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Commitment to Science

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You may well find the conclusions of my first two lectures distressing. If there is one thing in which all philosophers have agreed, all the way from Plato via Descartes to Gilbert Ryle, it is, that if we make a statement of fact we should know exactly what we mean and be able to tell on what grounds we affirm it. Now, in my first lecture I concluded that, not only can we not possibly know exactly what a statement of ours means, but that an attempt to make quite sure that we know it, would deprive the statement from a bearing on reality and hence from having any meaning at all. To be meaningful, a statement must be substantially indeterminate. The second lecture was equally disappointing about the possibility of telling exactly on what grounds we make any statement, even a simple statement of fact. For we are always relying for our observation of things to which we are attending on our awareness of many things to which we are not attending, some of them subliminal, and in any case, largely unidentifiable. And this shortcoming too appeared to be incorrigible. For I gave you examples suggesting that an attempt to remedy this condition radically might render us helpless, as a person would be, who would insist on using explicit directions for finding his way about when wearing inverting spectacles, or as the rider of a bicycle would be, who would insist on explicitly solving the equation for finding the curvature of the path which will compensate his momentary imbalance at his present velocity. We must know the elements on which we rely in these

cases, and the operations by which we integrate them, internally. We must rely on them in the way we rely on parts of our body for making sense of the world--namely by dwelling in them.

It is true that I did not discourage you from making statements which, by bearing on reality, were bound to anticipate inexhaustible implications, nor from tacitly interiorising clues which would reveal coherences in nature about which such statements could be made. On the contrary, I said that this manner of finding the truth was not only intrinsic to the use of our senses, but, far beyond that, was the very path to discovery in science.

But such a strange recommendation must at least be argued systematically, from first principles.

Let us examine the ideal of the exact sciences and see whether we could not return to this. The ideal of the exact sciences is a mathematical theory of the universe. Such a theory would, no doubt, be vastly elaborate, but it would yet have one very simple property. It could be wholly represented in one plane. All its data, however numerous, all its formulae, however complex, could be written on one single immense blackboard. But remember the structure of tacit knowing; how we tacitly attend <u>from</u> a set of particulars <u>to</u> their joint meaning, a meaning which tends always to be displaced further away, beyond its particulars--which is of course why we described such particulars as the proximal term and their meaning as the distal term of tacit knowing. These two terms are aligned radially outwards and along this line the knower enters and participates in that which he knows. But the ideal of a comprehensive mathematical theory of the world requires that all such tacit knowledge should be completely formalised, so that we could focus on each of the

data in question and explicitly relate them to each other. The radially aligned terms would have all to be flattened out into the plane of the giant blackboard.

Is this theoretically possible? We must answer that all meaning is established by understanding; and that to understand is to integrate particulars into a significant entity, which can be achieved only by interiorising the particulars with a bearing on their joint meaning. Thus a theory becomes meaningful only if you interiorise it and get to see things in its terms. The theory cannot interpret itself and bring itself to bear on the facts of experience: it can tell us something about experience only if we have brought it to bear on experience. This act always requires some degree of personal judgment and may require the highest scientific ability. Moreover, a theory can explain only something that is already known, though yet unexplained. The mathematical theory of a frog can explain the life of frogs only if frogs are non-theoretically known beforehand.

This is true of any theory of things in nature. These things must be identifiable without the theory, and the theory of these things can function as such only for a person who can identify these things and bring the theory to bear on them. If the theory applies to a class of things, the person must have a true conception of the class and be capable of subsuming a specimen under this conception. He will have to possess also a true understanding of the theory including the skill, trained by practice, for applying it. None of this knowledge and this skill is present in the theory, which can therefore only function by virtue of a framework of knowledge and skill that is external to it.

The declared ideal of exact scientific knowledge, aiming at a strictly detached explicit theory of nature, proves logically untenable. I have said this already when drawing the distinction between explicit content of a physical theory and its anticipatory powers which appeal to our imagination. I entered a caveat to warn you that the difference was only a matter of degree. For no mathematical formula means anything except as understood by him who applies it, and such an act of understanding and applying is necessarily informal. You will find this confirmed in the foundations of mathematics as understood at present. The far flung enterprise of David Hilbert undertaken at the beginning of this century, to establish mathematics as a set of purely formal operations, has failed. There is in mathematics a knowledge that cannot be made explicit; every time a formal deductive system is brought to bear on an interpretation of it, we evoke some of this tacit knowledge contained in mathematics. It is evoked by attending <u>from</u> the formulae of mathematics <u>to</u> something else that the formulae mean, or may mean.

This is a process of tacit knowing which as such is continuous with the way we know our body by living in it. It is a process of interiorisation. We have seen cases before where explicit rules of inference were useless, unless interiorised. Right seeing through inverting spectacles which could not be arrived at by applying explicit rules, was achieved by a process which tacitly applied these rules. The cyclist too, successfully used rules tacitly, which were useless when applied explicitly. But we have yet to see the actual process by which a formal system can be interiorised. It is

worth looking at an example of such a process. Take a manual for driving a motorcar and learn it by heart. Assuming that you have never seen a motorcar, you will have to identify it and its parts from the illustrations of the manual. You can then sit down at the wheel and try to carry out the operations prescribed by the text. Thus you will start learning to drive and eventually establish the bearing of the manual on all the objects it indicates and the skills it teaches.

We can observe here in detail the process of intelligent interiorisation by which an explicit directive is assimilated and made to function as a guide to a skilful performance. It is shifted to the back of the driver's mind, so that he can attend from it to the road in front of him. If the traffic were slowed down a thousandfold, one could perhaps drive a motorcar by referring at each move to a manual, but one can guide split second decisions only by tacitly relying on it. Psychologists have observed that the number of objects to which we can explicitly attend at one time can hardly be more than ten. We see once more, what I have already mentioned for the case of perceiving an object by integrating its sensory clues, that the richness and speed of tacit integration exceeds by far the powers of explicit adjustment carried out at the focus of attention.

But again, we must realise that the difference between using a manual explicitly, which would be impracticable, and using it properly as interiorised at the back of our minds, is a matter of degree: it is a difference between different depths of interiorisation. No rule or conception, however explicitly applied, can have

any sense or use, except by functioning as an extension of our eyes and ears and muscles.

Here is a point which brings to the lips of philosophers the name of Kant. He was the first to declare that external experience is possible only by our participation in the act of knowing. But the participation Kant postulated as the necessary condition of experience is very different from that which I am envisaging. It was thought to take place according to strict conceptual categories, which are necessarily fixed and leave neither need for intelligent effort nor scope for personal judgment. Hence Kantian legislation for experience is both infallible and impersonal, the knowing self is the recipient of knowledge over which he has no control. This is quite different from the process of tacit knowing by which we establish a coherence of clues jointly bearing on a comprehensive entity and anticipate the inexhaustible manifestations of its reality. It is quite different from the process of interiorisation by which we achieve the capacity for attending from an interiorised theory to the experience on which we are bringing it to bear. These participations of ours, which acquire dramatic force in the creative acts of the mind, are neither automatic nor infallible. They are hazardous operations developed by training, the aptitude for which varies from what is native to all men, to such as possessed only by genius.

But to see this difference, is to recognise why Kant could not possibly accept the views I am putting forward here. The author of the Critique of Pure Reason had come to rescue scientific reason from the blight cast upon it by Hume's scepticism and 'to gain for

ourselves' (as he wrote) 'a possession which can never again be contested.' He could not have accepted my recommendation for relying on our awareness of largely unidentifiable clues, for establishing an undefinably harmonious coherence, fraught with unlimited and perhaps unthinkable implications. It is, in fact, not a position which readily commends itself to the scientific mind of our culture.

Yet, had Kant only looked at his finger through a peep hole in a sheet of paper and moved the finger about, he would have seen that the transformation of raw sense impressions, which he called Anschauung, into the experience of an object, is a matter of degree, depending on the range of clues offered to our eyes. And perhaps he would have recognised then that the object itself, of which we thus get a glimpse, is not a mere unknowable residue, a Ding an Sich, shorn of all its sensuous qualities, but something substantial, pointing beyond itself to its inexhaustible implications.

For in spite of being strictly resolved on firmly establishing the legitimate powers of reason, Kant here and there admitted incidentally, that into all acts of judgment there enters, and must enter, a personal decision which cannot be accounted for by any rules. Kant says that no rules can ever determine exhaustively the operations of intelligence, for no system of rules can prescribe the procedure by which the rules themselves are to be applied. Of this ultimate agency which, unfettered by any explicit rules, decides on the subsumption of a particular instance under a general concept, Kant says only that it 'is what constitutes our so-called mother-wit'. Indeed, at another point he declares the faculty neces-

sary for the exercise of such judgment to be quite inscrutable. He says that the way our intelligence forms and applies the schema of a class of particulars 'is a skill so deeply hidden in the human soul that we shall hardly guess the secret trick that Nature here employs'. We are told, in effect, that every time we speak of dogs, trees or tables in general, or else identify something as a dog, a tree or a table, we are performing a secret trick which is not likely ever to be revealed to our understanding.

The formation of concepts and the subsumption of appropriate instances under a concept is in fact essentially a function of tacit knowing. Since every member of an empirical set of objects differs from the other in every particular, the subsumption of such objects under one title cannot be justified by any strictly formalised procedure, and the way in which it is nonetheless reliably carried out has long been a problem of philosophy. The solution lies in recognising the powers of tacit knowing to present us with the joint meaning of an aggregate of disparate particulars.

This resolves the ancient problem, what a man is like to whom the concept of 'man' applies. How can he be both fair and dark, both young and old, brown, black and yellow at the same time? Or if he is neither of these, how can he be a man without any of the properties of a man? The answer is that in speaking of man in general we are not attending to any particular man, but are relying on our tacit awareness of individual men, for attending to their joint meaning. This meaning is a comprehensive entity. Its knowledge is wiped out by attending to its particulars in themselves and hence the concept of man cannot be identified with any mere aggregate men, past or future.

A class of natural objects, like dogs or men, is real, for the things that hang together in terms of such a class, may be expected to hang together also in other altogether inexhaustible ways. This fact has always been clear, but it mistakenly appeared inexplicable, because it could not be accounted for by any explicit mental operations. Kant rightly regarded, therefore, its understanding to lie beyond the powers of his system.

Modern philosophers regard conceptions, as nominalists have done since Abelard, as mere collections of objects designated by a common name and they would overcome the difficulty that such a name would designate an indefinite variety of disparate objects, by ascribing an 'open texture' to the conception going by such a name. But this begs the question, how a designation can be applied with such openness as is required for covering all the disparate members of a natural class and yet be able reliably to exclude others that are not its members. The conception of natural classes cannot be understood without acknowledging the powers of tacit knowing.

For centuries past the systematic thinking of modern man has been based almost invariably on the assumption that a process of inference must be explicit. But there have been important thinkers, since the last eighty years or so, who have anticipated parts of the position I am trying to establish here and to me their work seems clearly to point in the direction which I am following here.

About the turn of the last century, German thinkers postulated that indwelling is the proper means of knowing man and the humanities. Dilthey taught that the mind of a person can be understood

only by reliving its workings and Lipps represented aesthetic appreciations as our entering into a work of art and thus dwelling in the mind of its creator. Dilthey and Lipps were right in saying that such knowledge can be achieved only by indwelling. But my analysis of tacit knowing shows that they were mistaken in affirming that this fact sharply distinguishes the humanities from the natural sciences. There is a continuous transition from indwelling in science, to the fuller participation of the knower in the study of literature and history.

My conception of indwelling is more deeply affiliated to existentialism and to Husserl's phenomenology. I am aiming, as Husserl did, at rescuing the reality of an essentially hierarchic universe from being flattened out by a Laplacean analysis of the world. But I shall not try to unfold the true structure of things, as Husserl tried, by excluding the question of their reality. Husserl takes over from Brentano the intentionality of knowledge and enters thereby into lived experience. For him, intentionality creates the conditions for the objectivity of such experience. He thought, until the last part of his life, that, by excluding its bearing on reality, the analysis of such lived structures becomes unerring, transcendental. But when this dream dissolved, as he confessed, such structural analysis was reduced to subjectivity. I shall show how my theory of knowledge tries, on the contrary, to discipline intentionality by its bearing on reality.

Husserl has proved so far the most influential thinker of the twentieth century. As it became clear that knowledge of lived experience, which he was seeking, was knowledge possessed by indwell-

ing, it transpired that it was a knowledge of being. So we arrive at Heidegger and French existentialism.

From the theory of tacit knowing we can derive the being-in-the-World, the Dasein of man, as defined by Heidegger. For every meaningful thought and action of ours interiorises particulars for the purpose of attending to their joint significance, and thus we populate the known world with comprehensive entities the elements of which function logically as parts of ourselves. Our being extends then over the range of our understanding. We have here Heidegger's Field of Being (as William Barrett has called it) and we discover its logical theory: which is that every act of comprehension shapes jointly our existence and our knowledge.

Once interiorisation is accepted as intrinsic to knowing, an analysis of knowledge will keep bringing up various aspects of existence, and such observations will confirm the results of existentialist philosophy. But they will go beyond existentialism by revealing the logical structure of the observed existential commitments.

Yet the existential elements of human knowledge have a different quality from the existential elements of human destiny. Man's life and fate evoke a more intense and immediate interest than does man's knowledge of things. This may partly account for the difference between the perspectives into which being is fitted by the two enquiries. Heidegger brings out man's being-in-the-world by confronting him with death which cancels his projects. To me, man's striving for truer being and knowledge appears justified within a cosmic process of organic evolution leading on to responsi-

ble manhood in a society of explorers.

Yet a fundamental problem of existentialism, as formulated by Sartre, will be with us all the time. Throughout this enquiry I shall seek to answer the question on what grounds we can possibly justify a choice of existence.

This puzzling query will be seen to be linked to the problem of discovery. For discovery presents us with a kindred paradox, which has long been neglected. We shall approach it by asking ourselves once more: what is a problem?

It is a commonplace that all research must start from a problem. But how can one see a problem? For to see a problem is to see something that is hidden. It is to have an intimation of the coherence of hitherto not comprehended particulars. To see a problem that will lead to a great discovery is not only to anticipate something hidden, but to see something of which the rest of humanity cannot have an inkling. All this is commonplace; we take it for granted, without noticing the clash of self-contradiction entailed in it. Yet Plato has pointed out this contradiction in the Meno. He says that to search for the solution of a problem is an absurdity; for either you know what you are looking for, and then there is no problem; or you do not know what you are looking for, and then you are not looking for anything and cannot expect to find anything.

The solution which Plato offered for this paradox was that all discovery is a remembering of past lives. This explanation has hardly ever been accepted, but neither has any other solution been offered for avoiding the contradiction. So we are faced with the fact that for two thousand years and more, humanity has progressed

by the efforts of people solving difficult problems, while all the time it could be shown that to do this was either meaningless or impossible. For the Meno is essentially right. It points to the fact that so long as we think of knowledge as having a determinate content, the conception of a problem is self-contradictory and the achievement of discovery is incomprehensible. For discovery is an act of tacit knowing, guided by an anticipation of its achievement.

Whenever we come to understand something, we must pass a stage when we have partly understood it. When things are understood at a glance, as when we recognise familiar objects in a well lit room, we shall not be able to catch an imperfect stage of understanding. But think of long-drawn efforts to see things through inverting spectacles. Any incomplete stage of such an exertion must be filled with a striving towards its completion, even though this will require the invention of a novel way of seeing, never experienced before.

A problem is then the partial comprehension of a coherence, striving for its consummation. An intellectual appetite responds here, like all appetites, to a potential increment of its own satisfaction. The pursuit of a problem feels its way towards discovery, by sensing the growing proximity of discovery.

The two terms of tacit knowing are radially aligned so that the knower projects himself along this line into that which he knows. The pursuit of discovery extends this projection over a sequence of stages, each successive stage being achieved by an act of tacit knowing based on the stage that preceded it. Thus the vectorial character of tacit knowing is intensified into a sustained drive

on the trail to discovery.

From our experience of the way tacit knowing is achieved in making out what we see or in trying to feel our way with a stick, we may expect such an effort to have the following characteristics.

1) The effort will consist in trying to attend from a set of proximal particulars to their unknown joint meaning. These particulars are interiorised and not attended to in themselves; they may indeed be subliminal. They usually cannot be fully specified and sometimes not even approximately identified.

2) The relation by which they will be integrated into a comprehensive entity will be physiognomic or skilful and hence virtually undefinable.

3) When eventually integrated to such an entity, their appearance will assume a new quality, never experienced before.

Great discoveries will tend to show a high degree of indeterminacy in all three respects: in the choice of data, in the mode of their integration and the novel quality of the result. Remember the origins of relativity in the puzzling question whether a moving light source could overtake a beam emitted by it. Such a problem is wide open; Einstein has described the decade during which it was gestated. "During all these years" he wrote, "there was a feeling of direction, of going straight towards something concrete. It is, of course, very hard to express that feeling in words; but it was decidedly the case, and clearly to be distinguished from later considerations about the rational forms of the solution." This long drive towards something concrete which had yet no rational form, was a tacit effort to achieve coherence, and its result was a

comprehensive conceptual innovation, transforming the appearance of the world.

The creation of a new interpretative framework transforms the mind of him who achieves it. Only a new forcible interiorisation of elementary features can bring about such a rebirth of our intellectual selves. The problem which has led to such a result must have anticipated an existential change. Relativity not only changed our interpretative framework, but also contributed to a shift in our standards of intellectual valuation towards an appreciation of more abstractly mathematical harmonies. Discovery must therefore have been striving towards new kinds of intellectual beauty, more satisfying to our transformed intellectual selves.

We have here the characteristic features of supreme originality. A new comprehensive coherence is achieved, having a novel appearance and making us see the world in a new way. It involves a change of ourselves by making us interiorise a new interpretative framework and adopt novel standards of intellectual excellence.

Such deliberate self transformation may raise the question on what grounds we can possibly justify such a change of our identity. Could it be that man can in fact choose his own values, as Sartre and before him Nietzsche would have him do?

We are brought up here sharply against the full significance of the dilemma with which I presented you in recommending a path to discovery starting from the unexamined acceptance of unspecifiable grounds and aiming at a result distinguished by its vague and inexhaustible implications. All that I have said since then about the foreknowledge that would guide us along such a path and of the

self transformation involved in any major success of it, only adds to the questionable character of such an enterprise.

I accept the charge, but for the moment I shall counter it only by saying with Kierkegaard, "Either Or"--look at the alternative.

There are ways of advancing knowledge without navigating over seas of fantastic indeterminacies. Some problems can be solved by merely surveying all possible solutions. Existentially, surveying is the opposite extreme to the creative solving of major problems. To map out a country by triangulation, to extend the geography of the heavens by photography, or to follow through a series of systematic variations in the conditions of an experiment, is an explicitly prescribed mode of extending knowledge. It requires a minimum of indwelling, and thus approaches as closely as possible, the ideal of scientific detachment. It does not involve us personally, as the moulding of our minds into the comprehension of a hidden meaning. In fact, it presents no problems to torment us, evokes no hunches to excite us, offers no triumphs and causes no surprises. But consequently, it is dull, it is soul killing: detestable to minds gifted for creative tasks. And it is sterile. So let us return, after all, to the pursuit of discovery with all its vagaries.

A good problem is an anticipation of a hidden truth and its clues represent an aspect of the future discovery to be made by solving the problem; to recognise a problem is to discern an aspect of a hidden truth, not visible to others, less sensitive to the tell-tale traces of a pattern in nature. Yet, often when I lecture

on the precious knowledge contained in a good problem, and of the special gifts needed to recognise a good problem, my audience would suggest that problems consist simply in observing something that seems to contradict the hitherto accepted laws of nature. This is a far too narrow view of what constitutes a problem, and even so it begs the question which it disposes of. For to recognise a good problem in an apparent deviation from the currently accepted laws of nature, is to judge, and rightly judge, that the deviation is real and that it is also important and likely to be capable of elucidation. Such judgments require the very kind of scientific insight which I have said to be necessary for recognising any good problem.

Take the case of extra sensory perception. Some scientists regard these observations as pointing to an important problem, while others prefer to set the evidence aside, believing that there is nothing in it. The question, possibly one of greatest importance, remains open. Similar questions face the working scientist time and again. Inexplicable things keep turning up in a laboratory and are brushed aside as dirt-effects. One risks thus to ignore important clues. Dequerel discovered radioactivity and Rontgen discovered X-rays by inquiring into the fogging of photographic plates which they might have set aside as insignificant accidents. But to enquire into every inexplicable observation would be to undertake a succession of wild goose chases. Scientists must unceasingly discriminate between significant facts which may present a problem and accidental events not fit for investigation. A wrong choice may be fateful, while an exceptionally good choice may prove

a mark of genius.

We must realise also, that for a working scientist to accept a problem as his subject, means to engage in an enterprise. All the conditions of this enterprise must be assessed by him. It is not enough that his problem should point to a potential discovery. It had been known for a long time that in the periodic system the sequence of two pairs of elements was inverted. This was eventually explained by Moseley's discovery of atomic numbers equal to the charge of the nucleus. But any enquiry into this question before Moseley's study of X-ray spectra would have been a waste of time. A problem is good only if it is ripe.

It must be feasible; and this means, feasible by the scientist who considers to undertake its pursuit. He must be able to assess his own powers, his special gifts and resources as a means for solving the problem. He must assess also whether the chances of discovery and the importance of a prospective discovery are such as to justify the investment of his powers. A lesser use of them would be almost as wasteful as their application to a problem which will prove insoluble. Most working scientists can bitterly remember suffering both kinds of waste.

These requirements may appear extravagant. To assess jointly the prospects of all the clues which point to a problem, its soundness and ripeness, its feasibility in view of the scientist's special faculties and resources, and its importance compared with any alternative use of these faculties, may seem to be beyond the power of any mind. They are, of course, far beyond the power of any explicit evaluation. The number of objects to which we can ex-

plicitly attend, even though only to estimate their number, will in the simplest experimental conditions be hardly more than ten. But the variety and number of items that can be tacitly integrated to a decision is vast. Remember, once more, the split second decisions of a skilful driver, compared with someone trying to drive a car by referring to a detailed prescription. Or think of the numberless clues combined at every moment in watching an object moving about in front of us. It is by his powers of tacit integration that the scientist can swiftly combine and appraise the many disparate clues and resources which might contribute to his enquiry.

Such acts of tacit integration that are vital both to the inception and conduct of scientific enquiry, are obliterated by achieving success. Once solved, a problem can never puzzle us again. Steps which required exceptional penetration and imaginative powers, may well appear obvious. Looking back today on the year 1923 when de Broglie put forward the wave theory of matter, it would seem obvious that it would be tested by looking for the diffraction of electron beams by crystals in analogy to the diffraction of X-rays. An elementary computation would have shown that beams of right wave length could easily be obtained. Yet I have told you how astounded we were, when two years after de Broglie's theory was published, Elsasser first suggested such a possibility. When, eventually, another two years later Davison and Germer in America and G. P. Thomson in England actually produced such diffraction patterns, this was still regarded as a feat of sufficient originality, to secure the Nobel prize to its authors.

Intellectual passions, like bodily passions, are abated by

their satisfaction. It needs the art of a novelist, like Arthur Koestler, to revive in our imagination the years of Kepler's struggle with the wanderings of the planet Mars, which would accord with no reasonable combination of steady circular motions.

The fact that a completed act of tacit knowing obliterates its antecedents assists those current theories of discovery which would ignore tacit powers of the mind or set them aside as none of their business. The corresponding tendency to explain discovery, as far as possible, by explicit operations was systematically misleading. The scientist straining his tacit powers in pursuit of discovery, is immersed in what he does. The interiorisation of clues, the groping for intellectual harmonies, the passionate anticipation of a still hidden truth of which these harmonies are the tokens, involve his whole person. A theory that ignores the mechanism of tacit knowing must ignore or deny these commitments.

The scientist's commitments are minimised also by giving a false impression of the fact, that he is prepared to abandon any particular hunch, if it proved false. The tentativeness of his every step is taken to show that he is uncommitted. But in an important sense every step taken in the conduct of research is <u>definitive</u>, for it definitely disposes of the time, the effort and the resources used up in making it. This is no small matter, for these investments add up with frightening rapidity to the whole professional life of those engaged in research, and will exhaust even before this the credit of a scientist responsible for conducting scientific enquiries. To think of scientific workers cheerfully trying this and trying that, calmly changing course at each failure,

is totally misleading. The researcher's position is more like that of the chess player, who has only a short time for making his next irrevocable move.

This applies to all kinds of moves: to the adoption of a problem, the acceptance of a hypothesis for testing it and to the claims made for the final result in publishing it. It is widely admitted today that hypotheses arise by intuition. But we must consider that unless a hypothesis has a fair chance of proving true, or at least partly true, it is useless. Unless the ideas which a scientist will undertake to test have a chance of at least one in ten to succeed, he would waste more than nine months out of ten in fruitless testing. He would not last long in his profession. Considering the number of conceivable ideas that might be suggested at each stage, a faculty which can produce a valid surmise at least in one try out of ten, must be credited with the power of discovery. To describe this power as intuition, and set it aside as such, is to set aside what is essential to discovery at all stages. For at every step the same powers of tacit knowing carry on the deepening of our insight, which eventually results in discovery.

A scientist's claim to a discovery is a personal commitment and in accepting his claim, the scientific community shares and the lay public shares too, at second hand, this commitment. Recent literature has tried to make the justification of such a commitment easier, by saying that science does not claim certainty for its results and puts them forward only as probable. But think of the way you can wipe out all opposition if in an argument you can declare, that something has been proved by science. We have as

much confidence in the laws of nature as affirmed by science, as we have in any human utterance. If this is not certainty, then there is no such thing, and the word is meaningless. In any case, the question, on what grounds we accord such great confidence, as we do, to the teachings of science remains the same, whether this confidence attributes certainty or probability to science.

To minimise the claims of science in order to reduce the problem of our acceptance of science, we are told also that science is merely tentative, always ready to move on to a new position, if challenged by new evidence. But this again is beside the point. However ready we are to move on, we shall always be at some place at any particular moment. Existentialism and the modern theory of choice have both taught us to acknowledge that the choice to do nothing, or to go on trying, is as irrevocable as a decision to act. Declarations to accept the theories of science only tentatively, are, in fact, merely verbal. They attempt to avoid our actual commitment, by a fiction which, were it true, would be irrelevant.

The fact remains, that we grant our confidence to the theories of science without any formal proof of its justification. We commit ourselves in the light of our personal judgment.

Let me sum up in preparation for my final argument. From the moment when the scientists first surmised that there was something there that was puzzling; through the stage where he fixed on this as a definite problem; through the pursuit of successive hunches that arose from this problem; to the dawning of discovery and the public affirmation of its claims; we have seen the same urge of comprehension seeking to exercise its powers and groping for the

direction in which they are increasingly satisfied, but still leaving open, when crowned by a discovery, a degree of incompleteness which is accepted as a token of yet unseen implications, to be revealed one day to others, who will follow after.

The predominance of our tacit faculties in shaping the course of discovery and stamping its conclusion with our personal satisfaction is now clearly established. But does this achievement not open at our feet once more the abyss of self-doubt, in the very terms in which I opened this lecture? We seem to be left up in the air, with nothing to keep us up there, except a firm hold on our own boot straps.

However, I should hope that science itself might provide us with a more substantial principle of levitation. There is an aspect of our self reliance in the pursuit of science, which we yet have to bring fully to bear on our situation. A scientist's originality lies in seeing a problem where others see none and finding a way to its pursuit, where others lose their bearings. These acts of his mind are strictly personal in the sense that they are attributable to him and only to him. But they derive their power and receive their guidance from an aim that is strictly impersonal. For his quest pre-supposes the existence of an external reality. Research is conducted in these terms from the start and continues to grope for a hidden truth towards which our clues are pointing; and the discovery which terminates the pursuit and satisfies its author, is still sustained by a vision of reality pointing beyond it.

This is why even the most original ideas of a scientist engaged in research, still stand under an impersonal discipline. He

can put forward a scientific problem only in the conviction that there is something there to be discovered, something real over which he has no control, and this fills him with a compelling sense of responsibility for the pursuit of a hidden truth, which demands his services for revealing it. He exercises a personal judgment only in adducing evidence of an external reality. Hence, however original may be a scientist's way of conducting his research, however passionate and solitary his vision, there is no trace in these of self-indulgence. The satisfaction of originality lies in the intensely personal character of a triumphantly universal result.

There is, admittedly, great personal satisfaction to be found in successful scientific research. But such pleasure is legitimate only if it is derived from a valid pursuit of discovery: subjective satisfaction can never be the proper aim of originality. It seems wrong, therefore, to describe the personal element in scientific originality, as subjective. A problem, a clue, a hunch, a discovery--they all contain an element that is personal; the whole heuristic process is personal, yet its significance is not subjective, for it consists in anticipating some part of the truth yet to be discovered, which when discovered will point beyond itself to reality.

To meet this situation, I have coined the term Personal Knowledge. I have described as tacit knowing the less intensely personal form of indwelling, the most striking feature of which lay in its unspecifiability. By passing on to scientific enquiry and to discoveries of great originality, we meet with a more dynamic knowing to which the distinctive powers of the knower make a decisive con-

tribution. Here the term "personal knowledge" becomes more appropriate.

All tacit knowing is an indwelling which mentally extends the knower, enlarges his existence and raises his sense of rational being; but only in its major enterprises does this expansion become fervid. Here we see scientists not merely puzzled, but obsessed by a problem; here are hunches which grip his mind suddenly with violent hopes; where discovery comes as a triumph to its author and a dazzling surprise to his audience. These emotions are part of our having problems and hunches, and making discoveries. They account for the dynamic powers by which problems are grasped and pursued, hunches are hit upon and developed, discoveries are sighted and established. All major enquiry must be motivated throughout by these heuristic passions and be guided at every step by seeking to satisfy them.

These passions differ from those stirred up by our bodily needs. They are generous desires which do not deprive others in any share of that which gratifies them, but spread widely what they enjoy, by the very act of enjoying it. They teach their own pleasures and perpetuate themselves by their own fulfilment. Man in thought strives to give life to thought. His anticipation of possible ideas urges him to force his way into them and thus come to participate in a deeper coherence never yet entered before.

Highest originality is manifested in the capacity to transform one's own outlook on the world. We may create new standards of beauty by serving them. This is how a choice of existence takes place in science, as it does elsewhere too. The existentialist

dilemma, how values created at our command can bind us, does not arise. Admittedly, explicit determination cannot create new standards. If you regard a choice of values as you would of a choice of a menu, you cannot expect to find that these values have authority over you. But originality is no explicit choice. Originality, which alone can establish new values, accepts their authority in the very act of creating them.

Since a scientist may put forward his conclusions only if he trusts that they arise from a true understanding of experience in its bearing on reality, he holds that others, equipped as he is, must reach the same conclusion. Such is the universal intent of a scientific discovery. Having relied throughout his enquiry on the presence of something hidden out there, the scientist must continue to rely on that external presence for the validity of the result that satisfies his quest. As he has accepted throughout the discipline which this external pole of his heuristic endeavour imposed upon him, he cannot but expect that others will recognise likewise the impersonal authority that guided him. On the grounds of the self discipline which bound him to objectivity, he must claim that his results are universally valid.

He knows not whether his claims will be accepted; they may be true and yet fail to carry conviction. He may even know that this is likely to happen. Nor does eventual acceptance guarantee truth. To claim universal validity for a statement says merely that it ought to be accepted by all. The affirmation of scientific truth has an obligatory character which it shares with other valuations deemed to be universal.

Both the anticipation of discovery and discovery itself, may turn out to be a delusion. But it is futile to seek for strictly impersonal criteria of their validity, as philosophies of science have been trying to do. To accept the pursuit of science as a reasonable, successful, enterprise is to share the kind of commitment on which scientists enter by undertaking this enterprise. You cannot formalise the act of commitment, for you cannot express your commitment non-commitally. To attempt this is to exercise the kind of lucidity which destroys its subject matter.

We should be glad to recognise instead that science has come into existence by powers of anticipation akin to those on which all hopes for truth and beauty are grounded, and that science rests ultimately on such intangible powers of the mind. If this leaves science up in the air, it will keep us company there. It will restore our confidence in convictions, which its supposed exactitude and detachment has undermined so long. The current ideals of science are false and misleading. These ideals were invented for the benefit of physicists, who flourish by disregarding them, and they play havoc with other branches of science and with the humanities, who venerate them. These false ideals will be well lost for a truer image of science, which will allow us once more to place first things first: the living above the inanimate, man above the animal, and man's duties above man.