, and correspondingly reduce the status of our raw impressions to that of dubious or altogether misleading appearances.

It seems to me that we have sound reasons for thus considering theoretical knowledge as more objective than immediate experience. A theory is something else than myself. It may be set out on paper as a system of rules and it is the more truly a theory the more completely it can be put down in such terms. Mathematical theory reaches the highest perfection in this respect. But even a geographical map fully embodies in itself a set of strict rules for finding one's way through a region of otherwise uncharted experience. Indeed all theory may be regarded as a kind of map extended over space and time. It seems obvious that a map can be correct or mistaken so that to the extent to which I relied on my map I shall attribute any mistakes that I made in consequence of doing this, to my map. A theory on which I rely is therefore objective knowledge in so far as it is not I but the theory which is proved right or wrong when I use such knowledge.

And there are other aspects of the situation to support this claim. I can smell onions, have a headache or feel humiliated: all these are states of consciousness; but my theory cannot be in any of these states; it exists like a stick or a stone without any consciousness. Hence a theory cannot be lead astray by illusions. To find my way by a map I must perform the conscious act of map-reading and may be deluded in the process, but the map cannot be deluded and remains right or wrong in itself in an entirely impersonal manner. Consequently, a theory on which I rely as part of my knowledge is a part of it that remains unaffected by any fluctuations occurring within myself. It has a rigid formal structure on the operation of which I can rely whatever mood may trouble or desire obsess me; just as my living flesh can ever rely for its varied activities on the same stony shafts hinged rigidly together to form the structure of my skeleton.

Since the formal affirmations of a theory are unaffected by changes in the persons accepting it, theories may be constructed without regard to our normal approach to experience. Here is a third reason why the Copernican system being more theoretical than the Ptolemaic is also more objective. As its picture of the solar system disregards our terrestial location it may claim equal interest to the inhabitants of Mars, Venus, or Neptune, and will likewise commend itself to them, provided that they share our intellectual pleasures.

Actually, when we claim greater objectivity for the Copernican theory we do imply that our appreciation of its excellence is not a matter of personal taste on our part but an inherent quality of it deserving universal acceptance. We abandon the cruder anthropocentrism of our senses in favour of a more ambitious anthropocentrism of our reason. In doing so we claim the capacity to formulate ideas which command respect in their own right and have in this sense an objective standing.

Here then are the true characteristics of objectivity as exemplified by the Copernican theory. And we see that it does not demand that we estimate man's significance in the universe by the minute size of our body and by the brevity of our past history or our probable future career. It does not require that we see ourselves as a mere grain of sand in a million Saharas but inspires us on the contrary with the hope of overcoming the appalling disabilities of our bodily existence, even to the point of conceiving a rational idea of the universe which can authoritatively speak for itself. It is not a counsel of self-effacement but on the contrary a call to the Pygmalion in the mind of man.

In this sense the objectivity of classical mechanics constitutes an intensification of the creativity of the intellect and to this extent of the personal element in knowledge. While by the same token, the increasing achievement of objectivity in modern science has alienated man from the sensuous experience of the universe and impaired his personal communion with nature.

But this process has not been uniformly maintained. It is true that ancient science was contemplative and personal; while modern science is predictive and impersonal; but if we trace the development of classical mechanics through to relativity, we shall find the contrast less marked. The increasingly mathematical character of contemporary science has strangely renewed our communion with nature. Let me tell you the story of this development as I see it.

Pythagorean theory was an extension of the contemplation of nature: it studied the perfection of the heavens as an aid to a mystic communion with the universe. Its contemplation of celestial harmonies was a manifestly personal act, full of wonder and awe. The astronomical theory of antiquity remained for centuries following Pythagoras a form of contemplative appreciation, and even the renewal of astronomic theory by Copernicus and Kepler continued the Pythagorean quest for harmonious numbers and geometrical excellence. In the volume containing the first statement of his third law, Kepler speculates intensely on the way the sun, which is the centre of the cosmos and therefore somehow *nous* itself, apprehends the celestial music performed by the planets: "of what sort of vision is in the sun, what are its eyes, or what other impulse it has... even without eyes... for judging the harmonies of the (celestial) motions", it would be, he says "for those inhabiting the earth, not easy to conjecture" - yet one may dream at least "lulled by the changing harmony of the band of planets",.. that "in the sun there dwells an intellect simple, intellectual fire or mind, whatever it may be, the fountain of all harmony" (Harmonies of the world, Bk.V. Ch. X). Galileo prepares the transition to a dynamic in which numbers enter for the first time as measured quantities into mathematical formulae. But with him this yet applies only to terrestial events, while in respect to heavenly motion he still holds the Pythagorean view that the book of nature is written in geometrical characters. In the "Dialogue concerning the Two Great Systems of the World" (1632), he argues from the principle that the parts of the world are perfectly ordered. "Ma noi supponghiamo quelle esser perfettamente ordinate") *Opere*, Florence, 1942, Vol. I, p. 24). From this assumption he concludes that the motion of the heavenly bodies - in fact "natural" motion as such - must be circular. Rectilinear motion implies change of place, and this can occur only from disorder to order: in the transition from primeval chaos to the right disposition of the parts of the world. (p. 24-5). Such an order once given, all bodies are "naturally" at rest or in circular motion. Uniform rectilinear motion, on which Galileo himself founded modern dynamics, appears thus only in the interstices of a Pythagorean universe: "I conclude therefore," he writes, "that only circular motion can naturally belong to the natural bodies composing the universe and disposed in the best arrangement; and rectilinear (motion), as far as we can say, is assigned by nature to its bodies and their parts whenever they are situated in places far from those proper to them, in an incorrect arrangement, and therefore in need of returning as quickly as possible to their natural state". (p. 38).

In the generation following Galileo, the method of experimentation which he used only for the demonstration of his theories became the supreme instrument of discovery. Thus proper experimental research was started, which considerably widened the possibilities of testing a theory and gave rise for the first time to the mutual interaction between theory and experiment which Boyle recognised at an early stage and Newton formulated definitely in his Optics. After this we see gradually emerging the modern conception of theory as an instrument of description or prediction rather than an insight into the nature of things. Contemplation and sensuous experience never became altogether extinguished in science but exact scientific knowledge was henceforth cast prevalently in the dual form of mathematical theory referring to numbers obtained by measurement. Science became wedded to a mechanical conception of the universe interpreted in terms of classical dynamics.

The discovery of relativity has ~~been~~ in an important sense brought the supreme fulfilment for this vision. This perspective has been convincingly outlined by Max Born in the Introduction to his book on relativity. "The further we go back in the history of the sciences, the more we find the natural picture of the world determined by the qualities of ~~the~~ sense. Older physics was subdivided into mechanics, acoustics, optics and theory of heat. We see the connexions with the organs of sense, the perceptions of motion, impressions of sound, light, and heat. Here the qualities of the subject are still decisive for the formation of conceptions. The development of the exact science leads along a definite path from this state to a goal which, even if far from being attained, yet lies clearly exposed before us: it is that of creating a picture of nature which, confined within no limits of possible preception or intuition, represents a pure structure of conception, conceived for the purpose of depicting the totality of all experiences uniformly and without inconsistencies." (Max Born, Einstein's Theory of Relativity, London: Methuen, 1924, p.2). And, after describing what modern science has already achieved in this direction he sums up by saying, "Inaudible tones, invisible light, imperceptible heat, these constitute the world of physics, cold and dead to him who wishes to experience living Nature, to grasp its relationships as a harmony to marvel at her greatness in reverential awe." (Ibid p. 3).

Yet science, we are told, must persist in eliminating from itself every vestige of personal experience. And Einstein is credited with achieving another decisive step in this process by discarding from science the difference between rest and motion. Many animals see objects only when in motion and every figure perceived by man is seen against a background that is regarded as at rest. Newton's postulate, of "absolute space" which "in virtue of its nature and with reference to any external object whatsoever, always remains inscrutable and immovable", is the scientific formulation of this experience which Einstein eliminates by constructing a world in which you cannot possibly distinguish either between being at rest or in uniform rectilinear motion or whether you are at rest in a gravitational field or are being propelled in an accelerated motion outside such a field. Impossibility to distinguish is regarded as equivalent to identity: the differences in question are supposed not to exist. The first of these postulated invariances implies the laws of special relativity, the second those of general relativity. They supply us with new conceptions of space and time claiming scientific objectivity.

I would concede this claim but only in the sense that Einstein discovered a rational, and therefore objective, conception of nature; a vision aiming once more at the Pythagorean ideal of contemplating the intrinsic rationality of the universe. I hope to make the meaning of this statement clear by the following evidence which supports it.

Everybody knows that relativity was discovered on the grounds of the Michelson Morley experiment . And everybody is wrong. The programme of the theory of relativity was first formulated by Ernst Mach in his "Die Mechanik in ihrer Entwickelung" (1883) on the grounds that two conditions which were not distinguishable within the framework of mechanics should be regarded as indistinguishable in every other respect, that is, identical. The property of space of being at rest without reference to any external object, which Newton assumed as self-evident and Kant explicitly stated to be a necessary condition of experience was condemned by Mach as nonsensical on the grounds of its unverifiability. Newtonian absolute time was subjected to a similar critique.

Einstein has paid tribute to the "profound influence" which this book exercised on him as a student (Albert Einstein, Philos~~o~~opher-Scientist, Evanston, Library of Living

Philosophers, 1949, p. 21.). He acknowledges in his own account of the genesis of the special theory of relativity the important part played by Mach's critique. The insight essential to the formulation of the special theory resulted, he says, "after ten year's reflection.. from a paradox upon which I had already hit at the age of sixteen: If I pursue a beam of light with the velocity c (velocity of light in a vacuum), I should observe such a beam of light as a spatially oscillatory electromagnetic field at rest. However, there seems to be no such thing, whether on the basis of experience or according to Maxwell's equations. From the very beginning it appeared to me intuitively clear that, judged from the standpoint of such an observer, everything would have to happen according to the same laws as for an observer who relative to the earth, was at rest. For how, otherwise, should the first observer know, i.e. be able to determine that he is in a state of fast uniform motion?"

"One sees that in this paradox the germ of the special relativity theory is already contained. Today everyone knows, of course, that all attempts to clarify this paradox satisfactorily were condemned to failure as long as the axiom of the absolute character of time, viz. of simultaneity, unrecognisedly was anchored to the unconscious. Clearly to recognise this axiom and its arbitrary character really implies already the solution of the problem. The type of critical reasoning which was required for the discovery of this central point was decisively furthered, in my case, especially by the reading of David Hume's and Ernst Mach's philosophical writings". (ibid., p. 53).

It is clear from this account that relativity was essentially a response to Mach's scepticism, rather than to the observations of Michelson and Morley. The usual textbook account of relativity as an answer to the riddle presented by the Michelson-Morley experiment is historically false, or at any rate seriously distorted.

Even today relativity cannot be considered as a necessary response to the Michelson-Morley experiment, except on the grounds that we believe it to be rational. The Lorentz-transformations which fully accounted for the constancy of the observed velocity of light could otherwise be recognised as a new fundemental natural law, in the same manner as today we accept the Pauli principle as a natural law that is wholly extraneous to quantummechanics. The fact is that once relativity has been grasped it seems almost impossible to think again in different terms. The overwhelming presumption which had developed in its favour as early as 1923 was illustrated by the refusal of physicists to pay serious attention to Miller's repetition of the Michelson-Morley experiment which claimed to have observed a considerable "ether-drift" where Michelson and Morley had denied its existence. This was the first time that the experiment had been repeated since its original performance in 1887 and in view of the progress in technique that had been made in the past 36 years its result should have carried overwhelming weight against that previously obtained. But Miller's announcement of his results to a meeting of the American Physical Society had no such effect on his audience. By this time scientists had fairly closed their minds to any suggestion which threatened the new rationality achieved by Einstein's world-picture. They told Milner to go home and get his results right.

At this early stage relativity had yet made few predictions that could be definitely confirmed by experiment. It's empirical support lay so far mainly in a number of already known observations. The new account which it gave of these known phenomena was considered as rational since it derived them from one single convincingly rational principle. It was the same as when Newton's comprehensive account of Kepler's three laws, of the moon's period and of terrestial gravitation in the unified terms of universal gravitation exalted this law to a position of surpassing authority, even before any predictions had been deduced from it. It is thus that Max Born, despite the strong empirical emphasis of his account of science was moved as early as 1920 to salute "the grandeur, the boldness, and the directness of the thoughts involved" in relativity. (op. cit. p. 289).

Since then the passing years have brought precise confirmation of at least one formula of relativity over a wide range of new observations. The reduction of mass (m) by the loss of energy (e) accompanying nuclear transformation has been repeatedly shown to confirm the now famous formula $e = mc^2$ where c is the velocity of light. Such confirmations of relativity are also confirmations of the right judgment of those who had hailed it at its first advent. And it is an even more remarkable justification of earlier strivings for a more rational foundation of mechanics setting out a programme for relativity at a time when no opening could yet be seen towards this objective.

A scientific theory can be said to have grandeur and power only if it is believed to be true in fact. In science these words of praise can be applied only to a valid conception. Astrology surpasses natural science in the comprehensiveness of its pattern in which the fate of men is interwoven with the course of the stars. For centuries past its teachings have fascinated the imagination and the belief of highly intelligent people, even such as Kepler. But as I do not believe in astrology I appreciate it only as a myth and cannot ascribe to it such beauty and power as I do to relativity, ~~since~~ for the sentiments expressed in such praise are integral to my affirmation of relativity as an objective truth. Accordingly, I do not regard these sentiments merely as my feelings but claim them to be objectively appropriate. They represent the personal component of my submission to the rationality of an idea.

The beauty and power inherent in the rationality of contemporary physics is, as I have suggested already, of a novel kind. When classical physics first superseded the Pythagorean tradition, mathematical theory was reduced to an instrument for computing mechanical events which were supposed to underlie all natural phenomena. Geometry also stood outside nature, claiming to offer an a priori analysis of the three-dimensional space which was the scene of all natural phenomena, but not involved in them. In the first place, both relativity and quantum-mechanics have moved back towards a mathematical conception of reality. Essential features of the theory of relativity were anticipated as mathematical problems by Riemann in his development of non-Euclidean geometry; while the further elaboration of relativity relied on the powers of the hitherto purely speculative tensor calculus of Ricci and Levi-Civita. Similarly, Max Born found the matrix calculus ready to hand for the development of Heisenberg's quantummechanics, which could otherwise never have reached concrete conclusions. These examples could be greatly multiplied. By them modern physics has demonstrated the power of the human mind to discover and exhibit rationality of the kind which governs nature, before ever approaching the field of experience in which the harmonies of a mathematically anticipated rationality ~~are~~ may eventually be revealed as empirical facts.

Relativity has in fact gone further and restored up to a point the blend of geometry and physics which Pythagorean thought had rather naively taken for granted. We now realise that Euclidean geometry, which until the advent of general relativity was taken to represent experience correctly, referred only to comparatively superficial aspects of physical reality. It gave an idealisation of the metric relations in rigid bodies and elaborated these exhaustively, while ignoring entirely the masses of the bodies and the forces acting on them. The opportunity to expand geometry so as to include the laws of dynamics was offered by its generalisation into many dimensional and into non-Euclidean space by the previous work of pure mathematicians. The first step was taken by Minkowski in 1908 by presenting a geometry which expressed the special theory of relativity and included of course classical dynamics as a limiting case. The laws of dynamics now appeared as geometrical theorems of a four dimensional non-Euclidean space. Subsequent investigations by Einstein led to the general theory of relativity by a further generalisation of this type of geometry, its postulates being so chosen as to produce invariant expressions in terms of any frames of reference assumed to be physically equivalent. As a result of these postulates the trajectories of masses follow geodetics, and light is propagated along zero lines. When the laws of dynamics thus appear as particular instances of geometrical theorems we may infer that the confidence placed in them owes much to the same distinctive attributes from which pure geometry and pure mathematics in general derive their interest and for the sake of which they are cultivated.

We cannot ever truly account for our acceptance of such theories without acknowledging their peculiar intellectual excellence and especially their beauty and profundity. Attempts to replace these personal terms by valuations of a more objective kind cannot go far without committing what I should call the fallacy of pseudo substitution. It is legitimate, for example, to regard simplicity as a mark of rationality, in support of which we might quote many great scientists who have paid tribute to a theory as a triumph of simplicity. But great theories are rarely simple in the ordinary use of the term; both quantummechanics and relativity are very difficult to understand and are in this sense by no means simple. It takes only a few minutes to memorise the facts accounted for by relativity, but years of study may not suffice to master the theory and see these facts in its context. H. Weyl lets out the cat from the bag by saying: "the required simplicity is not necessarily the obvious one but we must let nature train us to recognise the true inner simplicity". (H. Weyl, Philosophy of Mathematics and Natural Science, Princeton, 1949, p. 155). In other words, simplicity can be made equivalent to rationality only if it is used in this special sense, but we then understand the meaning of the term 'simple' only be recalling the meaning of the term 'rational' or 'reasonable' or 'such that we ought to assent to it' which the term 'simple' is supposed to replace. This is the kind of disguise, presenting our true personal beliefs in philosophically more respectable neutralised terms, which I would call a pseudo substitution.

What has been said of simplicity applies equally to symmetry, economy and generality. They are contributing elements in the excellence of a theory, but can fully account for its merit only if the meaning of these terms is stretched far beyond their usual scope so as to include the much deeper qualities which make the scientist's heart go out to a vision like that presented by relativity; namely its qualities of beauty, and its profundity, and its power of revealing, more deeply and permanently than sense experience, an objective truth.

We have even more glaring instances of pseudo-substitution in the positivistic analysis of scientific theory to which Ernst Mach first (quoted by Weyl, p. 157) gave currency, when describing scientific theories as mere hypotheses whose essential function it is to stimulate new experiments which will broaden our experience.. "The seafarer in whose imagination the objects thrown up by the ocean upon the beach create a vivid picture of the distant land, sets out to find that land. Whether his search will succeed or not, whether in place of the expected Indian or Chinese coast he discovers a new one, at any rate his experience has been widened". (Mach, Erkenntnis und Irrtum, p.231) Surely, if that were all, the seafarer could as well have started at random. A theory can be said to have been truly fertile only to the extent to which its pursuit has proved it to be true, at least in the sense of having set a reasonable and important question. Indeed, if it is said that relativity was significant to the extent to which it lead to new experiments which widened our knowledge, this would be grossly misleading - but for the fact that we would only intend this analysis as a pseudo-substitution. In other words, after having described scientific theory in terms which deprive it of all its essential values, we would proceed to interpret our neutralised definition as expressing our unaltered knowledge of these values:- while retaining the advantage of a superior critical point of view, in comparison with those who frankly uphold these values.

Let me repeat then, returning once more to my principal subject, that objectivity can be said to be achieved in mathematical physics only to the extent to which the speaker claims the capacity to discover the rationality in nature. But there are further important aspects of the objectivity of a theory which arise from the fact that a theory is an external object, which can be exemplified by a map.

If we regard a physical theory as a space-time map, of its subject we may say that every use of the theory requires first, that we find our place on the map and second, that we find our way on the map from this place to some other place. The first process may be called generally a reading which would include measurement, the second is a process of inference from the theory. Readings or measurements are the residue of sensory experience left within the operations of a mathematical theory. They reduce the personal element to ~~such~~ a minimum at which it is no longer thought to impair objectivity. Theoretical inferences of a routine character may be carried out impersonally, by the mere operation of a machine automatically governed by the readings. We may think here of the predictors used for the aiming of guns at a swiftly moving target; once you have made your readings the machine proceeds to compute and carry out for you a future event; namely to hit the target.

Processes of reading and inference in which the personal element is reduced to a minimum may be expected to proceed unchanged, irrespective of who is performing them. They may therefore be readily accepted as valid by a wide community and this sharing of impersonal knowledge adds a new aspect to its objective character.

A wholly personal act of knowing something that is an act of connoisseurship, may be repeated and checked in various ways of which I shall say more in later chapters. But it certainly lacks the same opportunities for critical examination which can be applied to a process of inference operating impersonally. Take for example the adding up of a column of figures. If you simply keep repeating the process you may make the same mistake over again, but you can avoid this almost certainly by varying the sequence of the figures in the column. Formal processes of inference are thus open to systematic scrutiny and this adds further to a great extent to their status of objective validity.

The process by which classical physics achieves objectivity has its parallels over wide ranges of everyday life. The most comprehensive development of this kind is observed in the maturation of children. Parrallel instances to this are found by the comparison between primitive and modern mentality, as well as of mental abnormality and mental health, as cases contrasting lesser and greater objectivity.

Objectivity is achieved here without the construction and use of a formal theory, but lies instead in the application of a conceptual framework. The relation of a conceptual framework to a formal theory can be understood by the following example. A geograhpical map is a formal theory of all possible itineraries that can be read off from it. A conceptual equivalent to a map is supplied by a glance from a hill top. By such an inspection we can take in a comprehensive picture of a region which will serve us as a guide in travelling through it. It provides us with a conceptual map in terms of which we can identify the landmarks we are encountering and by which our imagination can devise ever new itineraries for us to follow.

A visual survey forms its own characteristic theory of a region by picking out certain features as landmarks, but this theory is an <u>informal theory</u> for it is not embodied in any object or machinery like a map or a calculus. Consequently, it is not possible to examine and ascertain the indications of a conceptual map in the same way as we can do for a map printed on paper and to this important extent conceptual theories lack objectivity compared with theories set out on paper. But they do function similarly as fixed frameworks by which experience is currently identified and inferences are drawn for the future. Also, like a formalized framework, its informal counterpart acts as a screen which splits across the contemplative state in which the contemplator is merged with the object of his contemplation. Our sense of being persons examining and handling objects arises commonly when we devise a conceptual framework by which we handle and examine things, while these things acquire thereby the character of external objects. In saying this I have particularly in mind conceptual frameworks which do not refer to other persons as persons nor apprehend objects in any intensely personal manner. This excludes for the moment such conceptual systems as moral codes or the conceptions guiding our innate appetites. These form as it were less impermeable screens which do not divide me so sharply from the things under my notice. I shall return to these more permeable frameworks in my next lecture.

As an example of a conceptual framework which emerges during normal maturation, we may take the kind of inarticulate geometry which an infant may be assumed to construct when he begins to recognise objects as having constant sizes and shapes and learns to handle them accordingly. Piaget has studied in detail the gradual establishment of these concepts involving the progressive elimination of the child's personal point of view in his way of seeing and accounting for his surroundings. We may take as an illustration Piaget's experiment with three figures A, B, C, (say a doll, an elephant and a teddy-bear) horizontally mounted in a row along a stick, which are pushed behind a screen. When this array is pushed into a tunnel and then pulled out again, the younger child will invariably expect that figure to reappear first which had disappeared last, but gradually he will learn to expect the reverse if the array is pulled out at the other end of the tunnel, opposite to that into which it was pushed. The elementary geometrical theory which the child has learned to use here detaches the array A, B, C from its personal relation to the child and places it into an impersonal relation to the tunnel, which the child has now learnt to operate outside itself. We have the elimination of a self centred relation in favour of an objective conception.

This process prefigures the progressive objectivation of the scientific framework of which I have spoken earlier. Take the typical error which children commit for example when they compare the length of two sticks A and B shown parallel to each other at different distances. The child always tends to overestimate the size of the stick used as standard of reference. To children at this stage $A > B$ is not equivalent to $B < A$. The tendency to grant absolute status to our standards of reference is eliminated in this case by normal maturation; while we have seen that further stages of the same process are achieved by great scientific discoveries like that of the Copernican system or that of general relativity.

Piaget describes this trend towards objectivity as the achievement of 'reversible' modes of thinking. We will understand this term by recalling the operations of a formalised theory. A routine calculus or the use of a map can be run backwards and forwards in a purely mechanical manner. The conceptual framework of the child approaches "reversibility" when its handling becomes similar to that of such a calculus or map.

Other psychologists (see Katz on orientation, Animals and Men, p. 130 ff.: also Gestaltpsychologie, on Körperschema, p.72) have described the manner in which we normally retain our sense of being in a definite position in relation to our surroundings. If we look at a wall in front of us and then shut our eyes and turn round so that we turn our back on the wall, we cannot imagine it being still in front of us, because we carry with us constantly a definite scheme of our position in space. Russell Brain has described a patient in whom this function was disturbed: "She found her way back to her own bed, but on two occasions when halted some yards from her bed and asked to point to it with eyes closed she pointed to a bed on the right of it." (W. R. Brain, Brain, 1941, vol. 64, p. 249).

Psychologists have noted and each of us can confirm it up to a point from his own experience, that the conceptual framework by which we keep track of our orientation in space acts as a screen which separates us from the things around us.

Katz describes the effect of the sudden dissolution of this screen (on waking up in a strange room, "finding that we have no sense of left and right .. of position of head and feet"): "We feel lost: it is like a sudden dissolution of the feeling of personality." (Animals and Men, p. 134). Most of us remember how it felt when as children we rolled down a slope and completely lost our orientation for a few seconds. The normal distinction between ourselves and the things around us seemed to dissolve during such moments. They had the dreamlike quality of a visionary flash in which our selfhood was merged in the panorama around us.

We must recognise, therefore, in the development of our everyday manipulation of experience, the growth of mechanisms very like the impersonal framework of classical mechanics. The maturation of our habits of perception resembles a series of Copernican revolutions in which we have won wider perspectives through greater detachment. We have learned to see more, but only by erecting barriers between ourselves and the things seen. This last statement suggests, moreover, that in the life of the individual as in the history of science, objectifying mechanisms evolve at the expense of a more intimate and often more delicately skilful contact with things.

Piaget has described how the child's progress towards formalised thinking is regularly accompanied by an initial loss of intellectual skill. A problem which the child could already solve effortlessly on an inarticulate level requires renewed concentration and may prove too difficult at first when transposed into articulate terms. For example, the child had difficulty, when told that a given colour is both darker than one and lighter than a third, in discovering which of the three is lightest. These difficulties show very clearly on the verbal plane between the years of 7 and 11, whereas on the plane of action they have ceased to exist. (Piaget, Judgment and Reasoning in the Child, p. 214).

It has been found that English children can learn to read more quickly and acquire a better knowledge of spelling if they are not given at first any inkling of the alphabet. The difficulty of putting together letters to represent the sound of a word is avoided and each word is learned as a whole. The additional burden to memory is outbalanced by avoiding the task of analysing words in terms of phonemes and representing phonemes, or groups of phonemes, by letters, while allowing for the ambiguities of this representation in English spelling. When we have doubt about the spelling of a word we revert even in adult life to the test of writing down the word to see whether it looks right. Though the use of the alphabet is much more efficient than ideographic writing, yet the transposition of words into letters gives rise also to the kind of intellectual losses which accompany all processes of formalisation.

Or, to turn back to spatial orientation, a similar loss may be noted if we compare the richness of this complex mechanism in primitive and civilized people. Tom Hopkinson reported recently of the Lapps: ("The Listener", January 3 1952, "Land of Reindeer and Bears", p. 27) they "have a sense of direction through their trackless forests, and over their hundreds of miles of winding lakes, which so-called civilised man has lost. If they had not this, they could never have survived. The forest is featureless: the range of vision seldom more than a few hundred yars. There are no villages in our sense of the word, only scattered huts. For weeks on end total darkness reigns, with perhaps even the stars obscured. Yet the Lapp finds his way without map or compass, and he does not do it by thinking or working it all out by calculation. He simply knows. Such knowledge is entirely inarticulate. Von Middendorf in 1873 reported his experience among the Samoyeds: "I tried to question them about their gift and pressed them whenever I had the chance; but they looked at me abashed and wondered at my astonishment, and told me that such everyday things went without saying; indeed, they could not understand our inability to find our bearings." (quoted in Katz, Animals and Men, p. 130, from A. von Middendorf, Sibirische Reise, 1873-4). This sense of direction which primitive people exhibit has been lost in modern man, living in settled communities connected by fixed paths and roads. By means of signs, maps and compasses we have acquired a more flexible range of localization, but our immediate sense of place has been seriously impaired.

Bergson has revealed this destructive principle in its most elementary form, by showing that any transposition of the flux of consciousness into conceptual terms necessarily disrupts its original continuity and suppresses by the imposition of stereotypes the unique experiences of creative duration. We may regard this perhaps as the primordial step in that progressive depersonalization of knowledge manifested in the successive stages of classical physics, and culminating in the discovery of relativity. We shall see, however, that there are systems other than classical physics which greatly amplify, rather than reduce the variety and vividness of our personal experience.