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Lecture 3

The Creative Imagination

by Michael Polanyi

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My lecture, last week, dealt with some curious facts. It showed a number of instances in which we integrate experiences to something on which they bear. We are aware then of such subsidiaries - be they clues, or parts, or pointers, or names, or tools, or probes, or motions, in terms of that to which they are directing our attention. We are aware for example of perceptual clues only in the appearance of things we are looking at. It is amazing at what speed such clues are integrated without being identifiable.

Such is the way subsidiaries are brought into action by our powers of tacit integration, and such is, I believe also, the way we discover coherence and reality in nature. This is the idea I want to develop today.

If natural science is - as I assume it to be - a generalised form of perception, we might find the prototype of scientific discovery in the way we solve a difficult perceptual problem. Take the way we learn to find our way about while wearing inverting spectacles. When you put on spectacles that show things upside down, you feel completely lost and remain helpless for days on end. But if you persist in groping around for a week or more, you find your way again and eventually can even drive a car or climb rocks with the spectacles on. This fact, well known today, was discovered - in essence - by Stratton seventy years ago. It is usually said to show that after a time the visual image switches round to the way we normally see it.

Most of the literature says so. But more recent observation has proved that this interpretation is false.

It happened, for example, that a person perfectly trained to get around with upside down spectacles, was shown a row of houses at a distance, and was asked whether he saw the houses right way up or upside down. The question puzzled the subject and he replied, after a moment, that he had not thought about the matter before, but that now that he is asked about it he finds that he sees the houses upside down.*

Such a reply shows that the visual image of the houses has not turned back to normal; it has remained inverted, but the inverted image no longer means to the subject that the houses themselves are upside down. The inverted image has been reconnected rationally to other sensory clues, to touch and sound, and weight. These all hang together with the image once more in a way that though the image remains inverted we can again find our way by it safely. A new way of seeing things rightly has been produced, a new sensory mode established. And since the meaning of the upside down image has now changed, the term 'upside down' has lost its previous meaning, and it has become confusing to enquire whether something is seen upside down or right way up. The new kind of right seeing can be talked about only in terms of a new vocabulary. I was told that in the Psychology Department at Innsbruck University where these results

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* See F. W. Snyder and N. H. Pronko, Vision with Spatial Inversion, Wichita, Kansas (1952). For fuller evidence and its interpretation in the sense given here, see Heinrich Kottenhoff, Was ist richtiges Sehen mit Umkehrbrillen und in welchem Sinne stellt sich das Sehen um? Psychologia Universalis, Vol. 5 (1961).

were first clearly developed by Heinrich Kottenhoff (around 1960), they avoid confusion by applying the German words for right and left for the ordinary seeing of things, but use the English words 'right' and 'left' when seeing things rightly through right-left inverting spectacles.

We may say that the wearer of inverting spectacles re-organises scrambled clues into a new kind of coherence. He again sees objects then, instead of meaningless impressions. He again sees real things, which he can pick up and handle, which have weights pulling in the right direction and make sounds that come from the place at which he sees them. He has made a novel sense out of chaos.

In science, I find the closest parallel to this perceptual achievement in the discovery of relativity. Einstein has told the story how from the age of 16 he was obsessed by the following type of speculation. Experiments with falling bodies were known to give the same result on board a ship in motion as they do on solid ground. But what would happen to the light which a lamp would emit on board a moving ship? Supposing the ship moved fast enough, would it overtake the beams of its own light, as a bullet overtakes its own sound by crossing the sonic barrier? Einstein thought that this was inconceivable, and persisting in this assumption, he eventually succeeded in renewing the conceptions of space and time in a way which would make it inconceivable for the ship to overtake, however slightly, its own light rays. After this, questions about a definite span of time or space became meaningless and confusing - exactly as questions of "above" and "below" became meaningless and confusing to a subject who had adapted his vision to inverting spectacles.*

It is no accident that it is the most radical innovation in the history of science that appears most similar to the way we acquire the capacity for seeing inverted images rightly. For only a comprehensive problem, like relativity, can require that we reorganise such basic conceptions as we do in learning to see rightly through inverting spectacles. Relativity alone involves conceptual innovations as strange and paradoxical as those we make in reorganising an inverted vision.

The experimental verifications of relativity have shown that the coherence discerned by Einstein was real. One of these confirmations has a curious history. Einstein had assumed that a light source would never overtake a beam sent out by it, a fact that has already been established before by Michelson and Morley. In his autobiography Einstein says that he made this assumption intuitively from the start, which is to say that he recognised it by an act of tacit knowing. But this account failed to convince his contemporaries, for intuition was not regarded as a legitimate ground for knowledge. Text books of physics described, therefore, Einstein's theory as his answer to the experiments of Michelson. When I tried to put the record right, by accepting Einstein's claim that he had intuitively - that is tacitly - recognised the facts already demonstrated by Michelson, I was attacked and ridiculed by Professor Grünbaum of Pittsburgh, who argued that Einstein must have known of Michelson's experiment, since he could not otherwise have based

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* References to Einstein's autobiography are based on Albert Einstein, "Biographical Notes" in Albert Einstein, Philosopher-Scientist, ed. P. A. Schilpp, New York, (1949) p. 53.

himself on the facts established by these experiments.*

But if science is a generalised form of perception, Einstein's story of his intuition is clear enough. He had started from the principle that it is impossible to observe absolute motion in mechanics, and when he came across the question whether this principle holds also when light is emitted, he felt that it must still hold, but he could not quite tell why he assumed this. This is exactly how unaccountable assumptions are made in the way we perceive things and these assumptions can affect also the way scientists see them. Newton's assumption of absolute rest, the assumption which Einstein was to refute, owed its convincing power to the way we commonly see things. We see a car travelling along a road and never the road sliding away under the car. We see the road at absolute rest. We generally see things as we do, for this establishes coherence within the context of our experience. So when Einstein extended his vision to the universe and included the case of a light source emitting a beam, he could make sense of this only by seeing it in such a way that the beam was never overtaken, however slightly, by its source. This is what he meant by saying that he knew intuitively that this was in fact so.

We can understand now also why the grounds on which Copernicus claimed that his system was real could be convincing to him, though not convincing to others. We have seen that the tacit powers that are at work in perception integrate clues which, being subsidiarily known, are largely unspecifiable; we have seen further that the intuition by which Einstein shaped his novel conceptions of time and space was also based on clues which were largely unspecifiable; we

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* Adolf Grünbaum, Philosophical Problems of Space and Time, New York (1963), pp. 378-85.

may assume then that this was true also for Cpernicus shaping his vision of reality.

And we may sum up by saying. Science is based on clues that have a bearing on reality. These clues are not fully specifiable; nor is the process of integration which connects them fully definable; while the future manifestations of the reality indicated by this coherence are inexhaustible. These three indeterminacies defeat any attempt at a strict theory of scientific validity and prove indispensable the powers of tacit knowing.

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This gives us a general idea of the way scientific knowledge is established at the end of an enquiry; it tells us how we judge that our result is coherent and real. But it does not show clearly how we start an enquiry; nor how we know, once we have started, which way to turn for a solution. At the beginning of a quest we can know only vaguely what we may hope to discover; it may seem strange, therefore, how we can ever start off and go on with an enquiry without knowing what exactly we are looking for.

This question goes back to antiquity. Plato set it in the Meno. He said, in effect, that if we know the solution of a problem, there is no problem - and if we don't know the solution, we do not know what we are looking for and cannot expect to find anything. He concluded that when we do solve problems, we do it by remembering past incarnations. This strange solution of the dilemma may have prevented it from being taken seriously. Yet the problem is ineluctable and can be answered only by recognising a kind of tacit knowing or intuition, that is more dynamic than the one I have dwellt on so far.

I have spoken repeatedly of our powers to perceive a coherence bearing on reality, with its hidden future manifestations. And I have mentioned in my first lecture also a more specific knowledge of hidden coherence: the kind of foreknowledge we have in a problem. And we know that the scientist's imagination sees problems, produces hunches, and, stirred by these anticipations, pursues his quest towards them. We may say that this quest is guided at every stage by feelings of a deepening coherence, of feelings that have a fair chance of proving right. We may recognise in them the working of a dynamic intuition: in other words, the power which achieves tacit knowledge.

The mechanism of this power can be illuminated by an analogy. Physics speaks of potential energy that is released when a weight slides down a slope. Our search for deeper coherence is guided likewise by a potentiality. We feel the slope towards deeper insight as we feel the direction in which a heavy weight is pulled along a steep incline. This is the dynamic intuition that guides the pursuit of discovery.

That is how I would resolve the paradox of the <u>Meno</u>: we can pursue scientific discovery without knowing what we are looking for, because the gradient of deepening coherence tells us where to start and which way to turn, and eventually brings us to the point where we may stop and claim a discovery. The resemblance to the way the painter or the poet are guided by the hidden coherence they are seeking seems clear.

But we must yet acknowledge further powers of intuition without which scientists or inventors could neither rationally choose a particular problem nor pursue any chosen problem successfully. Think of Stratton devising his clumsy inverting spectacles and then groping about guided by the inverted vision of a single narrowly restricted eye for days on end. He must have been firmly convinced that he would learn to find his way about within reasonable time, and also that the result would be worth all the trouble of his strange enterprise - and he proved right. Or think of Einstein, when as a boy he came across the speculative dilemma of a light source pursuing its own ray. He did not brush the matter aside as a mere oddity, as anybody else would have done. His intuition told him that there must exist a principle which would assure the impossibility of observing absolute motion in any circumstances. Through years of sometimes despairing enquiry, he kept up his conviction that the discovery he was seeking was within his ultimate reach and that it would prove worth the torment of its pursuit; and again, Einstein proved right. Kepler too might have reasonably concluded, after some five years of vain efforts, that he was wasting his time, but he persisted and proved right.

The power by which such long range assessments are made may be called a <u>strategic intuition</u>. It is practised every day on a high level of responsibility in industrial research laboratories. The director of such a laboratory does not usually make inventions, but is responsible for assessing the value of problems suggested to him, be it from outside or by members of his laboratory. For each such problem the director must jointly estimate the chances of its successful pursuit, the value of its possible solution, and also the costs of achieving it. He must compare this combination with the joint assessment of the same characteristics for rival problems. On these grounds he has to decide whether the pursuit of a problem should be undertaken or not, and if undertaken, what grade of priority should be given to it in the use of available resources.

The scientist is faced with similar decisions. An intuition that merely points out a number of problems does not tell him which problem to choose. He must be able to estimate the gap separating him from discovery and he must also be able roughly to assess whether the importance of a possible discovery would warrant the investment of the powers and resources needed for its pursuit. Without this kind of strategic intuition, he would waste his opportunities on wild goose chases and be soon out of a job.

The kinds of intuition I have recognised here are the dynamic forms of tacit knowing. Such an intuition is quite different from the supreme immediate knowledge called intuition by Leibniz or Spinoza or Husserl. It is a skill for guessing with a reasonable chance of guessing right; a skill guided by an innate sensitivity to coherence, improved by schooling. The fact that this faculty often fails does not discredit it; a method for guessing ten percent above average chance on roulette would be worth millions. Of the infallible intuition of idealistic philosophy I know nothing and I doubt that it exists.

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But to know what to look for does not lend us the power to seek it and find it. I have spoken in my first lecture of the way the anticipatory powers of the scientist's imagination sees a problem; I must work out now more generally the part played by the imagination in the dynamics of tacit knowing.

All thoughts of things that are not present, or of things not <u>yet</u> present - or perhaps never to be present - all such thoughts I shall call acts of the imagination. When I intend to lift my arm, this intention is an act of my imagination. In this case imagining is not visual but muscular. An athlete keyed up for a high jump is engaged in an intense act of muscular imagination. But even in the effortless lifting of an arm, we can recognise a conscious intention, and an act of the imagination, distinct from its muscular execution. For we never decree the muscular performance itself, since we have no direct control over it. This delicately co-ordinated feat of muscular contractions is ordered spontaneously, in response to our imaginative act of volition.

This dual structure of deliberate movement was first described by William James seventy years ago. We see now that it corresponds to the two kinds of awareness that we have met in all tacit knowing. We may say that we have a focal awareness of lifting our arm, and that this focal act is implemented by the integration of subsidiary muscular particulars. We may put it as in the case of perception, that we are focally aware of a deliberate achievement and aware of its particulars only subsidiarily, by attending to that which they jointly constitute.

But a new life, a new intensity, enters into this two-levelled structure the moment our intention meets with difficulties. The two levels fall apart then and the imagination sallies forward, seeking to close the gap between them. Take the example of learning to ride a bicycle. Our imagination is fixed on this aim, but our present capabilities being insufficient, our execution of it falls behind. By straining every nerve to close this gap, we gradually learn to keep our balance on a bicycle.

We find that such an effort results in an amazingly sophisticated policy of which we know nothing. Our muscles are set so as to counteract at every moment our accidental imbalance, by turning the bicycle into a curve with a radius proportional to the square of its velocity, divided by the angle of our imbalance. Millions of people are cycling all over the world by skilfully applying this formula which they could not remotely understand if they were told about it. This puzzling fact is explained by the two-levelled structure of intentional action as follows. The use of the formula is invented on the subsidiary level in response to the efforts to close the gap between intention and performance; and since the performance has been produced subsidiarily, it may remain focally unknown.

Remember also Hefferline's experiments showing how an active intention can evoke covertly, inside our body, the means of its implementation. There is a detail of this experiment I have not told you about. Spontaneous muscular twitches, imperceptible to the subject, were rewarded by a brief pause in an unpleasant noise; and as soon as this was done, the frequency of the twitches multiplied about threefold. And when in some cases the subject was shown on a galvanometer the electrical effect of his twitches, the frequency of the twitches shot up to about six times their normal rate.* For years I have been puzzled by this effect, until it dawned upon me that the galvanometer readings support the subject's intention, by serving him as a guide to his imagination. I have found this effect confirmed in a number of other experiments by various psychologists.

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* See R. F. Hefferline et al. Science (1959) Vol. 130, pp. 1338-9. See also Science (1963) Vol. 139, pp. 834-5 and R. F. Hefferline "Learning Theory and Clinical Psychology" in Experimental Foundations of Clinical Psychology, ed. A. J. Bachrach, New York (1962).

Recent work in Russia has shown that the sight or sound of a novel intriguing kind evokes a general mobilisation of internal bodily processes. Such internal responses are found in animals right down to fishes. They have been called an orientation reflex and may be taken to signify the excitement of meeting a problem. If the problem is unpleasant and one of the mobilised internal events chances to bring it under control, this event will be repeated more frequently, as Hefferline's twitches were. If, on the other hand, the problem turns out to be of no consequence, habituation will set in: the animal will cease to worry. Rabbits show habituation after 6 to 15 presentations of a strange sight, but birds take longer and carps may cease to get excited only after seeing a problematic sight 170 times.* They are an ideal audience for telling it the same joke over and over again.

This is the kind of mechanism to which I ascribe the evocation of helpful clues by the scientist's imagination in the pursuit of an enquiry. But we must yet consider the fact that a scientist's problem does not set him a definite task. He differs in this from the practical inventor and resembles rather the artist. He knows his aim only in broad terms and must rely on his sense of deepening coherence to guide him to discovery. He must keep his questing imagination fixed on these growing points and force his way to what lies hidden beyond them; let us see how this is done.

Take once more the example of the way we discover how to see rightly through inverting spectacles. We cannot aim specifically

* Vedysev and Karmanova (1958) Personal Communication by Mr. Jeffrey A. Gray, Institute of Experimental Psychology, Oxford.

at re-connecting sight, touch, and hearing. Any attempt to overcome spacial inversion by telling ourself that what we see above is really below may actually hinder our progress, for the meaning of the words we would use were misleading. We must go on groping our way by sight and touch, and learn to get about in this way. Only by keeping our imagination fixed on the global result we are seeking, can we induce the requisite sensory reintegration.

No quest could have been more indeterminate in its aim than Einstein's enquiry that led to the discovery of relativity. Yet he has told that during all the years of his enquiry, "there was a feeling of direction, of going straight towards something definite. Of course," he said, "it is very hard to express that feeling in words; but it was definitely so, and clearly to be distinguished from later thoughts about the rational form of the solution." We meet here the integration of still largely unspecifiable elements into a gradually narrowing context, the coherence of which has not yet become explicit.

The surmises made by Kepler during six years of toil before hitting on the elliptic path of Mars were often explicit. But Arthur Koestler has shown that Kepler's distinctive guiding idea, to which he owed his success, was the firm conviction that the path of the planet Mars was somehow determined by a kind of mechanical interaction with the sun. This vague vision - foreshadowing Newton's theory - had enough truth in it to make him exclude all epicycles and send his imagination in search of a single formula, covering the whole planetary path both in its speed and in its shape. This is how Kepler hit upon his two laws of elliptic revolution.

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We begin to see now how the scientist's surmises are formed. The imagination sallies forward and the intuition integrates what the imagination has lit upon. But a fundamental complication comes into sight here. I have acknowledged that the final sanction of discovery lies in the sight of a coherence which our intuition detects and we accept as real; but history suggests that there are no universal standards for assessing such coherence: they have changed repeatedly during the past centuries.

Copernicus criticised the Ptolemaic system for its incoherence in assuming other than steady circular planetary paths and fought for the recognition of the heliocentric system as real, because of its superior consistency. But his follower, Kepler, abandoned the postulate of circular paths, as causing meaningless complications in the Copernican system, and boasted that by doing so he had cleansed an Augean stable.* Kepler based his first two laws on his vision that geometrical coherence is the product of some undefinable mechanical interaction;** but this conception of reality underwent another radical transformation when Galileo, Descartes, and Newton found ultimate reality in the smallest particles of matter obeying the mathematical laws of mechanics.

We must ask, therefore, by what standards we can change the very standards of coherence on which our convictions rest. On what grounds can we change our grounds? We are faced with the existentialist dilemma, how values of our own choice can have authority over us who decreed them.

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* Arthur Koestler, The Sleepwalkers (1959), p. 334.

** Ibid., p. 316

We must look once more then at the mechanism by which imagination and intuition carry out their joint task. We lift our arm and find that our imagination has issued a command which has evoked its implementation. But the moment feasibility is obstructed, a gap opens up between our faculties and the end at which we are aiming, and our imagination fixes on this gap and evokes attempts to reduce it. Such a quest can go on for years; it will be persistent, deliberate, and transitive; yet its whole purpose is directed on ourselves; it attempts to make us produce ideas. We say then that we are <u>racking our brain</u> or <u>ransacking our brain</u>; that we are <u>cudgeling</u> or <u>cracking</u> it, or <u>beating our brain in trying to get it to work</u>.

And when such effort leads to success, the discovery induced in us by this ransacking <u>is felt as something that is happening to us</u>. We say that we <u>tumble</u> to an idea; or that an idea <u>crosses</u> our mind; or that it <u>comes into</u> our head; or that it <u>strikes</u> us; or <u>dawns</u> on us, or just <u>presents itself</u> to us. We are actually surprised and exclaim: Aha! when we suddenly have an idea. Ideas may indeed come to us unbidden, hours or even days after we have ceased to rack our brain.

Discovery is made therefore in two moves: one deliberate, the other spontaneous, the spontaneous move being evoked in ourselves by the action of our deliberate effort. The deliberate thrust is a focal act of the imagination, while the spontaneous response to it, which brings discovery, belongs to the same class as the spontaneous co-ordination of muscles responding to our intention to lift our arm, or the spontaneous co-ordination of visual clues in response to our looking at something. This spontaneous act of discovery deserves to be recognised as the creative intuition.

But where does this leave the creative imagination? It is there, it is not displaced by the intuition, it is imbued with it. When recognising a problem and engaging in its pursuit, our imagination is guided both by our dynamic and by our strategic intuition and it ransacks then our available faculties, guided by the creative intuition. The imaginative effort can evoke its own implementation only because it follows intuitive intimations of its own feasibility. Remember, as an analogy, that a lost memory can be brought back only if we have clues to it; we cannot even start racking our brain for a memory that is wholly forgotten. The imagination must attach itself to clues of feasibility supplied to it by the very intuition that it is seeking to evoke; sallies of the imagination that have no such guidance are idle fancies.

The honours of creativity are due then in one part to the imagination, which demands of the intuition a feasible task and, in the other part, to the intuition which rises to this task and reveals the discovery that the quest was due to bring forth. The intuition informs the imagination which, in response, evokes the powers of the intuition.

But where does the responsibility for changing our criteria of reality rest then? To find that place we must probe still deeper. When the quest has ended, imagination and intuition do not vanish from the scene. Our intuition recognises our final result to be valid and our imagination points to the inexhaustible future manifestations of it. We return to the quiescent state of mind from which the enquiry started, but return to it with a new vision of coherence and reality. Herein lies the final acceptance of this vision; any new standards of coherence implied in it have become our own standards, we are committed to them.

But can this be true? In his treatise on The Concept of Law (Oxford 1961), Professor H. L. A. Hart observes rightly that, while it can be reasonable to decide that something will be illegal from tomorrow morning, it is nonsense to decide that something that is immoral today will be morally right from tomorrow. Morality, Hart says, is "immune against deliberate change"; and the same holds clearly also for beauty and truth. Our allegiance to such standards implies that they are not of our making. The existentialist dilemma still faces us then unresolved.

But I shall deal with it now. The first step is to remember that scientific discoveries are made in search of reality - of a reality that is there, whether we know it or not. The search is of our own making, but reality is not. We send out our imagination deliberately to ransack promising avenues, but the promise of these paths is already there to guide us, we sense it by our spontaneous intuitive powers. We induce the work of the intuition, but do not control its operations.

And since our intuition works on a subsidiary level, neither the clues which it uses nor the principles by which it integrates them are fully known. It is difficult to tell what were the clues which convinced Copernicus that his system was real. We have seen that his vision was fraught with implications so far beyond his own ken that, had they been shown to him, he would have rejected them. The discovery of relativity is just as full of unreconciled thoughts. Einstein tells in his autobiography that it was the example of the two great fundamental impossibilities underlying thermodynamics that suggested to him the absolute impossibility of observing absolute motion. But today we can see no connection at all between thermodynamics and relativity. Einstein acknowledged his debt to Mach and it is generally thought, therefore, that he confirmed Mach's thesis that the Newtonian doctrine of absolute rest is meaningless; but what Einstein actually proved was on the contrary that Newton's doctrine, far from being meaningless, was false. Again, Einstein's re-definition of simultaneity originated modern operationalism; but he himself sharply opposed the way Mach would replace the conception of atoms by their directly observable manifestations.*

The solution of our problem is approaching here. For the latency of the principles entailed in a discovery indicates how we can change our standards and still uphold their authority over us. It suggests that while we cannot decree our standards _explicitly_, in the abstract, we may change them _covertly_ in practice. The deliberate aim of scientific enquiry is to solve a problem, but our intuition may respond to our efforts by a solution entailing new standards of coherence, new values. In affirming the solution we tacitly obey these new values and thus recognise their authority over ourselves, over us who tacitly conceived them.

This is indeed how new values are introduced, whether in science, or in the arts, or in human relations. They enter subsidiarily, embodied in creative action. Only after this can they be spelled out and professed in abstract terms and this makes them appear then to have been deliberately chosen, which is absurd. The actual grounds of a value, and its very meaning, will ever lie hidden

* Albert Einstein, "Biographical Notes" in _Albert Einstein Philosopher-Scientist_, ed. P. A. Schilpp, New York (1949), p. 49.

in the commitment which originally bore witness to that value. An explicit choice of new values is nonsensical.

I shall speculate another time about the kind of universe which may justify our reliance on our truth-bearing intuitive powers; tonight I shall speak only of their part in our endorsement of scientific truth. 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, attributable to him and only to him. But they derive their power and receive their guidance from an aim that is impersonal. For the scientist's quest pre-supposes the existence of an external reality. Research is conducted on these terms from the start and goes on then groping for a hidden truth towards which our clues are pointing; and when discovery terminates the pursuit its validity is sustained by a vision of reality pointing still further beyond it.

Having relied throughout his enquiry on the presence of something real hidden out there, the scientist will necessarily rely on that external presence also for claiming the validity of the result that satisfies his quest. As he has accepted throughout the discipline which this external pole of his endeavour imposed upon him, he expects that others, similarly equipped, will likewise recognise the authority that guided him. On the grounds of the self-command which bound him to the quest of reality, he must claim that his results are universally valid; such is the universal intent of a scientific discovery.

I speak not of universality, but of universal intent, for the scientist cannot know whether his claims will be accepted; they may be true and yet fail to carry conviction. He may have reason to expect that this is likely to happen. Nor can he regard a possible acceptance of his claims as a guarantee of their truth. To claim universal validity for a statement indicates merely that it ought to be accepted by all. The affirmation of scientific truth has an obligatory character which it shares with other valuations, declared universal by our own respect for them.

Both the problem which anticipates discovery and discovery itself may be a delusion. But it is futile to seek for explicit impersonal criteria of their validity. The content of any empirical statement is, as I have said, three times indeterminate. It relies on clues which are largely unspecifiable integrates them by principles which are undefinable, and speaks of a reality which is inexhaustible. Attempts to eliminate these indeterminacies of science merely replace science by a meaningless fiction.

To accept science, in spite of its essential indeterminacies, is an act of our personal judgment. It is to share the kind of commitment on which scientists enter by undertaking an enquiry. You cannot formalise commitment, for you cannot express your commitment non-commitally; to attempt this is to perform the kind of analysis which destroys its subject matter.

We should be glad to recognise that science has come into existence by mental endowments akin to those in which all hopes of excellence are rooted, and that science rests ultimately on such intangible powers of our mind. This will help to restore legitimacy to our convictions, which the specious ideal of strict exactitude and detachment have discredited. These false ideals do no harm to physicists who only pay lip service to them, but they play havoc with other parts of science and with our whole culture, which try to live by them. They will be well lost for truer ideals of science, which will show us once more first things first: the living above the inanimate, man above the animal, and man's duties above man.