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Tacit Knowing: Its Bearing on Some Problems of Philosophy

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PART I

IN this paper I shall try to carry further, in outline, an inquiry that I have been pursuing for several years. For this purpose, it is necessary, first of all, to recapitulate some arguments which I have developed elsewhere.

There are things that we know but cannot tell. This is strikingly true for our knowledge of *skills.* I can say that I know how to ride a bicycle or how to swim, but this does not mean that I can tell how I manage to keep my balance on a bicycle or keep afloat when swimming. I may not have the slightest idea of how I do this, or even an entirely wrong or grossly imperfect idea of it, and yet go on cycling or swimming merrily. Yet, it cannot be said that I know how to bicycle or swim and *not* know how to coordinate the complex pattern of muscular acts by which I do my cycling or swimming. It follows that I know how to carry out these performances as a whole and that I also know how to carry out the elementary acts which constitute them, but that, though I know these acts, I cannot tell what they are.

We perform a skill by relying on the coordination of elementary muscular acts, and we are aware of having got these right by accomplishing our skillful performance. We are aware of them *in terms of this performance* and *not* (or only very incompletely) aware of them *in themselves.*

This fact can be generalized widely. There are vast domains of knowledge, of which I shall speak in a moment, that exemplify, in various ways, that we are generally unable to tell what particulars we are aware of when attending to a coherent entity which they constitute. Thus, there are two kinds of knowing which invariably enter jointly into any act of knowing a comprehensive entity. There is (1) knowing a thing *by attending to it,* in the way we attend to an entity as a whole and (2) knowing a thing *by relying on our awareness of it for the purpose of attending to an entity to which it contributes.* The latter knowledge can be said to be *tacit,* so far as we cannot tell what the particulars are, on the awareness of which we rely for attending to the entity comprising them.

These two kinds of knowing are not only distinct, but also in an important sense mutually exclusive. Motion studies may teach us to identify some of the elementary acts constituting a skill, and this may be useful in training. But, while attending to the elements of a skill in themselves, we impair their smooth integration to the joint performance that it is their function to serve. If we succeeded in focusing our attention *completely* on the elements of a skill, its performance would be paralyzed altogether.

The mutual exclusiveness of the two kinds of knowing can be expressed in terms of a *logical disjunction.* When we know something by relying on our awareness of it for the purpose of attending to something else (i.e., we know a particular for the purpose of attending to a comprehensive entity to which it contributes), we cannot at the same time *not* rely on it for this purpose—as would necessarily be the case if we attended to it exclusively in itself.

We may call "knowing by attending to" a *focal* knowing, and "knowing by relying on" a *subsidiary* knowing, and reformulate in these terms the conclusions we have arrived at as follows. We know subsidiarily the particulars of a comprehensive whole when attending focally to the whole which they constitute; we know such particulars not in themselves but in terms of their contribution to the whole. To the extent to which things are known subsidiarily in terms of something else, they cannot be known at the same time in themselves.

We may call the *bearing* which a particular has on the comprehensive entity to which it contributes its *meaning,* and can then say that when we focus our attention wholly on a particular, we *destroy its meaning.* My introductory statement, that there are things that we know but cannot tell, can then be developed as follows. We can tell what the things are which we know by attending to them focally, but we are uncertain, or entirely ignorant, of things that we know only by relying on our awareness of them for attending to something else, which is their meaning.

What is subsidiarily known is tacitly known; but it seems appropriate to extend the meaning of "tacit knowing" to include the integration of subsidiary to focal knowing. The structure of tacit knowing is then the structure of this integrative process, and knowing is tacit to the extent to which it has such a structure. So if (as it will appear) all knowing ultimately relies on a tacit process of knowing, we shall say that, ultimately, all knowledge has the structure of tacit knowledge.

Tacit knowing cannot be strictly opposed to focal knowing because the process of tacit knowing includes our knowing of the subsidiary particulars in terms of the entity to which they contribute and to which we are focally attending. But the tacit character of knowing can be *reduced* by switching our attention to the particulars. We replace then, to this extent, tacit knowing by explicit inference, and *in this sense tacit knowing can be opposed to* (focally known) *explicit inferences.*

Four points must yet be clarified.

(1) I have mentioned that motion studies can identify some of the muscular acts which contribute to a skill. Let us be clear that this does not contradict my statement that we *can* know things we cannot tell, for previous to the motion study we knew how to perform and coordinate these muscular acts, but could not tell what they were. It may be possible to find out how we keep our balance on a bicycle or keep afloat when swimming, but we *can* know how to cycle and swim without having found out how we do it. Besides, motion studies are always incomplete, as can be seen from the fact that you cannot acquire a skill merely by learning to perform its fragments, but must also discover the knack of coordinating them effectively. I shall clarify this further in my next point.

(2) It may be said that since we can teach a skill, we can, in fact, also convey the knowledge of how to perform the several muscular acts of such a skill. The answer is that to the extent to which our teaching will have to rely for its success on our pupil's intelligent and dexterous effort to carry out our instructions, we are, in fact, *not* defining what he has to do. Definitions of terms bearing on external objects must always ultimately rely on pointing at things that are instances of what we mean. This is called an "ostensive definition"; but this term conceals a gap to be bridged by an intelligent effort of the person using our definition. If he succeeds in bridging this gap, he will have discovered for himself something we have not been able to tell him. *This is the sense in which I say that we can know things we cannot tell.*

(3) Is subsidiary knowledge the same as unconscious knowledge? No, the two must not be identified. Subsidiary and focal awareness are different in kind. Focal awareness is always conscious, whereas subsidiary awareness may range from a conscious level, down to levels altogether inaccessible to consciousness. A skier racing down a slope is intensely aware of controlling every part of his body, though he could not tell by what principles he keeps his balance. By contrast, studies by Hefferline and his collaborators have shown that a human subject can learn to silence an unpleasant noise by a muscular twitch so slight that he cannot feel it at all.[1] When tacit knowing relies on such low levels of consciousness, it becomes unspecifiable in a stronger sense.

(4) The experiment I have just quoted is an outstanding example of an inquiry in which an increasing number of experimental psychologists have been engaged in the past ten years and that has aroused wide popular interest—the inquiry into the process now usually called 'subception.' The term was coined by Lazarus and McLeary.[2] A number of nonsense syllables were briefly shown to the subject and certain of these were followed by an electric shock. Presently the subject anticipated shock on the sight of "shock syllables," but, on questioning, he wrongly identified these syllables; this was called 'subception.'

The authors acknowledge similar experiments by earlier authors and they were followed by a number of others demonstrating variants of subception in the anticipation of shock.[3] In all these cases the subjects had acquired knowledge, the particulars of which they could not specify. However, once these particulars were identified, they could be readily observed in themselves. Some subjects of Ericson and Kuethe did in fact consciously avoid shocks, and, in consequence, behaved differently from those avoiding shocks by subception. By contrast, Hefferline's experiments represent a subception of *subliminal stimuli.* Earlier observations of this type are exemplified by the work of Smith and Henrickson.[4] They exposed the picture of a smiling face so briefly, that it could not be identified, and found that unsmiling faces exposed immediately afterwards (long enough to be identified) were seen as smiling slightly.

[1] See Hefferline, Keenan, and Harford, Science **130**, 1338 (1959). (The twitches were observed by registering their action currents, amplified one million fold.)

[2] Lazarus and McLeary, J. Person. **18**, 171 (1949); Psychol. Rev. **58**, 113 (1951).

[3] Cf. Lacey and Smith [Science **120**, 1045 (1954)] who refer back to K. Diven [J. Psychol. **3**, 291 (1937)] and J. G. Miller [*Feelings and Awareness* (New York 1950)]; also Ericson and Kuethe [J. Abn. Soc. Psychol. **53**, 203 (1956)]; and Razran [Psychol. Rev. **68**, 81 (1961)].

[4] Smith and Henrickson, Acta Psychol. **11**, 346 (1955).

Summing up the whole position, as Sectional President of the British Association for the Advancement of Science at its meeting of 1959, Vernon[5] acknowledged a ". . . type of perception of which we are not directly aware, but which nevertheless affects our actions in some ways."

These observations of subception strikingly confirm the relation between the subsidiary and focal awareness, as a relation between "awareness by relying on" for the purpose of an "awareness by attending to"—a relation that I had derived from the findings of Gestalt psychology. It would seem, therefore, that observations of subception are but an experimental demonstration of the integration of particulars to form a gestalt—the particulars being sometimes subliminal.

This view of the situation finds support in an analysis by Klein.[6] He notes that learning to avoid items inducing electric shock, without being able to tell which these items are, is but a variant of the way we recognise a physiognomy without being able to tell what features we distinguish it by.[7] Klein also offers evidence that subliminal activation is but a special instance of transient or incidental stimuli of all kinds. In his view it is not so much the subliminal status that is characteristic of such a stimulus than "the meanings and properties it acquires . . . at the periphery of thought and action."

This is consonant with my conclusion, that subsidiary awareness may range from a conscious level, down to levels altogether inaccessible to consciousness. I consider, therefore, that the evidence found for subception is an experimental illustration of the relation between a subsidiary and a focal awareness. And that, accordingly, *wherever I shall speak of the unspecifiable particulars that are known to us in terms of a comprehensive entity to which they contribute, I may be taken to speak of a form of subception.*

We now pass on to other forms of tacit knowing, the structure of which is similar to that of knowing a skill. We can find most of these taught in the laboratories and hospitals of universities. Among the main things taught there is how to identify specimens by their characteristic appearance.

Textbooks of diagnostics teach the medical student the several symptoms of different diseases, but this knowledge is useless, unless the student has learnt to apply it at the bedside. The identification of the species to which an animal or plant belongs, resembles the task of diagnosing a disease; it too can be learnt only by practicing it under a teacher's guidance. A medical practicioner's diagnostic ability continues to develop by further practical experience; and a taxonomist can become an expert, e.g., for classing new specimens of insects (of which 800 000 are known), only after many years of professional practice. Thus, both the medical diagnostician and the taxonomist acquire much diagnostic knowledge that they could not learn from books.

The art of recognizing a characteristic appearance by unspecifiable particulars is actually quite common. We practice it every day when watching the delicately varied expressions of the human face, and recognizing its moods without being able to identify, except quite vaguely, the signs by which we do so. This is also the way in which we commonly recognize a familiar face. Any description we can give of a person will usually apply equally to millions of other people, from all of whom we could distinguish him at a glance. The number of elements involved in such discrimination can be illustrated by the way in which the British police construct the likeness of a person whom a witness has seen. They use a slide file of 550 facial characteristics, such as different sets of eyes, lips and chins. The witness picks the individual features that most closely resemble his idea of the criminal's face, and from this selection a composite picture is assembled. Even so, such a picture can merely serve as one clue among others. For the identification of a person is such a delicate operation, that even a genuine photograph of him may not suffice. When Claus Fuchs was shown pictures of a man called Gold who was suspected of being his accomplice, he hesitated to identify him, and only when a film was shown of Gold walking about, did Fuchs recognize him. A witness may fail to recognize a person by a photograph, but pick him out at an identification parade.

We have seen that recent studies of subception have confirmed experimentally the fact that we can know how to discriminate a complex pattern of things, without being able to tell by what features we discriminate it. Though studies of subception have covered only a narrow section of unspecifiability and have thrown no light on its structure, they may convince even the most reluctant minds of the existence of unspecifiable knowledge.

The characteristic appearances of a disease; of the specimen of a species; of the mood in a face; of the identity of a person, I shall call their *physiognomy*. The structure of tacit knowing which recognizes a physiognomy resembles that of a skill. It is an intel-

[5] M. D. Vernon, Advancement of Science **16**, 111 (1959).
[6] George S. Klein, J. Nerv. Dis. **128**, 293 (1959).
[7] "It requires no experimental demonstration to say confidently that we are not aware of all the stimuli which we use in behavior," G. S. Klein, reference 6.

lectual skill, in which a complex pattern of delicately graded features takes the place of a dexterously coordinated set of muscular acts. We do not attend to these features and their pattern in themselves, but rely on our awareness of them for attending to the physiognomy to which they jointly contribute. Hence, we know a physiognomy but cannot tell, or only inadequately tell, how we recognize it.

We know the unspecifiable particulars of a physiognomy only in terms of its total appearance. They serve us as *clues*, which we have learned to integrate by a practiced effort of intelligence. Thus we achieve the *understanding* of a physiognomy, which is the intellectual counterpart of the *performance* of a skill.

Although the analysis of a physiognomy tends to make us lose sight of it as a whole, it will deepen our understanding of it if followed by a renewed integration of its separated elements; this is analogous to the effect of motion studies. Some of the clues to a physiognomy may be so slight as not to be noticeable in isolation, others are experienced on the same level of consciousness as the physiognomy to which they contribute. But when any particular clue of a physiognomy is isolated and thereby ceases to function as a clue, it looks different from what it looked like as a clue. Gestalt psychology, on which I am drawing throughout this attempt to establish the logic of tacit knowing, has given many examples of this fact.

The characteristic physiognomy of a man may be said to be the meaning of the clues which point to it; but a physiognomy is itself a clue to something else, namely, to the mood that it expresses, or, more generally, to the mind at work in it. The same principle applies to all other cases of skilful diagnosing. The comprehensive entity that we identify in meeting an acquaintance is not his appearance, but his person; the medical practicioner does not diagnose the appearance of a disease, but its presence; and the same is true when we identify a specimen of a species. We may say, also, that our performance of a skill presents a permanent coherent entity forming part of our bodily equipment, though such a practical entity is, admittedly, less substantial than the things comprehended by identifying a physiognomy.

Owing to the structural kinship of the two leading types of tacit knowing (the practical and the intellectual), these two are always found combined to some extent, and are sometimes found combined equally. This is true for the art of *testing* which is widely taught in practical classes and teaching hospitals. Medical percussion is a delicate skill combined with a joint appreciation of tactile and audible clues elicited by the percussion, and such a test is itself to be interpreted within a comprehensive set of other tests, all of which combine the exercise of practical and intellectual skills. We shall presently meet other intimate combinations of these two kinds of skills in the process of visual perception.

Meanwhile, I shall pass from the performance of tests to use of *tools* in general. Tools are akin to the particulars of a comprehensive entity, for an object is a tool by virtue of the fact that we rely on it for accomplishing something to which we are attending when using the tool. In this case we can, admittedly, identify the thing on which we rely, even though mostly we do not quite know how we actually use it. But it is still true that we cannot direct our attention to a tool as a mere object, while relying on it as the tool of a skilful performance. You must keep your eye on the ball, and if you look at your bat instead, you lose the stroke. A skilful performance is paralyzed by attending focally to its particulars, whether these are the dexterous movements of our body or the tools which we employ.

The skilful use of a tool actually identifies it to an important extent with our own body. The rower pulling an oar feels its blade tearing the water; when using a paper-knife we feel its edge cutting the pages. The actual impact of the tool on our palm and fingers is unspecifiable in the same sense in which the muscular acts composing a skilful performance are unspecifiable; we are aware of them in terms of the action our tool performs on its object, that is, within the comprehensive entity into which we integrate the effective use of a tool. The same is true of a probe used for exploring a cavity or a stick by which a blind man feels his way. The impact made by a probe or a stick on our fingers is felt at the tip of the probe or stick, where it hits an object outside, and in this sense the probe or stick is integrated to our fingers that grasp it.

A feature of great importance enters here in the way the assimilation of an instrument to our body is achieved gradually by learning to use the instrument intelligently. When first groping our way blindfold with a stick, we feel it jerking against our hand. But as we learn to understand these jerks in terms of the impacts of the stick against outer objects, we begin to feel the end of the stick knocking at these objects. Thus the jerks against our hand, when integrated to our purpose, undergo (along with a change in quality) *a transposition in space*. We see here that when a particular is integrated into a comprehensive entity it may acquire a meaning which is sensed at some distance from the original

position of the particular, at which it had been previously experienced in itself, meaninglessly. Other examples of such shifts, directed likewise away from our body, will be met in the use of language and the act of visual perception.

We can pass from probes to *language* by thinking of pointers. We rely on our awareness of a pointer in order to attend on what it points at, and this is its meaning. Seen in itself, as a mere object, the pointer is meaningless. Words used in speech and, more particularly, nouns, verbs, and adjectives, are used like pointers to designate things they mean. The comprehensive entity to which we are attending in meaningfully uttering such words is, to use E. C. Tolman's term, a sign-gestalt: It is our act of designating something and the means for doing so, when jointly experienced as pointing to that which we designate. Owing to the partial transposition of this experience to a distance, by which it is attached to the designated object, this object becomes in effect what we mean by our utterance.

When we identify the elements of speech to which we are not attending at the time of our utterance, and switch our attention to them, our utterance becomes meaningless. Repeat the word table, table, table, twenty times over, attending carefully to the sound of the movement of your lips and tongue, and the meaning of the word will become remote, and finally dissolve altogether. That is often expressed by saying that words used meaningfully are transparent and that, when we concentrate on a word as a sound, it becomes opaque. The transparent word is like a telescope through which we see its meaning—while, when rendered opaque, the word ceases to show us things beyond itself and blocks our sight by its own meaningless body. To make explicit our tacit knowledge of a spoken word is to destroy the comprehensive entity, the sign-gestalt, to which the word contributed.

This example of tacit knowing has extended the scope of the term. A *tacit coefficient* now appears to be integral to all explicit statements. The bearing of a statement on experience can only be known tacitly; no statement can carry conviction unless it is understood, and all understanding is tacit.

Tacit knowing can, indeed, be identified with understanding, if understanding is taken to include the kind of practical comprehension which is achieved in the successful performance of a skill. This being allowed for, understanding may be recognized as the faculty, cast aside by a positivistic theory of knowledge, which the theory of tacit knowing acknowledges as *the central act of knowing*. In this sense the practice of skills, the diagnosing of physiognomies, the performance of tests, the use of tools and probes, and the meaningful uttering of denotative words, are so many acts of understanding complex entities.

Finally, among the most primitive forms of knowing, we meet the act of *visual perception*, and find in it the very paradigm of that structure of comprehension that I have postulated for knowledge at all levels. Seeing has supplied Gestalt psychologists with material for their discoveries which I am expanding here into a theory of knowledge. They have shown that our seeing is an act of comprehension for which we rely, in a most subtle manner, on clues from all over the field of vision, as well as on clues inside our body, e.g., in the muscles controlling the motion of the eyes and in those controlling the posture of the body. All these clues become effective only if we keep concentrating our attention on the objects we are perceiving. Many of the clues of perception cannot be known in themselves at all; others can be traced only by acute experimental analysis; but all of them can serve the purpose of seeing, only if we make no attempt at attending to them in themselves. They must be left to abide in the role of particulars of which we are aware in terms of the spectacle perceived by our eyes, if we are to see anything at all. The clues on which we rely for looking at an object will then appear to us in terms of the shape, color, size, position, and other visible features of the object. This is their meaning to us; and this meaning is considerably displaced away from our body, where many of its clues are situated.

PART II

To introduce the bearing of my analysis of tacit knowing on some problems of philosophy, I shall deal with a question raised fairly recently by Brain. Having noted the curious fact that some patients feel part of their body to be an external object, the author raises the question as to how we normally distinguish our body from external objects.[8] He suggests that 'dropableness' is the quality by which a small object differs from a part of one's own body.

But we do distinguish our own body also from objects, whether small or large, that are not dropable. The distinction lies deeper. The unique character of our body lies in the fact that it is the only collection of things which we know almost exclusively by relying on our awareness of them for attending to some-

[8] W. Russel Brain, *Mind, Perception and Science* (Oxford University Press, New York, 1951), p. 18. ". . . 'dropableness' is the primary quality which distinguishes a small body from a part of one's body." The author says nothing about large bodies.

thing else. All parts of our body serve us as tools for observing objects outside us and for manipulating these for purposes of our own. Every time we make sense of the world, we rely on our tacit knowledge of impacts that the world makes on our body and of the responses of our body to these impacts. Hence, the exceptional position of our body in the universe.

But hence also our capacity for assimilating to ourselves things outside, by relying on our awareness of them for attending to something else. When we use a tool or a probe and, above all, when we use language in speech, reading, or writing, we extend our bodily equipment and become more effective and more intelligent beings. All human thought comes into existence by grasping the meaning and mastering the use of language. Little of our mind lives in our natural body; a truly human intellect dwells in us only when our lips shape words and our eyes read print.

Tacit knowing now appears as an act of *indwelling* by which we gain access to a new meaning. When exercising a skill we literally dwell in the innumerable muscular acts which contribute to its purpose, a purpose which constitutes their joint meaning. Therefore, since all understanding is tacit knowing, all understanding is achieved by indwelling. The idea developed by Dilthey[9] and Lipps,[10] that we can know human beings and works of art only by indwelling, can thus be justified. But we see now also that these authors were mistaken in distinguishing indwelling from observation as practiced in the natural sciences. The difference is only a matter of degree: Indwelling is less deep when observing a star than when understanding men or works of art. The theory of tacit knowing establishes a continuous transition from the natural sciences to the study of the humanities. It bridges the gap between the I–It and the I–Thou, by rooting them both in the subject's I–Me awareness of his own body, which represents the highest degree of indwelling.

We can extend this perspective to include a more ancient philosophical problem. Galileo, Locke, and their successors, have taught that external objects are merely masses in motion and that the sights, sounds, and smells which appear to belong to them, are not actually theirs but are generated in us by the impact of motions coming from them into our eyes, ears, and noses. Modern neurology has borne out the belief in the internal location of colors, sounds, and smells, by proving that they can be produced internally as afterimages, illusions, or hallucinations. Furthermore, it has gone beyond this by tracing the neural processes by which the external impact is conducted to the cerebral cortex and identifying the several cortical centers which produce our awareness of sights, sounds, and smells. Modern knowledge has thus added compulsive force to the philosophical problem: How do we come to know external objects, if our awareness of them is altogether internal?

The current remedy of analytic philosophy is to restrict the applicability of terms like 'seeing,' 'hearing,' 'smelling' to what is experienced by the speaker, disregarding the neural and cortical processes which underlie these experiences. This usage, however, is not acceptable, for it would ban the language of sense physiology and thus ignore all its discoveries.

An earlier school of thought, originating with Lord Russell, assumes that the sights, sounds, etc., arise inside the brain where room is made for them by postulating a private perceptual space, as distinct from the physical space in which the brain itself is located. Lord Brain developed this idea further by assuming that these sensory qualities are experienced in the brain not in themselves, but as symbols by which we become aware of external objects with their corresponding qualities of color, sound, smell, etc. Sensory experiences are compared to the pictures on a radar screen on which we can observe distant objects. But since the question is left open as to who interprets the symbols and by what means, or who watches the radar screen and how he interprets its signs, Lord Brain's explanation brings us back to the original question, how we come to know external objects, of which we are originally aware internally.

Let us look at this question within the framework of tacit knowing. Remember the way we know skills and physiognomies, make tests, use tools and probes, utter words, and the way I have fitted visual perception into the structure that applied to all other instances of tacit knowing. These were all shown to be particular instances of the fundamental fact that we are able to make sense of clues or particulars to which we are not attending at the moment, by relying on our awareness of them for attending to something else—so that the appearance of that to which we are attending, may be said to be the meaning of these clues or particulars. Once we had grasped this way of making sense, we also realized that the position at which the meaning of the clues appeared to be situated did not coincide with the position of the clues themselves and could lie in some cases nearer to, in others further away from them. We have seen that in

[9] Cf., e.g., W. Dilthey *Gesammelte Schriften* (Leipzig and Berlin, 1914–36), Vol. VII, p. 213–216; [translation by H. A. Hodges, *Wilhelm Dilthey* (Oxford University Press, New York, 1944), p. 121–124].

[10] T. Lipps, *Ästhetik* (Hamburg, 1903).

the use of tools and probes the impact that their handle makes on our hands and fingers is not felt in itself at the place where it happens, but as an impact of our instrument where it hits its object. A similar process of integration rendered spoken words transparent, their meaning being found in the things they designate. Visual perception appears then as yet another instance of relying on a wide variety of clues, some inside, some outside our body, for attending to their joint meaning, which in this case appears to us in terms of the shape, color, size, position, and other visible features of an object.

Many of these clues, particularly those inside our body, cannot be experienced in themselves by those who use them. Their existence is revealed only by the physiological observation of the bodily processes affecting the way a subject sees things. But this does not distinguish visual perception from other instances of tacit knowing. I have quoted an experiment showing that we can actually be trained to control external events by minute muscular contractions which are too weak to be felt in themselves. All the physiology of vision can thus be assimilated to previous instances of tacit knowing. The fact that the physiologist may be capable of tracing all the relevent clues of an act of visual perception without being able to rely on these clues for seeing what they mean to the subject, in the same way as he sees it, might be regarded as an instance of the destruction of meaning which takes place when we focus our attention on the isolated particulars bearing on a comprehensive entity. We may look upon this also as the difference between degrees of indwelling. The subject's awareness of his own neural processes has a much higher grade of indwelling than the physiological observation of them.[11]

One may distinguish, of course, between our awareness of subliminal impacts on, or in, our body and neural processes at cortical centers to which all stimuli are conducted; but this difference does not affect the issue. For we know that sensations which are primarily felt at some point of our body may come to be felt further out in space, for example at the tip of a probe, and that we can be conditioned to respond to impacts inside our body that are too weak to be felt at that point at all. Hence, if we were to assume that sensory experiences do occur in the first place in the cortex, we might still expect that a process of tacit knowing would make us sense them elsewhere; so that our assumption that they had occurred originally in a place where we do not feel them, would not present any new problem.

This view of the localization of sights seen does not tell us how such sights, or any other states of consciousness, arise from (or in conjunction with) neural processes. *This problem is set aside in this paper.* We only assume that whenever we *have* conscious experiences, we also have the power of integrating them meaningfully. It is by this power then that we see things as we do, and the fact that the physiologist does not see these things when observing the visual processes in the cortex, can be ascribed to the fact that he attends to these neural processes in themselves. The rest of this paper will serve mainly to consolidate and elaborate this conclusion.

It is interesting to compare, with this in mind, the process of integration by which we arrive at tacit knowing, with a formal process of inference by which we might arrive at the same conclusion. Optical illusions offer a good example for such an enquiry. In a famous experiment of Ames we are facing the wall of a room in which we see one corner occupied by a small boy and the opposite corner by a grown man. An illusion makes us see the boy as taller than the man. This is due to the skew shape of the room, which we had not noticed. In this room, the distance between ceiling and floor is much less at the other corner where the man is placed. At the same time the boy's corner is nearer to us than the man's. Helmholtz (1866) has described perception, including optical illusions, as the result of unconscious reasoning. In this case the premise of such reasoning would be, that rooms are right-angled parallelepipeds in which (1) the distance between ceiling and floor is everywhere the same and (2) from a point facing the middle of a wall the two corners of the wall are equidistant. Hence a boy whose head touches the ceiling is taller than a man whose head leaves a gap of a foot or so under the ceiling; the more so, if the angle of vision enclosing the boy, from head to foot, is correspondingly larger than the angle under which the man is seen. To be more precise, we would have to introduce an intermediate state of reasoning which causes us to see the skew shaped room as if it were normal. The experiment is arranged in such a manner that from the point from which we view the room, the angles of vision by which we see its corners are the same as they would be for a normal room. This fact is taken to confirm with respect to the room in

[11] This is not to accept the distinction of two kinds of experience, one from inside, the other from outside. The physiologist's view of organs and their functions is an internal comprehension of a living being, compared with a purely physical and chemical topography of a living body which would contain no such understanding. I am envisaging a continuous range in degrees of indwelling; not two aspects, one from inside, the other from outside.

front of us, our major premise, that all rooms are right-angled parallelepipeds.

In terms of tacit knowing we would say that we rely on our awareness of numberless rooms seen before, and of the other elements of the framework within which the two figures are presented to us, and integrate all these particulars into the way we see the boy and the man on whom our attention is focused.

Optical illusions cannot, as a rule, be dispelled by recognizing them to be illusory, and psychologists have refused to follow Helmholtz in describing as unconscious reasoning a process which compels our assent to what we know to be false. The question is whether we can substantially recast this discussion by classing an optical illusion as a case of mistaken tacit knowing.

I think we can, for the analysis of an optical illusion in terms of an unconscious inference corresponds to a process that fulfills an important function in respect of all manner of tacit knowing. It belongs to the same class as (1) the analysis of skills by motion studies, (2) the characterization of a physiognomy by listing its typical features, (3) the giving of detailed directions for carrying out a test or using a tool, (4) the analysis of speech by grammar, and (5) the physiological analysis of perception.

This may appear a bewilderingly disparate collection, remote from the interpretation of optical illusions as a process of unconscious reasoning. And this impression is hardened if we realize how vast are some of the areas I have set out here. Motion studies should be taken to include the practical teaching of every kind of artistic performance, of all skilled workmanship, and all manner of sports. The analysis of physiognomies covers an even richer field. It includes, along with the diagnostics of medicine and taxonomy, all criticism of art and literature, by which our understanding of paintings, architecture, music, poetry, drama, and fiction is educated, guided, and deepened. The analysis of speech includes, in addition to grammar, the study of voice production and phonetics, as well as lexicography, stylistics, and rhetoric. The field extends further to analytical philosophy, which studies language rules, with a view to the clarification of philosophic problems. Finally, the theory of perception, which stands last on my list, is but an example of the whole range of sense physiology with its roots spread over anatomy, neurology, and psychology, with the selection of its particular subjects taken from the entire range of the animal kingdom.

Yet all these inquiries have it in common with each other and with the analysis of optical illusions, that they attempt to understand acts of tacit knowing in which we attend to something by relying on our awareness of elements that we are not attending to in themselves at the time. These acts might be loosely called intuitive to distinguish them from processes of explicit reasoning, and the inquiries I have listed can then be said to be directed towards discovering explicit rules, the operations of which would be equivalent to these intuitive actions. These rules would have both to specify the particulars on the awareness of which intuition relies for attending to a comprehensive entity formed by them, and to spell out the integrative relations by which the particulars form such entities.

If such formalization of tacit knowing were possible, it would convert all arts into mathematically prescribed operations, and thus destroy them as works of art. The analysis of art can be profoundly revealing, but only if it remains incomplete. It must limit itself to the discovery of maxims, the application of which is itself a work of art. However greatly it may profit from incorporating a skeleton of such maxims, the originally tacit act will still remain tacit, for it will rely on a subsidiary awareness of its maxims and keep their application under tacit control.

We can see also, accordingly, that in optical allusions, such as that which makes us see a boy taller than a grown man, 'unconscious reasoning' can serve only as the kind of rule which leaves open important alternatives to be decided by a tacit act of the subject. Instead of the premise "all rooms are rectangular parallelepipeds," which leads to the conclusion that a young boy can be taller than a grown man, we could use the premise "young boys are smaller than grown men," and reach the conclusion that a room can be skew-angled, which would dissolve the illusion and thus show that its formalization as of unconscious reasoning does not explain why the eye prefers to see the illusion.

The reason for this preference lies in the fact that we irresistibly see the room as having a normal shape. Our subsidiary awareness of a great many normal rooms presents itself to us in terms of our seeing the room in this way. Most of these rooms cannot be identified. We cannot remember more than a few of the thousands of regular shaped rooms that we have seen in the past. Yet it is the joint weight of these memories at the back of our mind that is effective, as is shown by the fact that primitive people who have seen fewer normal rooms are less susceptible to this kind of illusion.[12] Moreover, an undefinable

[12] Cf. G. W. Allport and T. F. Petigrew, J. Abn. Soc. Psych. 55, 104 (1958).

range of external clues can destroy the illusion. For example, if we are allowed to tap the wall of the room with a stick, at some point the cumulative effect of such clues will cause the skew room to emerge and the illusion to be destroyed.

This exemplifies the rival attraction of two alternative ways of seeing a system of clues. The one which preponderates over the other for any particular configuration, may be said to be more readily integrated, or otherwise preferred, by the observer. Gestalt psychology has attempted to define the qualities of a figure which facilitate its integration, but my present paper will not go into this question. I merely accept it, for example, that integration can be destroyed by focusing attention on the individual particulars and that this is favored by certain ways of looking at the integrated whole, e.g., from very near. More about this later.

The process by which the conception of a normal room is formed here, and a particular object identified as an instance of it, bears on an ancient problem of philosophy, the elucidation of which will throw further light on the powers of tacit integration and the limit set to a formalization of these powers.

Plato was the first to be troubled by the fact that *in applying our conception of a class of things, we keep identifying objects that are different from each other in every particular*. If every man is clearly distinguishable from another and we yet recognize each of them as a man, what kind of man is this, as which all these men are recognized? He cannot be both fair and dark, both young and old, nor brown, white, black, and yellow at the same time; but neither can he have any one of these alternative properties, nor indeed any particular property whatever. Plato concluded that the general idea of man refers to a *perfect man* who has no particular properties, and of whom individual men are imperfect copies, corrupted by having such properties.

That something so utterly featureless as the concept of man should have such a perfectly characteristic nature, presents great difficulties which have occupied philosophers ever since Roscelinus raised them close to 900 years ago. But his own view, that the word 'man' is but the name for a collection of individual men, leaves open the question how we can justify the labelling of a collection of different individuals by the same name—a question that is further accentuated by our expectation that we shall yet be able to subsume under this label future instances of men differing in every particular from any man thus labeled before. The difficulty is not eliminated by specifying the characteristic features of man, since in doing so we must again repeatedly use one name for instances of a feature that are different in every particular.

All these difficulties arise only because we are seeking *an explicit procedure* for forming collections of objects which can be justifiably designated by the same universal term. Let us watch instead the way in which perception identifies certain objects according to their nature. The illusion of seeing a skew room as normal should remind us of the fact that in thousands of other cases we have correctly seen normal rooms as such, however different each was from the other, and however different the angles were under which we saw any particular room at a particular moment. It also demonstrates that the identification of particular things goes on without naming them, which is confirmed by the fact that animals readily identify members of a class, though they have no language. What is at work here is a process, common to all manner of perception, in which we rely on our awareness of a great many clues to which we are not attending at the time, for seeing things in a particular way which is the meaning of these clues comprehended by us.

We must note here that the problem of how a universal concept is formed is part of the problem of empirical *induction*. All attempts to formulate strict rules for deriving general laws from individual experiences have failed. And one of the reasons is again, that each instance of a law differs, strictly speaking, in every particular from every other instance of it. Such indeterminately variable experiences can indeed be subsumed under the same law only by relying on our awareness of them as clues to it. And just as for perception, many clues of empirical induction will be easily identified in themselves, while many will not be, and not all of them can be, identified. In other words, the scientist's "hunches" may be based to a greater part on subception. And just as a keen eyesight enables one to discriminate objects that others cannot see, so does a gift of scientific discovery reveal natural laws in a scientific experience, which signifies nothing to others not so gifted. Those who insist on finding a formal procedure of induction, would reject the acknowledgment of such powers of discovery, as mysterymongering. Yet these powers are not more mysterious than our powers of perception but, of course, not any less mysterious, either.

But am I not, in fact, disposing of an enigma by postulating a miracle? Not altogether. I am interpreting the formation of class concepts (along with the discovery of natural laws) as based ultimately on a precess of tacit knowing, the operations of

which I have exemplified in the learning of skills, the recognition of physiognomies, the mastery of tests, the use of tools, the uttering of speech, and the act of visual perception. The powers of integration which achieve these acts have the same structure throughout. And I believe that it can be shown, though this lies beyond the scope of this paper, that they are all variants of the same organismic process.

Two points concerning the formation of concepts require special attention. First, we are assuming here that our integrative powers can resolve the apparent contradiction involved in taking an aggregate of objects which differ in every particular, to be nevertheless identical in some other way. Is there any evidence that tacit knowing can establish a uniform meaning for clues, which, regarded in themselves, have nothing that is the same in them? The answer is that tacit knowing can in fact integrate conflicting clues in various ways. In the Ames experiment the sight of a boy and a grown man contradicts the distance of their heads from the ceiling of the room, and perception integrates these contradictory clues by presenting the boy as taller than the man. This solution is admittedly illusory; but there is an important case when conflicting visual clues are integrated to a true sight. We fuse the two different pictures of an object cast on the retina of our eyes by forming its stereoscopic image. Here perception resolves a contradiction by revealing a *joint meaning* of conflicting clues in terms of a *new quality*. A similar synthesis is achieved when we hear a sound as coming from a definite direction by combining its impacts that reach first one ear and then the other. This is also what happens in the formation of a general conception.

But there is also an important difference, which faces us as the *second point* to which we must attend. It lies in the curiously *unsubstantial character* of the joint meaning ascribed to a group of objects by a general term. Compared with optical illusions or stereoscopic images, general conceptions are abstract, featureless. The focus in terms of which we are aware of the members of a class appears vague and almost empty. We may ask whether there are other instances of tacit knowing of a similar structure. The question brings up yet another traditional problem of philosophy the clarification of which will help to consolidate and elaborate further the conception of tacit knowing.

I have said that when we are attending to the joint appearance of the particulars composing a man's physiognomy, we are attending to his person, and that when we watch the mood expressed by his face, we are watching his mind at work in his face. Two things are apparent here. First, that tacit knowing may penetrate its object in stages. We may first recognize a man, then discover what he is doing, then again realize what his motives might be, and eventually reconsider our conception of his personality. An aspect apprehended by the integration of elementary particulars thus becomes, in its turn, a clue to a more comprehensive entity, and so on. I have also hinted that we thus gradually penetrate to things that are increasingly real, things which being real, may yet manifest itself on an indeterminate range of future occasions.

I can only deal briefly here with this analysis of the mind, which I have carried out at some length elsewhere. It should illustrate here the fact that, as we move to a deeper, more comprehensive, understanding of a human being, we tend to pass from more tangible particulars to increasingly intangible entities: to entities which are (partly for this reason) more real: more real, that is, in terms of my definition of reality, as likely to show up in a wider range of indefinite future manifestations.

The time sequence used for this description must not be taken literally. We usually take in all levels of a person to some extent straight away. We certainly recognize a human face at first sight and can say only from a subsequent analysis, and then rather inadequately, by what particulars we recognized it. If we could ever see the fragments of a face without realizing their coherence as parts of a face, we could not distinguish them from other things around them. This is actually true for any object and is more easily demonstrable for other objects than human faces. An object becomes invisible if its particulars cannot be picked out against a distinctive background, as for example, when it is camouflaged. We then see the particulars of the object, but do not know which of them belong to the object that we do not see and may not even know about.

The position thus reached shows the impossibility of behaviorism. It follows from it that we can identify tangible manifestations of mental processes only by first recognizing the mind at work in them; that in fact a rational pattern of behavior must be comprehended as a whole, before we can set out to analyze it; and finally, that if we did succeed, *per impossibile*, in keeping track of the elements of mental behavior without reference to mind, these particulars, observed in themselves, would remain meaningless, and experiments conducted with these meaningless fragments would also be meaningless. The actual practice of behaviorist experimental

psychology is rescued from this fate, by tacitly relying on the mental interpretation of its observations, which are then translated into an objectivist language.

The present analysis also differs from that of Ryle[13] by the distinction of two kinds of knowing. If, as I suggest, we know the mind by relying on our awareness of its workings for attending to their joint meaning, then Ryle's conclusion that the workings of the mind *are* the mind, is like saying that the word 'table' *is* a table.

What I have said about the mind also bears on the theory of *phenomenalism*. This doctrine teaches us to look upon sense data as our ultimate information about the outside world, and to regard our knowledge of the objects to which sense data refer, as based on inference from these data. This gives rise to the insoluble problem of the manner in which such inference can be carried out.

The school of linguistic analysis disposed of this problem by affirming that we never perceive sense data as such, but are aware of them only as the qualities of objects, which are what we actually do perceive. This view, however, fails to account for the fact, demonstrated by the experiments on apes brought up in the dark, that learning to see needs considerable time and effort; a fact confirmed for human infants by observations on their eye movements. Before they learn to see objects, both apes and babies do in fact see sense data, that is, patches of light and color. And this is the case also when normal adults observe the meaningless fragments of a puzzling sight and have to make an intelligent effort in order to see the objects of which these are the qualities.

Such an effort is a process of tacit integration by which the object is recognized as the meaning of the sense data which constitutes its appearance. It is not a process of explicit inference, and hence the question of the ways in which such inference can be conducted does not arise. The same is true for the insoluble question of the way in which the existence of other minds is inferred. It does not arise; for we know other minds, not by explicit inference, but by a tacit process of integration. This solution of the problem of other minds differs from that proposed by Strawson, who shows by linguistic analysis, that the doubting of the existence of other minds is self-contradictory.[14] This proves that modern usage implies belief in other minds. But in the language of Azande it is self-contradictory to doubt the efficacy of oracles, and this only proves that Zande language cannot be trusted in respect of oracles.[15]

The view of our knowledge of solid objects and of a person's mind, as the meaning of their particulars, restores the metaphysical notion of common sense, which speaks of things and a person's mind as distinct from the clues by which they happen to manifest themselves to the observer. And the same can be claimed then for universals: They are the joint meaning of things forming a class. This meaning is something real, for, to repeat my phrase, it is capable of yet manifesting itself indefinitely in the future.

It has, indeed, an heuristic power that is usually twofold. (1) A universal concept usually anticipates the occurrence of further instances of itself in the future, and if the concept is true, it will validly subsume these future instances in spite of the fact that they will unpredictably differ in every particular from all the instances subsumed in the past. (2) A true universal concept, designating a natural class, for example a species of animals, anticipates that the members of the class will yet be found to share an indefinite range of uncovenanted properties; i.e., that the class will be found to have a yet unrevealed range of intension.

This illustrates the most striking powers of tacit knowing, owing to which we can focus our attention on the joint meaning of particulars, even when the focus to which we are attending has no tangible center. It represents our capacity to know a problem. A problem designates a gap within a constellation of clues pointing towards something unknown. If we

[13] Gilbert Ryle, *The Concept of Mind* (Barnes and Noble, Inc., New York, 1950).

[14] P. F. Strawson, *Individuals. An Essay in Descriptive Metaphysics* (Humanities Press, Inc., New York, 1959), p. 107. The argument is based here on the special character of '*P.* predicates', i.e., predicates referring to persons. "For just as there is not in general one process of learning . . . an inner private meaning of predicates of this class, then another process of learning to apply such predicates to others on the strength of a correlation, noted in one's own case with certain forms of behavior, so—and equally—there is not in general one primary process of learning to apply such predicates to others on the strength of behavior criteria, and then another process of acquiring the secondary technique of exhibiting a new form of behavior, viz., first-person *P.*-utterances." The author then goes on to warn that one must not couch one's rejection of this structure in the language of that structure.

[15] E. E. Evans-Pritchard, *Witchcraft, Oracles and Magic among the Azande*, (Oxford University Press, New York, 1937). "Let the reader consider any argument that would utterly demolish all Zande claims for the power of the Oracle. If it were translated into Zande modes of thought it would support their entire structure of beliefs" (page 319). "They reason excellently in the idioms of their beliefs but they cannot reason outside or against their beliefs because they have no other idiom in which to express their thoughts" (p. 338). Mr. Strawson would rightly conclude that belief in poison oracles is part of Zande metaphysics, which can be descriptively studied in the logical structure of their language. But this would show only that Azande would have to use a different language (or use Zande language with a new meaning) if they wanted to repudiate their present metaphysical beliefs.

hold a problem to be a good one, we also imply that this unknown can yet be discovered by our own efforts, and that this would be worth these efforts. To undertake the search for the solution of a problem is to claim the faculty of sensing the increasing proximity of its solution—since no inquiry can succeed without such guidance. In all these anticipations, essential to any scientific endeavor, we focus our attention on a center that is necessarily empty.

This brings into sight once more the process of empirical *induction*. I have noted the heuristic powers of a true universal conception, and have now consolidated the idea of such powers by pointing out our capacity to recognize problems, to know good problems from bad ones, and to pursue these successfully, by feeling our steady approach to their solution. The work of the scientist consists in doing all these things. He notices clues that seem significant, and, if he is an experimenter, tries to turn up new clues that would give him further guidance. All the time his attention is fixed on the meaning of the clues he has collected so far, while he is feeling his way towards new ideas and new evidence, by following his sense of approaching discovery. This procedure does not essentially differ from that of perception, to which I have affiliated it. Any sustained effort to make out what confronts us in a confusing configuration of sights, is an exercise of similar powers of searching for clues by sensing the nearness of a significant shape to which they might tend to crystallize.

I have said that the capacity to know a problem is the most striking instance of our powers to integrate the meaning of a set of particulars by fixing our attention on a gap behind which we anticipate the presence of yet hidden knowledge. Before developing this further, let me recall that we had already recognized these heuristic powers in a less dynamic form wherever we rely on our awareness of particulars for establishing the presence of a comprehensive entity. For this was always viewed as something real, which being real, might be expected yet to manifest itself at some future time in unexpected ways. I have shown how this confirmed in its own way the common sense metaphysical belief that solid objects were something beyond the aggregate of their observed properties and that the mind is something beyond its overt manifestations; I have also shown that this conception of meaning reveals the thing that is named by a universal term. But it is still the course of scientific inquiry in which the metaphysical conception of a reality beyond our tangible experience is written out most clearly, for all to see. From its very start, the inquiry assumes, and must assume, that there is something there to be discovered. The fascination, by which alone the inquiry can make progress, is fixed on discerning what it is that is there, and when discovery is achieved, it comes to us accredited by our conviction that its object was there all along, unrecognized. The rise, the path, the end, all point at the same reality and cannot but tell of it. Swearing by the existence of this reality, the scientist imposes on himself the discipline of his vocation. And his sense of approaching nearer to reality is not exhausted by the consummation of discovery. It persists in the belief that what he has discovered is real, and being real, will yet mark its presence by an unlimited range of unsuspected implications. Deemed to be an aspect of reality, the new knowledge is believed to be fruitful and is claimed to be universally valid.

Here we meet the conception of truth. Modern antimetaphysical philosophies, like pragmatism, operationalism, positivism, and logical positivism, have tried to spell out the implications of asserting a proposition to be true. But if the truth of a proposition lies in its bearing on reality, which makes its implications indeterminate, then such efforts are foredoomed. They have in fact failed, and must fail, for the indeterminate cannot be spelt out without making it determinate. It can be known in its indeterminate condition only tacitly, by those tacit powers by which we know more than we can tell.

The antimetaphysical analysis of science assumes that the logical foundation of empirical knowledge must be capable of definition by explicit rules. While the difficulties of this enterprise have not gone unnoticed, the reluctance to abandon it in principle still seems universal. My attempts to acknowledge tacit powers of personal judgment as the decisive organon of discovery and the ultimate criterion of scientific truth, have been opposed, by describing these agencies as psychological, not logical, in character. But this distinction, going back to Kant's separation of the phenomenal from the noumenal, is not explained by my critics. Is an act of perception which sees an object in a way that assimilates it to past instances of the same kind, a psychological process or a logical inference? We have seen that it can be mistaken and its results be false; and it certainly has a considerable likelihood of being true. To me this suggests that it is a logical process of inference even though it is not explicit. In any case, to perceive things rightly is certainly part of the process of scientific inquiry and to hold perceptions to be right, underlies the holding of scientific propositions to be true. And if, in consequence, we must accept

the veridical powers of perception as the roots of empirical science, we cannot reasonably refuse to accept other tacit veridical processes having a similar structure. This is what I have been urging all along since I first wrote ". . . that the capacity of scientists to guess the presence of shapes as tokens of reality, differs from the capacity of our ordinary perception only by the fact that it can integrate shapes presented to it in terms which the perception of ordinary people cannot readily handle."[16] And this is what I have tried to elaborate also in my present paper.[17]

PART III

This concludes the philosophic survey set in motion by pondering the strange fact that the experience of our senses is somehow to be accounted for in terms of neural processes within our body. In conclusion, I shall deal now with the general context of the distinction between primary qualities representing the objective reality of all things and secondary qualities deemed to be subjective. Galileo's vision of a universe consisting ultimately of masses in motion, has ruled the minds of scientists and philosophers until the end of the nineteenth century, when it was first seriously modified within physics itself by the discovery of the electrical character of ultimate particles. Today we would have to regard as the primary qualities of the universe the parameters (statistical functions) determined by physics, and to ask how these give rise to the additional qualities of colors, sounds, tastes, and smells by means of a particular configuration of these parameters within the nervous system.

However, it will be simpler, and involve no loss of generality, if I set out the Laplacean vision in terms of its original model of primary qualities consisting of the masses, positions, velocities, and forces of ultimate particles. Laplace declared that the prediction of this configuration for the universe would supply us with a knowledge of "all things to come." It was always agreed that we were technically incapable of establishing the initial configuration on which to base such calculations and that we could not possibly carry out these calculations even if we knew the original configuration. But it has never been doubted that if we were presented with the complete atomic configuration of the universe at any moment, we would know about it everything that we might conceivably want to know. This is what I shall contest here.

The law of irreversibly increasing entropy governs the fundamental processes of equilibriation in nature. But the entropy of a system cannot be computed from a knowledge of its atomic configuration, for it is measured by the extent to which this configuration is uncertain. This argument can be made more definite by assuming quantization. The entropy of a precisely known atomic configuration is, then, zero and remains zero throughout the future; equilibriation by increasing entropy does not take place. We can have equilibriation only if we introduce conceptions of probability, by assuming that the configuration of atoms is to a considerable extent uncertain.

We meet with the same kind of situation wherever we assess chances. If, in throwing dice, we know the exact physical particulars of our throws and hence could predict their outcome, the probability of any particular sides of the dice turning up would be inconceivable, and no actions based on such probabilities (e.g., betting) could be justified. Even so in physics, if all atomic particulars were specified, processes governed by probabilities, e.g., irreversible equilibriations, would be inconceivable and their actual occurrence could not be accounted for. We may regard, therefore, such processes as comprehensive features, which disappear when their particulars are specified in terms of a Laplacean topography.

This illustrates the logical deficiency of the Laplacean conception of universal knowledge at an elementary level. It faces us, more generally, in the fact that questions in which we are interested arise in the context of experiences which do not consist in atomic configurations, and which may not be derivable from the conceptual framework of atomic configurations.

Let me illustrate this further by the example of machines. Machines are solid structures made up of several parts, which have their several functions in the operation of the machine. Thus a machine can be described as a particular configuration of solids. The description would state the materials and shapes of the parts, and the boundary conditions by which they are joined together as a system. But this could describe only one particular specimen of one kind of machine. It could not characterize a class of machines of the same kind, which would include specimens of different sizes, often of different materials, and with an infinite range of other variations. Such a class would be truly characterized by the operational principles of the machine, including the principles

[16] M. Polanyi, *Science, Faith and Society* (Oxford University Press, New York), p. 10.

[17] I would emphasize at this point once more that the origin of the veridical powers of tacit integration lies beyond the scope of this paper; I am concerned here only with defining their structure and illustrating their range.

of its structure. It is by these principles, when laid down in the claims of a patent, that all possible realizations of the same machine are legally covered; a class of machine is defined by its operational principles.

What conceptions, if any, are introduced here that cannot be derived from an atomic topography? Let us suppose, for the sake of simplifying the argument, that the difficulties of deriving the laws of physics and chemistry from a Laplacean knowledge of the world's atomic configuration can be overcome. We may observe then (1) that a particular specimen of a machine is characterized by the nature of its materials, by the shape of its parts and their mutual arrangement, which can be defined by the boundary conditions of the system,[18] and (2) that the laws of physics and chemistry are equally valid for all solids, whatever their materials and shapes, and the boundary conditions determining their arrangement. From which it follows that neither the materials nor the shapes of the solids forming part of a (particular) machine, nor their arrangement, can be derived from physics and chemistry. And that hence physics and chemistry cannot account for the existence of a machine, cannot even identify a machine as a machine, and still less identify its workings and account for these.

This limitation becomes clearer if we consider a *class* of one type of machine, for example, steam engines. Such a class, could be effectively covered by a patent or be referred to in a trade agreement. The description of the principles on which steam engines are constructed and operated would enable a court of law to decide whether an object is a steam engine or not, and even to identify damaged engines that do not work. In order to account for the existence of such a class in terms of physics and chemistry, it would be necessary to derive from the laws of physics and chemistry a general relationship of materials and shapes of a group of solids, of their mutual arrangement, given by the boundary conditions of the system, and their purpose, which would jointly characterize all objects that are steam engines, even when broken down.

In order to envisage this task, we shall assume that an individual specimen of a certain type of machine has been fully described in terms of its physical and chemical topography. The task is then to identify and generalize such features of this topography as characterize a steam engine, including one that has broken down. The laws of thermodynamics will of course be referred to in any such generalization. But these laws do not define the steam engine: A steam engine is something that relies on these laws for its workings. To define a steam engine is to tell in what way it utilizes the laws of thermodynamics and other laws of physics and chemistry. Any principles utilizing the laws of physics and chemistry are compatible with these laws, and therefore no special set of these principles can be derived from physics and chemistry. That is why these principles are part of a distinctive science, the science of engineering. Engineering deals with principles of technical success, and hence can also identify technical failure, as in broken down steam engines.

It follows that even if physics and chemistry could be derived from predictions of atomic topography, the existence of the machines could not be stated, let alone accounted for, in these terms. And, accordingly, the knowledge of engineering (as defined above) and of all problems of engineering, as well as of inventions and arguments conducted in terms of engineering, would be absent in a knowledge of the physical and chemical topography of the universe, and, *a fortiori*, in its atomic topography.

The nature of this limitation is logical. Its reasons are of the same kind as those for which physics and chemistry cannot identify a printed page (even though printing relies on the laws of physics and chemistry), nor tell us what the print says.

I have argued this conclusion extensively, as much because of its general significance, as for its particular bearing on biology. Physiology is the study of the operational principles by which living things survive and propagate themselves. There is some difference of opinion today whether all living functions are machine-like; the *predominant view* is that they are all machine-like. I am not concerned here with the question whether or not this view is true; my argument bears on the *unanimous view*, held by both sides of the controversy, that the machine-like explanation of physiological functions is equivalent to their explanation in terms of physics and chemistry. My demonstration that machines cannot be accounted for in terms of physics and chemistry applies equally to the machine-like operations of animals. I must conclude, therefore, that to equate any machine-like explanation with an explanation in terms of physics and chemistry is a logical absurdity. This does *not*

[18] The purpose served by a device may also be decisive for its identification. Some years ago Phillips (Eindhoven) and United Incandescent Lamps (Ujpest) were in conflict about the question whether the newly invented sodium discharge lamps were to be classed as 'neon lights' under an agreement to which both firms were parties. An important point made for *not* classing them thus, was that sodium lights are used for *seeing by them* and neon lights for *being seen*.

mean that these mechanisms could not have come into existence phylogenetically by processes of physics and chemistry. I myself do not think this is possible, but physiology is not a theory of evolution, and I do not include evolution in my conclusions here, any more than physiologists do, when saying that they are explaining physiological functions in terms of physics and chemistry.

Let me return then to my general argument. The Laplacean conception of universal knowledge, which is but a particular illustration of the theory of primary qualities on which science has been based since Galileo, has always been thought to require a superhuman mind capable of collecting the initial data and then calculating future atomic constellations. But it has been consistently overlooked that at this point the universal mind meets with more fundamental difficulties. I believe that I have shown (1) that there is no evidence to suppose that the "universal knowledge" conceived by Laplace would answer any questions that we are interested in; (2) that to find out the entropy, temperature, and pressure of a system from a Laplacean universal knowledge requires estimates of probability, a conception not derivable from an atomic topography; (3) that all engineering and technology comprising operational principles lies logically beyond the range of Laplacean knowledge; and (4) that the same is true for the operational principles established by physiology as the functions of living things.

The list could be extended indefinitely. An obvious case to be added would be the impossibility of accounting for sentience in terms of the primary qualities defined by physics. But enough has been said to substantiate a general conclusion in terms of the principles of tacit knowing explained in this paper. Atomic configurations are the ultimate particulars assumed to be underlying all the manifestations of more comprehensive entities in the universe. We have seen that the particulars of such entities lack the meaning which the entities possess. Consequently when we focus our attention on the ultimate particulars of the universe we are facing things which have the least possible meaning. A Laplacean mind that would compute from the present virtually meaningless atomic topography of the world its future similarly meaningless topography, would not materially advance our knowledge of the world, let alone represent a universal knowledge of it.

The world could be known from such a topography only if we had the power to integrate it by an act of tacit knowing. But such powers are far from unlimited. The integration produced in the Ames experiment with the skew room, is irretrievably lost by looking at the arrangement from a "forbidden angle." There is a well known guessing game which makes use of the fact that photographs taken from an unusual angle make familiar objects unrecognizable. The full range of colors produced according to Land, by super-imposing two monochromatic optical images, disappears when we look at the two components separately. All patterns vanish if we scan them through a sufficiently strong magnifying glass. (I repeat that these limits of our integrative powers are accepted in this paper as facts, without enquiring into their origin).

This should suffice to explain the obvious facts that no human intelligence could apprehend, by looking at an atomic topography of a frog, that it *is* a frog, nor understand from the frog's computed future topographies, the physiology of a frog. And, of course, what is true for its atomic topography, is equally true for a physical-chemical topography of the frog; we could perceive in it nothing of the frog.

If we could rely on our awareness of the data forming a topography for attending to their joint meaning, the topography would become transparent, in the same sense as a text is transparent when we read and understand it. But since this is not possible, it can only block our view by its meaningless body—even as a text does, when we concentrate our attention on its physical details.

When one reaches the conclusion that an assumption widely taken for granted during a long time is patently false, one asks oneself, how such an error could have arisen and been perpetuated. The answer in this case is not far to seek. The Laplacean conception of universal knowledge, as well as its modern equivalents, are models of a completely formalized, or mathematical, representation of the universe. And ever since the middle of the eighteenth century, science has inflexibly set itself the ideal of casting all knowledge into mathematical form. Descriptive sciences were to be regarded as imperfect, immature branches of knowledge, that would sometime be replaced by definitive mathematical formulations.

But this ideal is logically absurd. Imagine a set of mathematical formulas that would answer any questions that we might ask about matters of experience. The object of such experience must be other than the mathematical formulas which are to explain it and hence these formulas are meaningless unless they bear on non-mathematical experiences. In other words, we can use our formulas only after we have made sense of the world to the point of asking questions about it and have established the bearing of

the formulas on the experience that they are to explain. Mathematical reasoning about experience must include, beside the antecedent non-mathematical finding and shaping of experience, the equally non-mathematical relating of mathematics to such experience and the eventual, also non-mathematical, understanding of experience elucidated by mathematical theory. It must also include ourselves, carrying out and committing ourselves to these non-mathematical acts of knowing. Hence a mathematical theory of the universe claiming to include its own bearing on experience would be selfcontradictory in the same sense as the conception of a tool would be if the tool were described as including its own user and the things to which it was to be applied.

Knowing is a process in two stages, the subsidiary and the focal, and these two can be defined only within the tacit act, which relies on the first for attending to the second. But again, why should this fact have been overlooked and a false ideal of science been perpetuated for centuries? Because the moment we admit that all knowing is rooted in an act of personal judgment, knowledge seems to lose all claim to objectivity. I have hinted at a way out of this difficulty by my definition of reality, and a substantial treatment of it has been given elsewhere. But the answer will yet have to be worked out fully in the future.

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The Transmission Coefficient in Reaction Rate Theory

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ALTHOUGH an equilibrium constant is defined when the particular reaction is specified, this is not true for either the forward or backward specific rates. Only the ratio is fixed and this equals the equilibrium constant. The mechanism leading to equilibrium often shifts with the conditions. Astronomy provides many examples of the effect of dilution on relaxation times. In our solar system the orbits of the planets, after billions of years, still cluster about the ecliptic. This is eloquent testimony of the rarity of collisions with other heavenly bodies. This example points up the fact that any useful statement of the ergodic hypothesis that strives to attach equal statistical weight to positions in phase space, having equal energies, must recognize a hierarchy of relaxation times. Regions of phase space connected by frequent transitions may be considered in equilibrium only when calculating much less frequent transitions. The rarity of collisions that disturb our solar system contrasts with the 10^{10} collisions per second which a molecule undergoes near atmospheric pressure. Almost every thousandth encounter at atmospheric pressure is a triple collision. This is important for the rate of recombination of atoms and radicals, since roughly a tenth of the triple collisions involving three hydrogen atoms abstract enough energy from a pair to leave it a stabilized molecule.[1,2]

In such a recombination, one of the three atoms may be replaced by any other molecule or by the wall, often with enhanced efficiency. If a molecule, or the wall, forms a complex with an atom, the percentage of collision between atoms involving a third body is increased proportionately. This speeds up the association reaction. At the very low hydrogen pressures of interstellar space, however, where radiation dissociates the hydrogen molecules, recombination of the atoms by a third-body collision is so infrequent that even stabilization by the emission of quadrupole radiation is faster. Whereas about one in 10^{13} collisions between pairs of hydrogen atoms is stabilized by quadrupole radiation, only one out of 10^{22} collisions will involve a third atom, at hydrogen concentrations of one atom per centimeter. Finally, of such three-body collisions, only about one in ten leads to molecule formation.

Catalysts likewise alter the course of reaction. Mixtures of hydrogen and oxygen, although thermodynamically unstable with respect to water, will

[1] H. Eyring, H. Gershinowitz, and C. E. Sun, J. Chem. Phys. **3**, 786 (1935).
[2] E. Wigner, J. Chem. Phys. **3**, 720 (1937).