A BRIDGE FROM SCIENCE TO RELIGION BASED ON POLANYI'S THEORY OF KNOWLEDGE

by William T. Scott

Michael Polanyi's writings on man and nature[1] constitute a major effort to establish a new paradigm for philosophical discourse, largely by producing a radically original view of knowledge in science. As a physicist with religious commitments, I find that Polanyi's thought points the way to a profound vision of the relation between science and religion.

Polanyi views scientific knowledge as grounded in the creative activity of responsible persons, reaching out in spite of their limitations to discover what is true and beautiful about the world. A scientist holds knowledge largely by commitment rather than by proof, in faith that beyond every partial truth there is more yet to be found. He both participates intimately in his subject matter and finds himself in a transcendent relation to the community in which knowledge is held, to the body of scientific knowledge, and beyond these to reality itself.

To show how the Polanyian system can lead to a bridge from science to religion, I shall proceed as follows: I shall begin with a discussion of Polanyi's principle of marginal control to show the fallacy of trying to explain comprehensive entities from the laws of their constituent parts, and then argue that mechanistic determinism is a feature of certain intermediate levels of complexity and cannot be logically transferred to higher levels. I then come to a description of tacit knowledge, the heart of the Polanyian system, establishing the irreducible personal element in all perception, thought, and achievement. The remainder of the paper explores certain implications of the concept of tacit knowledge: indeterminacy and creativity, the variable boundary of self and world, questions of commitment, the communal nature of scientific knowledge, and the role of authority. The essay concludes by using some of the Polanyian insights to discuss the concept of God and man's relation to him.

I should note three limitations to my discussion. I have rather under-

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emphasized biology and overemphasized physical science, largely because it is the field I know best. My references to religion are based on my limited acquaintance with modern Protestant thought as represented by such theologians as Paul Tillich, H. Richard Niebuhr, and Robert Calhoun.[2] Finally, in the brief space allotted I can scarcely begin to do justice to the richness and complexity of Polanyi's thought or to the profundity of the questions with which I deal.

Explanation

Polanyi's principle of marginal control[3] provides a clear denial of the reductionist claim that the structure and operation of an organized system can be explained in terms of the laws of the parts of the system. This principle allows us to affirm the autonomous existence of comprehensive entities and to show their necessary role in scientific explanation. Thus it provides a first step toward making sense of the truth-claims of religion.

The term "marginal control" refers to restriction or changes of the temporal, spatial, or more general boundaries within which a system operates in accordance with the laws of its constituents. Polanyi's principle states that the laws governing marginal control are always additional to and independent of the laws of the parts of a system. For instance, the laws of physics apply to a wide variety of occasions distinguished by different boundary and initial conditions. The occurrence of these conditions is usually said to be "arbitrary" in that they are set by the experimenter, or by the poser of problems for students, or by some contingency of nature. Any structure, such as a set of reflecting walls or mechanical linkages, that sets the arbitrary conditions in some regular way is said to exercise marginal control on the system. A simple example is that of a piece of clockwork, in which springs, gears, and levers obey the physical laws of inertia, elasticity, energy storage, lever action, and torque transmittal. It is only because of the arrangement of the parts to come under the marginal control of the escapement principle that they constitute a clockwork.

An explanation of the operation of a system in physical terms thus involves a specification of the elements of the system and of the laws governing them, together with a specification of the marginal controls, however set. One might characterize such an explanation by asking how much information is needed to specify each of the two sets of terms, the laws and the marginal conditions.[4] A structure exhibits a high degree of marginal control over its constituent elements when its explanation requires a considerable amount of information about its boundary and initial conditions.

Marginal control is exercised by ordering, operating, or organizing principles which are distinct from the laws governing the substituents. In fact, since marginal control operates within the range left "arbitrarily" open by the laws governing the parts of the structure, it is *logically* impossible to derive the marginal-control principles from the laws of the substituents. We call such principles of marginal control *higher* principles and the laws of operation of the substituents, *lower* principles. Since ordering, operating, or organizing principles generally have their own arbitrary marginal conditions, still higher principles can be envisaged. For instance, a clockwork becomes a clock only if it is arranged to show the time in accordance with public convention and if a means is introduced for setting its rate in agreement with a standard clock. Polanyi's assertion of the independence of marginal control at each level entails the existence of a wide-ranging hierarchy of irreducible regularities, each of which must have a role in the explanation of phenomena.

The need for marginal-control principles for the explanation of a hierarchical system can be illustrated by considering a modern digital computer, an example which is important because of similarities and contrasts between computers and living beings. In both systems there are many steps between the physics at the bottom of the hierarchy and the level of principal interest at the top. On the other hand, the deterministic set of operational principles of a computer contrasts sharply with the set of indeterminate, action- and meaning-centered principles of organization of living beings, which I shall be discussing later in this essay.

An explanatory account of a particular computer might start at the level of its electronic elements, such as magnetic memory units and transistors. The operations of these units are restricted to the use of certain kinds of pulses by specially ordered circuit connections. The interconnections of elementary circuits in accordance with a further set of ordering principles makes possible the arithmetic operations of addition and subtraction and the control features of address and transfer. Successively higher principles are needed for operations like multiplication, taking a square root, and search for a given number. Still higher levels of explanation are those needed by the computer user, involving the programming language that the machine can handle and the variety of available subroutines and control schemes—the user neither needs, nor can make use of, information concerning the lower levels.

A computer designer can choose at each level the particular devices with which to harness the structures of the next lower level. There are in general a variety of ways in which operations at a given level can be carried out and of course a much wider variety of arrangements which would fail. Thus an adequate explanation of a given computer requires specification of a whole series of logically independent principles. In no sense can the whole machine be explained in terms of the laws of its electronic elements, or a fortiori by the laws of their chemical and physical constituents.

It would be nonsensical to say that a computer is *really* just a collection of electronic parts; yet such an assertion would parallel exactly the often expressed view of a man as *really* a collection of elementary particles. A real entity is something we expect to meet again and again, and to have to reckon with on its own terms. A computer is surely a real thing, and so, of course, are each of its subsystems. In the view I am presenting here any comprehensive entity has reality in a number of ways simultaneously, corresponding to the different levels of hierarchy of marginal-control principles we find significant in studying that entity.

Determinism and Mechanism

The conventional paradigm of scientific explanation holds as an ideal the search for deterministic explanations at every level of complexity. Furthermore, it is assumed that deterministic behavior of any macroscopic system follows logically from the deterministic behavior of its ultimate physical constituents. The fact that atoms and molecules have a degree of uncertainty in their motions occasioned by their partially wavelike nature is generally taken as an effect whose relative importance diminishes as we go up the scale from atoms to macroscopic objects. Finally, the logic of determinism is independent of the logic of hierarchic principles of organization—no matter what higher principles are effective, they all are apparently required by the laws of physics to be deterministic in principle.

I believe this logic to be mistaken on three counts. In the first place, the determinism of physics—even classical physics—is far less stringent than commonly supposed. Second, the deterministic behavior of machines and machinelike elements of living organisms is a direct consequence of the operating and organizing principles of the entities in question. Third, it can be shown that mechanical determinism at one level does not guarantee the same behavior at a higher level. In fact, a machine can be more deterministic than its constituents, whereas other systems can be less so. Let me take up these points in order.

The usual expression of determinism in classical physics is couched in terms attributed to Laplace: if the positions and velocities of all the particles in the universe are known at a given instant of time, and if knowledge is available of the laws of force whereby each particle acts on every other, then the entire course of history both before and after the given instant is calculable in principle, that is, determinate. However, classical Newtonian mechanics is subject to inexactitude, and this inexactitude destroys the Laplacean ideal.[5] Newtonian mechanics is only known to be valid to the degree that the best available evidence corroborates it. Before the "modern" era of physics, the strongest evidence for Newtonian mechanics showed it to be accurate to roughly six or eight significant figures; current developments will probably extend the agreement to, say, twelve figures. While this accuracy is impressive, it is worthless for Laplacean determinism at the molecular level. A simple calculation shows that a deterministic prediction of the molecules of an ordinary sample of air would require 150 million figures in order to be valid for as long as one second,[6] and proportionately more for longer time. Even the most ardent metaphysicians could scarcely claim such a fantastic degree of accuracy for Newtonian mechanics.

Extraordinarily minor influences have effects at far lower levels of accuracy. For instance, the motion of the earth would be disturbed in about the thirtieth significant figure of its velocity by the reaction from dropping a pencil onto a table, and in about the fiftieth place by the collision of one air molecule with the floor. Heisenberg's principle would make an uncertainty in the earth's position in roughly the sixtieth figure. Furthermore, any unstable system, meaning one in which the parts or particles do not periodically return to the neighborhood of their original positions, is subject to a steady increase in the uncertainties that originate from inaccuracies in the initial conditions, in the basic laws, and in the actual calculational procedure. Error development of this sort is responsible for claims that the limit of foreseeable weather prediction lies somewhere between five and twenty days.[7]

The long-range prediction which is so successful in celestial mechanics becomes possible only for stable systems which are quasi-periodic in their behavior. The prime example is that of the moon's motion in relation to the earth and sun. A highly successful quantitative theory has been developed[8] and can be used to compute the moon's position at any given time within, say, one or two hundred years. It is difficult even in this case to identify the theory as predictive in the Laplacean sense, for the eight hundred or more terms in the formulas describing the moon's motion are derived not from positions and velocities at a given instant but from sets of observations extending over many decades. Furthermore, discrepancies between prediction and observation continue to develop as more refinements are made, each one being resolved by finding the effect of a new small disturbance.

Machines provide better examples of deterministic systems. A machine can be described as deterministic by specifying certain features of its marginal control without having to consider the entire set of its organizing principles. If in a computer the on-off or binary character of the pulse systems, amplifiers, control elements, and memory units involves sharply separated energy levels or operational states, we can safely assert that temperature fluctuations have no effect and that a given set of pulses will always generate the appropriate output at a later time. This assertion is independent of whether the output is mathematically significant or pure nonsense, and at the same time this consequence cannot be derived from the physical and chemical laws of the parts.

We see, then, it is to be expected that machinelike deterministic features in biology will require for their explanation a set of principles belonging to the organization of these features. In fact, Erwin Schrödinger has shown in *What Is Life?*[9] that biological systems make special use of the quantum-mechanical separation of energy levels in a way that suppresses the random effects of temperature fluctuations and individual atomic uncertainties. Such machinelike elements as the utilizing of genetic-code information and the on-off character of nerve impulses involve deterministic organizing principles of a purely biological kind.

The fact that determinism at one level does not entail determinism at a higher level is well known in the case of the statistical theory of gases. This theory, in the classical form derived by Boltzmann and Gibbs, deduces principles of a probabilistic type concerning the pressure and temperature in a gas by imposing certain very general statistical regularities on a system of presumably deterministic Newtonian particles. The random behavior of turbulent eddies in moving bodies of water or air can likewise be shown to arise when a deterministic fluid is considered in the light of a wide variety of observationally significant average characteristics.[10]

It will be seen in the remainder of this essay that the behavior of animals and men is neither machinelike nor random. The conclusion to be drawn from the consideration of this section and the last is that such behavior will require new principles of its own for elucidation, principles that may well avoid the traditional conflict between determinism and free will. However, the tradition of seeking deterministic explanations suggests that we should look for machinelike elements that simulate nonmachinelike behavior, a mode of thought which can be illustrated by current efforts to program computers for the recognition of patterns.

A way in which computers can be used to provide indeterminate outputs is by providing them with indefinite inputs. In several cases in which machines are being programmed to recognize patterns of variable aspect in variable contexts, the input is recognizable by the experimenter but not specifiable by him, so that the input may be described as indeterminate. However, the necessity of programming a machine for specified operation and the necessity of a machine to operate reproducibly means that the *same* input must always give the *same* output and that reliance on the machine for such powers of recognition that it may have is logically dependent on knowledge of its program of definiteness of response. Computers used in this way, while useful as models for some of the behavior of living organisms, are still far from attaining the pattern-recognition ability that our animal ancestors have evidently possessed for several hundred million years.[11] Still less do such computers have a bearing on the operating principles of tacit knowledge, to which I now turn.

Tacit Knowledge

The keystone of Polanyi's account of man in the world is his theory of tacit knowledge, which is based on our integrative, prearticulate abilities to perceive and recognize coherences. For any act of perception there are two kinds of awareness, the focal and the subsidiary. This assertion is most clearly explicable in terms of visual perception. When we look at a thing directly, focusing attention on it, we have in Polanyi's terms "focal awareness" of the object we observe. While we look at it, we notice in a subsdiary way, sidelong as it were, many particulars of the thing and of its background and context. According to Polanyi, we have "subsidiary awareness" of these features or aspects of our perceptual field. The subsidiary particulars are noticed not as things in their own right but as pointers or clues to the thing focused upon. We *rely* on these secondary elements for seeing, attending *from* them *to* the object of focal attention. For instance, we rely on many subtle features of a person's face for seeing who he is and what mood he is in. The relation between the elements and the whole, the parts and the *Gestalt*, is called by Polanyi the "from-to" relation.

There are at least three important reasons why we cannot say how it is that we rely on subsidiaries in this way. In the first place, perception proceeds by a recognition of integrated coherences, invariances as J. J. Gibson calls them.[12] The processes of integration and/or integral perception occur in automatic ways over which we have no control and of which we have no direct awareness. How the particulars we notice subsidiarily are integrated is not something we can learn to account for out of direct experience. Psychological studies may provide a retrospective account for certain regularized experimental situations, but these do not provide any actual direct account of perception.

Second, some of the clues we rely on for perception are bodily processes of which we are partly or completely unconscious.[13] The third and most stringent reason why we cannot speak about subsidiary elements is that to speak of them would require attending to them, in which case they would change their character, ceasing to be pointers or clues to something else.

Polanyi uses the term "tacit knowledge" to refer to things which we can be said to know but which we cannot articulate.[14] The integrative process by which we perceive the coherence of tacitly known clues is called by Polanyi an act of tacit inference, having not only the property of being logically unspecifiable but also having an indeterminate range of operation. For instance, the same entity may be perceived in a variety of circumstances that clearly entail our relying each time on different sets of clues and different integration procedures. We do not have complete certainty either during the process of tacitly inferring a coherence from its particulars, or in later reflective acts of trying to justify the inference. We are always entrusting ourselves to our tacit powers to guide us correctly, and yet always running the risk of being possibly mistaken.

The idea that perception is grounded in a particular quality of attention suggests that motivation is essential to perception. The interests of a perceiver concerning his perception are both subjective and objective, being grounded in wants and needs, yet depending for their satisfaction on seeing what is really there. The desire for knowledge of the real world forms a bridge between subject and object, a bridge which Polanyi develops into his theory of personal knowledge.[15] In so doing, he rejects the conventional paradigm of philosophy, which seeks an impersonal analysis of concepts, and the conventional paradigm of science, which pursues the ideal of detached, objective knowledge. In spite of this rejection, Polanyi is able to provide a sound and affirmative base for the actual functioning of philosophical analysis and scientific research.

An important example of tacit knowing is the rooting of speech in subsidiary and focal awareness, as described by Polanyi in *Knowing and Being*, chapters 12 and 14. Another case is the tacit base of logical argument. The meanings of propositions are read by subsidiary awareness of the symbols or words that express them; logical operations are tacitly judged for their correctness, including such matters as whether the repeated symbols continue to represent the same entities; and the overall gist of a proof is appreciated in a tacit integration of its separate steps.

Logical thought involves perhaps the least possible tacit component. More is involved in the tacitly based recognition of ordering and organizing principles. The structural principles of a cell or organism involve the recognition of features not reducible to rules—witness the insistence of biology teachers that their students learn about cells and tissues by actually seeing them under the microscope.

The concept of universals, such as, for instance, the recognition of an animal as a member of a species, can also be analyzed in terms of tacit knowledge. According to Polanyi, a universal appears as the coherence that unites a number of things into a class. In relying on some members of a class for attending to their common meaning, tacit knowledge of this common meaning is gradually acquired. As more members of the class are seen, this knowledge is verified and extended—or destroyed if the coherence proves finally to be spurious. The indeterminate and yet significant character of such universals as "owl" or "man" is accounted for in terms of a tacit integration whose sense is subject to continual modification by further tacit judgment.

The recognition of an achievement is another case of the from-to relation, in which subsidiary aspects of an action become integrated into a successful performance. An animal catches another for food, a man makes an intelligent move at chess, an automobile functions properly, someone perceives correctly what is in front of him—these are but a few of the kinds of achievements we recognize by acts of tacit inference.

A consequence of our ability to recognize a proper achievement is that we can also recognize an imperfect one, which implies that we recognize norms or ideals of achievement. We become able to give meaning to "perfectly intelligent chess playing," "perfectly functioning automobiles," and "perfectly healthy animals," even though none of these may ever be actually perceived. The recognition of value and the recognition of fact thus occur in quite similar ways in Polanyi's theory of knowledge,[16] countering the old view that facts are purely objective and values purely subjective, a view which has helped in the past to maintain a sharp distinction between science and religion.

The from-to relation appears in another way when we consider an achievement itself, as distinct from its recognition. When we carry out a bodily activity, such as walking, we have already in our imagination (even if only immediately beforehand) a focal awareness of the action and intent. Carrying out the activity involves integrating particulars of muscular flexing and coordination so that the joint result is the action intended. We may say roughly that the whole is imagined first and then the parts are arranged to bring it to pass. The same analysis can be applied to the achievement of saying something intended, or of using a tool to carry out an act.

The successful performance of a scientific research experiment is an achievement for which many particulars must be integrated to provide the outcome. This integration occurs under the guidance both of the experimenter's imagination, by which he has in mind what he is trying to do, and of his critical faculties, by which he judges the correctness of procedure and the reliability of the result. Not only the experimenter but others competent in the same field must judge his experiment successful if it is to be recognized as a contribution to science.[14] The Polanyian view substitutes responsible judgment for the operation of impersonal rules of methodology and verification as the foundation for the acceptance of scientific knowledge.

Indeterminacy and Creativity in Animals and Men

An important and far-reaching consequence of the concept of tacit knowledge is the affirmation of indeterminacy and creativity in living organisms, especially in man. It is not only practically but logically impossible to incorporate the from-to relation in an explicit, deterministic model for behavior. Even if we grant that the particular interest leading us to attend to a particular activity may be quite definite and perhaps determinate, we have seen that the subsidiary clues we rely on and the manner in which we integrate them are both unspecifiable and capable of operating to the same end in an indefinite variety of different circumstances.

We can, however, go further. Every application of the from-to relation has an irreversible character. When a person is looking for something in a fog or in the dark, he becomes aware of many possible clues and forms a variety of imagined integrations. The particulars are seen only vaguely and ambiguously as pointers, for the "directions" in which they point and the object to which they point are not yet fixed. However, when the object is discovered, some particulars emerge as valid clues while others recede into the background. An irreversible change occurs: the clues of which we were only subsidiarily aware have changed their character. As long as we do not attend to them focally, we cannot reverse their role as pointers to the object we have just found.

Once we have come to understand the meaning of a difficult sentence, we see the words in a special set of connotations, and we cannot go back to the state in which they first appeared meaningless. Once we have learned to coordinate our limbs for riding a bicycle, we have irreversibly grown in our abilities. Every adaptation of an animal to a new feature of his environment constitutes an irreversible bit of learning.

Irreversible change of this sort pervades all of our experience. Grounded as it is in subsidiary awareness, this kind of change is also unspecifiable and unpredictable. The prior specification of the mental state of an animal that would be needed for a deterministic account of his action is thus ruled out. If we imagine trying to overcome the difficulty by interacting with the animal at a given time to determine his mental state, we have a situation reminiscent of Heisenberg's uncertainty principle—the interaction will make unspecifiable and unpredictable changes of its own and again frustrate our efforts at determining the animal's course of action.

If living creatures continually change in the way they see the world, their experience of the world must be a continuously novel one. In particular, there is novelty in every attempt to convey meaning and in every account we read or hear, even if the novelty is no more than the application of what is said to the particular circumstances of time and place. All except the most trivial speech has genuine newness of meaning in itself. It is interesting to speculate whether this aspect of novelty in experience is the basic element in the appearance of consciousness in biological systems. Richard Semon made this suggestion half a century ago, along with some other suggestions concerning memory that have since been rejected.[18] In commenting on Semon's idea, Erwin Schrödinger pointed out that we are most aware of what is most new to us, and that habitual sights and actions recede from consciousness: "Consciousness is associated with the *learning* of the living substance; its knowing how is unconscious."[19]

The indeterminate, irreversible, and novel character of our experience contrasts so sharply with the essentially deterministic character of any conceivable computer[20] that it does not make sense to use a computer as a model for human behavior. It seems to me that the proper procedure is to formulate behavior models on principles that directly embody the from-to character of perception and action, seeking a paradigm of biological explanation centered around active, intending, and attending animals and persons.

The active participation of an individual in generating novelty is the basis of creative discovery. In Plato's *Meno,* the paradox of analysis is raised: how can you institute a search for that which you do not know, and how can you recognize the object of your search once you have found it? The paradox applies most acutely to the scientist's task of finding completely new knowledge, in contrast with the less mysterious case of the philosopher's explication of knowledge already contained implicitly in ordinary language. If knowledge were treated as purely explicit and articulate, then Meno's question is insoluble—there would be no motive for looking for something completely unknown, and no test for the result.

A solution appears, however, when we allow informal, tacit knowledge of elements in a situation that can be read as clues to an unknown to be found.[21] Just as in the case of seeing in a fog, clues appear and disappear, and many integrations may be tried. The existence of genuine scientific problems that scientists regularly recognize as fundamental to their work is explained by the vision of vague yet significant coherences pointed to by clues drawn from current knowledge, from the characteristics of apparatus, and from the insight and imagination of experimenters. It is these same clues that become the principal basis for a critical judgment of the outcome, although the character of the clues changes and sharpens irreversibly in the process of discovery.

Without the problem—the unfilled gap and the pointers toward a solution—science would not progress at all. It seems to me that there is a deep parallel in the religious life. I read the first of the Beatitudes in Matthew, "Blessed are the Poor in Spirit, for theirs is the Kingdom of Heaven," as pointing to the truth that spiritual insight comes only to those who recognize a gap within their own lives. The problem is needed before something can be found, and since spiritual insights normally demand irreversible and uncomfortable changes in our self-conceptions, only a problem acute enough to cause suffering will provide the motivation to seek a solution.

Religious faith is faith that a solution exists, or, in other terms, a vision that the clues in one's circumstances and in the depths of one's imagination do in fact point to a solution. The form and content of solutions to be expected may differ for different religious outlooks. I am only suggesting that the Christian outlook is that of a creative, changing world in which solutions to our existential anxieties are continually becoming available to us.

Science is likewise founded on faith—faith that it is possible to find a continuing series of answers to the steadily unfolding array of puzzles and problems that appear in man's effort to comprehend the world in which he lives. Scientific discovery is an interaction between man and nature, in which the former strives creatively to discover what the latter has to reveal. The receiving of religious insight by the person who struggles over his spiritual life has a similar interactional character. Whatever name is given to the source of insight—the Nature of Things, the Ground of Being, God—to the process belongs the traditional name of revelation, which is not a bad term for what happens in science either.

Indwelling and Commitment

Polanyi's theory of tacit knowledge also provides a radically new way of understanding the participation of the knower in the world he knows.

This new way of comprehending man in the world is grounded in the consideration of bodily activity. Muscular achievements involve the unconscious integration of bodily particulars into a performance focally attended to. We know our bodies almost exclusively in the subsidiary mode, relying on them for our activity, perceptions, formation of concepts, and communication. Our bodies have an instrumental relation to our conscious selves and are not perceived as identical with our selves. We are housed in our bodies in a special way for which the ordinary concept of inhabiting an edifice is but a rough model. In spite of the inadequacy of the model, Polanyi says that we *dwell* in our bodies, or, alternatively, that a person's relation to his body is one of *indwelling*.

When we come to use tools, such as pens or hammers or automobiles, we assimilate these objects to our bodies in the sense that we rely on them for performances and are aware only subsidiarily of the interactions between them and our actual bodies. As we focus attention on the pen point and the paper, the hammer and the nail, or the automobile in relation to traffic, the boundary of our self comes to reside functionally at the boundary of the tool. In this sense we come to dwell within the tool, or at least within those of its particulars that we rely on. Once we start to use the tool, we entrust ourselves to it, pledging ourselves, as it were, to its nature and its rules while we use it. We commit ourselves to the tool, and when our use of it is complex and our interest in the performance intense, we may properly say that we commit ourselves passionately.

We also dwell within the particulars involved in perception, pledging ourselves to them as we rely on them for seeing what it is we see. Metaphorically, our bodily boundaries are continually shifting. They move outward to the world as we relate to it, but they can also move inward, for example in the contemplation of the amputation of a finger. In cases in which we can focus attention on our own sensations, as when we concentrate on the pressures of the pen on the hand, they too cease to be relied-on parts of our bodies and become parts of the outer world.

Can we push the boundary inward to a "dividing line" between body and mind? I believe we cannot. Our sensations are among the clues we rely on for perception, and our muscles and nerves are particulars from which we attend to actions. If we should conceptually move the boundary to the near-side of our sensory and motor clues, they would become objects of focal attention in the outer world, and we could no longer make sense of the mental activities we carry out with their help. We cannot find a dividing line between mind and body by any such consideration of physiological boundaries.

The concept of mind must be constituted by an organizing principle of the entire person, and not of some part, such as the brain or nervous system. Polanyi characterizes the mind as the "meaning" of the body.[22] To know the mind of another is to become acquainted with his thoughts, memories, opinions, intuitions, emotions, and the like. In terms of Longuet-Higgins's computer metaphor,[23] the mind is the actual program, whereas the brain is the major part of the hardware, and its structure probably has built into it some software that governs how, but not what, we think.

To deal with mind as a whole, we have to consider a still further aspect of indwelling, our reliance on language, which is the most important and pervasive of the tools we use. We rely on words and the concepts they embody for thinking and communication, in fact for nearly all specifically human activities. Our mental existence is measured by our commitment to our language and our culture, to systems of beliefs, conceptions, attitudes, and expectations. Our mental boundaries become "located" in this scheme of thought at the regions of puzzlement and growth, the regions of changes in our thought patterns, of creative and novel ideas and feelings, in short, in the regions of our fullest consciousness. Even there they cannot be pinned down, for they continually shift with shifts of our attention.

We can see the variability and uncertainty of the boundary between self and world when we consider the commitments involved in trying to solve a problem. We are committed by indwelling to the particulars that point to the thing we are trying to find, and in another way to the thing itself, which is a commitment to something that is clearly distinct from ourselves, even if unknown. When we find it, our commitment deepens with our clarified vision, and we may come to dwell within the new discovery in relying on it for still further research efforts.

A factual discovery satisfies a passionate desire to find out what is going on out there. We also have desires to find out what is beautiful and what is good, what objects and what actions are worthy of appreciation. Moral and esthetic searches are similar, it seems to me, to factual searches, involving gaps we find pointers to and try hard to fill. In all cases, the background we bring to a problem, the conceptual and moral and esthetic frame of reference in which we dwell, provides many of the pointers for us. Only a few of the clues we use can be pinned down as peculiarly our own. I shall come back to this point in the next section.

A question that may be raised at this point concerns the problem of values in science. If fact and value are found in such similar ways, is there not a danger of science becoming value-laden and thus prejudiced and nonobjective? On the contrary—without an adequate conception of scientific value, no sense can be made of science. Objectivity, universality, rationality, coherence, and mathematical elegance are some of the values upon which science is based, and which scientists must embrace with considerable passion if they are to carry out their function as researchers.

Furthermore, every science has a set of norms in terms of which its particular results are understood. Crystal dislocations, a fundamental topic for solid-state physicists, can only be understood by reference to the idea of a perfect crystal. Normality and health must be established in biology before variations and disease can make any sense. Hence beyond the general values of science there are the particular values underlying particular sciences. Only when these kinds of values are understood can we properly attend to value judgments that interfere with science, such as having a distaste for sexuality while trying to study sexual behavior. The Polanyian concept of the recognition of coherences by tacit inference is what allows us to make adequate distinctions between values that are proper to science and those that are not.

Value judgments are subject to considerable disagreement, more so than factual judgments. However, the grounding of all knowledge in tacit coefficients shows that we can never escape from the necessity of making judgments that we know to be inexact and hence could possibly doubt. How can science function in the face of such limitations? Polanyi's answer is that, in spite of the inexactitude of our judgments, we make them and commit ourselves to them. We take the risk of faith in so committing ourselves, coming to dwell within the results of our judgments and relying on them for further research and indeed for our very lives. The fact is that in science, at least, we have been enormously successful.

Similar, but more risky and less certain, commitments are made by the religious person. And while he has a less broad historical experience on which to justify such commitments, he finds enough to hold to his faith in spite of doubt, for otherwise he would not be religious.

Community

Science, says John Ziman, is public knowledge.[24] Since no scientist can know by research and verification any sizable fraction of his science, nearly all of what he knows has been obtained from the public body of knowledge in this field as expressed in scientific documents and lectures. Ziman and Polanyi[25] have described how the body of knowledge held jointly by a scientific community is built up, maintained, and subjected to criticism. This body of knowledge exists in the printed literature and, more fundamentally, in the minds of those scientists who are competent to interpret it.

I as a physicist can dwell fully within only that small portion of physics in which I do research and am able to criticize the work of others. However, my commitment goes beyond the knowledge I rely on for my professional thinking and doing. My trust in a much wider range of physics is undergirded not by any special competence of my own, or even by the application of any general methodology, but by my commitment to the community of physicists. I join with this community in standing metaphorically under or before a superior body of knowledge to which we all owe allegiance.[26] Most of the clues I rely on for solving a research problem are drawn from the general body of physics, and only a few could I call strictly my own. I do not solve a problem for myself but for the community to which I am committed.

The interdependence of scientists in their community is a further source of normative judgments in science. The values of integrity, responsibility, and reasoned loyalty to the traditions and aspirations of a field have objective significance as conditions for the functioning and motivation of the community.

An authority in science is one who is trusted and revered by his colleagues in the confidence that he has competently employed his reason and experience to find reliable, if partial, truths about nature. It is on the judgment of such authorities that decisions are made as to what constitutes sound experimental and theoretical work, not on the basis of impersonal rules about scientific method. In Polanyi's view, science is an authoritative tradition, not a methodology.

Protestant Christianity is likewise based on authority and tradition. Authority functions for religious communities because each community has in its past and present life people who are judged competent to report authentic religious experience, to interpret it rationally, and to guide others to at least a small measure of religious experience of their own. In Protestant Christianity this type of authority is secondary to that of the Bible, which is revered as having been written, compiled, and edited in the community of faith as an authentic account of revelation. Considered as the Living Word, the Bible is treated not like a scientific document to be superseded with the advance of knowledge but rather as subject to continued interpretation in the light of present-day experience within the Christian tradition.

While a scientific community is based on the mutual trust of scientists qua scientists, a religious community involves a sharing of a much wider range of personal experience, aspiration, failure, and despair, all as understood in a common frame of reference. An idealized metaphor for a religious fellowship is Saint Paul's figure of the Body of Christ: those in the community form the members of this living body, each contributing according to his own talents. The same kind of sharing of specialization occurs in science, but the talents contributed are more exclusively intellectual and far less personal. Surely one reason why science can be so relatively free of controversies and religion can be so full of them is the much deeper existential and emotional involvement called forth by religious commitment.

Of course, men dwell in many other communities besides the scientific and the religious. We all participate in the community of those who speak our language. We also dwell within communities representing social class, levels of education, many kinds of common interests, and so on. On a broader level, each of us participates in the entire community of man, although our understanding of this participation will be derivative from our more localized religious, ethical, and intellectual commitments. Moral judgments arise out of these many communal relations in a way similar to the way normative judgments arise for scientists. Moral values are perceived as ideals called forth by the existence of people in relation to each other and to God.

CONCLUSIONS

The center of attention of the Polanyian view is on *persons*, not merely as not reducible to any kind of biological mechanism, but more fully as responsible and creative centers of thought and action—individuals who participate jointly in their culture, seeking to transcend their subjectivity and isolation by acts of passionate, universal intent. The ways in which scientists commit themselves to the standards of their discipline, exercise their responsibility for research of a universal and objective character, and rejoice in their discoveries are not sharply distinguishable from the religious functions of personal commitment to shared values of universal character, personal response to a calling to seek the truth and to come to know and love one another, and personal experience of revelation in response to existential difficulties. It is no longer possible to defend the old notion of value-free, impersonally objective science standing in sharp contrast with value-laden, unrealistically subjective religion.

Another traditional distinction between science and Christianity is that the former is concerned with universal, timeless regularities, whereas the latter claims to be essentially historical, grounded in the special event of revelation in Christ to a particular small community at a particular time in history. Nevertheless, there is a parallel here, too, for the scientific tradition has a unique history in Western culture, and each discovery has a unique appearance as far as this history is concerned. Only once can a group of scientists become convinced of something new and thus irreversibly enlarge their mental existence by dwelling within it.

The universality of science does not come from applying a time-independent, universal method but from the universal intent of the researcher, as well as of colleagues who judge the validity of his results. In exactly the same vein, Christians claim that the insights of the Christian revelation apply to all men everywhere and should not be applied so narrowly or dogmatically that they lose their own universal intent.

We have seen a scientific or religious community as a vehicle of authority and tradition transcending each member of that community, and the community as a whole standing under a still further transcendent body of knowledge and valuation. We participate in a complex variety of transcendent systems, whose ordering and organizing principles form the multidimensional hierarchy of levels of reality.

I should like to suggest that "God" is the significance given by a religious person to the top level of the complex hierarchy, the meaning of the whole of existence. There is a partial analogue to this concept in Polanyi's notion of a person as the meaning of his body. If we believe that the meaning of the whole exercises marginal control in some active way over the universe, we have a justification for the Christian metaphor of God as a person. At the same time, of course, we can scarcely apply to God the idea of a person in respect to his biological dependence on particular bodily structures, or to his mental dependence of dwelling within a self-transcendent community. Another metaphor for God appears if we take the meaning of the whole to manifest itself in the experience of what it is to *be,* so that our participation in being is also a participation in God as the Ground of Being. Whatever the metaphor, it is evident that we should expect the closest relation to God to occur within the highest levels of being we know—the personal and the communal.

How do we relate to God as thus conceived? If we ourselves constitute one category of the particulars that jointly form the meaning of the whole, it is rather difficult to see how we could have a focal, standoff awareness of this meaning. We can nevertheless dwell within clues that point to God and commit ourselves to him as the center to which they point, expressing devotion while not expecting any clarity of vision. The pointing of the clues may generate in us a sense of the holy, which Rudolf Otto calls "numinous,"[27] and we may on rare occasions arrive at that imageless experience of grounding in ultimate reality that the great mystics have reported.

Another type of relation to God is the experience of the Christian in receiving for himself the revelation expressed in Jesus, which could be described as a sense of discovering who a person is in relation to God and how he is called to live, revelatory experiences which are seen as profound pointers to God himself. Participation in the tradition of a particular church, and through this a sense of partaking in the whole Christian community, can lead to an experience of God's calling forth in man an ever-wider sense of the divine will. Finally, insofar as the moral values of a religious tradition are seen as derivative from God as ultimate meaning, these values are matters of ultimate concern, and living up to them is in itself a relation to God.

Just as scientific judgments are always threatened by the possibility of error and subjectivity, so also are all the ways of relating to God subject to human limitations. The traditional term for human failure at the moral and religious level is "sin," a word that has been degraded in meaning by being used for rigid moral rules that are less than ultimate. I find the term restored in significance by using the definition of the unknown author of *Theologica Germanica:* Sin is the turning of the creature away from the Creator.[28] The problem of sin is quite different from that of scientific failure. For the latter the critical and creative functions of the scientific community serve to overcome error. It is also true that the role of an honest, responsible scientist is fairly easy for a man or woman to adopt professionally regardless of the complexities of his or her personal life. On the other hand, sin in the sense I have given it is a major problem for the religious person, who must face his own emotional conflicts, the complicated commitments of his life in the world, and the inherent difficulty of knowing God.

Finally, let me touch on two questions that the concept of God raises for even an enlightened view of science: (1) whether the idea of God is necessary or even helpful in explaining the regularities of the natural world, and (2) whether any sense can be made of the notion of God's action in relation to events. I believe, as I suggested above, that the first question may be clarified in terms of marginal control. If there is a meaningful organization of the whole, it is likely to have the most significant marginal control at levels of being which are close to the top of the hierarchy—for example, human beings acting in history—and to be almost totally irrelevant to the physical sciences near the bottom. Wherever they are appropriate, mechanistic explanations have no need for the concept of God.

On the other hand, to give but one example, there surely must be a bearing of the Ground of Being on the long sweep of evolution which has brought persons into existence with the capability of yearning for the universal and the good and, to some extent, of satisfying their yearnings. The mechanisms of chance mutation and selective survival are undoubtedly those which have enabled the process of evolution to occur, but since organizing principles cannot be derived from laws of simpler systems, the character of a new species or a new biological feature cannot be derived from anything so elementary as these enabling laws. If and when we work out a truly adequate theory of the rise of man, it must have a place for the influence of higher principles as representing potentials for organization and somehow governing evolutionary development.[29] At the top of the set of principles will stand what the Christian might call the creative calling of God in evolutionary history.

So much for the explanatory function of God. What of his action? Again I think it is a matter of marginal control and has its chief significance at the level of man's calling to transcend his own limitations and seek universal truth, beauty, and goodness. Creative human actions of adaptation and reconciliation in the face of accident, suffering, and conflict are to me the best examples of where God has an influence in our lives. The immersion of each of us in a community of thought and evaluation means that no one can legitimately take credit as the originator of creative new actions. The clues and inspiration for such actions generally arise in unspecifiable ways both from one's own special nature and from the frame of reference in which one dwells. Many sources are possible for these clues, but insofar as one's community shares values of ultimate concern, it seems appropriate to include the level of the whole of being as agent in creative actions. Historical developments involving the response of communities and cultures to novel and difficult situations may also be seen as involving the hand of God.

These reflections on the idea of God are meant only to be suggestive —not so much to offer answers as to point to ways in which questions relating science and Christianity can be fruitfully discussed along the lines of Michael Polanyi's thought.[30]

NOTES

1. The principal Polanyian ideas presented in this essay can be found in any of the following: *Personal Knowledge: Towards a Post-critical Philosophy* (Chicago: University of Chicago Press, 1958; London: Routledge & Kegan Paul, 1958; New York: Harper Torchbooks, 1964); *The Tacit Dimension* (New York: Doubleday & Co., 1963); *Knowing and Being*, ed. Marjorie Grene (Chicago: University of Chicago Press; London: Routledge & Kegan Paul, 1969).

2. It is only fair here to record my belief that science has a closer relation to contemporary forms of Protestantism than to most other forms of religion.

3. I use here the term "marginal control" as found in *The Tacit Dimension*, p. 40, in contrast with the equivalent "boundary control" employed in *Knowing and Being*.

4. The one-dimensional concept of "bits" currently used in information theory is scarcely capable of giving a quantitative answer to this question, but qualitative estimates are nevertheless significant.

5. Polanyi has pointed out that even if the Laplacean program were successful, it would not tell us anything about macroscopic objects, for the identification of which atoms belong to which object can only be made by use of structural principles not derivable from the Laplacean information (see *Personal Knowledge*, pp. 139–41).

6. W. T. Scott, *Erwin Schrödinger: An Introduction to His Writings* (Amherst: University of Massachusetts Press, 1967), p. 122.

7. J. Smagorinsky, "Problems and Promises of Deterministic Extended Range Forecasting," *Bulletin of the American Meteorological Society* 50 (1969):266–311; E. N. Lorenz, "Three Approaches to Atmospheric Predictability," *Bulletin of the American Meteorological Society* 50 (1969:345–49.

8. Ernest W. Brown, "Theory of the Motion of the Moon," *Memoirs of the Royal Astronomical Society* 53 (1889):39–116, 163–202; 54 (1900):1–63; 57 (1905):1–145; 59 (1908):1–103. For a discussion of the principles underlying the theory, see D. Brouwer and G. M. Clemence, *Methods of Celestial Mechanics* (New York: Academic Press, 1961).

9. Erwin Schrödinger, *What Is Life?* reprinted together with *Mind and Matter* (Cambridge: Cambridge University Press, 1967). See also Scott, pp. 127–31.

10. L. D. Landau and E. M. Lifshitz, *Fluid Mechanics*, trans. J. B. Sykes and W. H. Reid (Reading, Mass.: Addison-Wesley Publishing Co., 1959), pp. 102–7.

11. See H. L. Davis, "Artificial Intelligence—a Long Way to Go," *Scientific Research* 27 (October 1969):21–25.

12. James J. Gibson, *The Senses Considered as Perceptual Systems* (London: George Allen & Unwin, 1968).

13. It may be questioned whether the term "awareness" can reasonably be stretched to cover unconscious occurrences. However, consciousness is an awkward term to apply to things which we do not observe directly. Because Polanyi includes in the term "subsidiary" anything relied on for attending to something else, regardless of our degree of consciousness, his system has no way of limiting the word to cases in which we can affirm consciousness.

14. The term "tacit" is used by Polanyi, not in the sense of things we could articulate but do not, but in the sense of things to which the concept of speech does not apply.

15. See esp. Polanyi, *Personal Knowledge*, pp. 300–303.

16. See the many references in Polanyi, *Personal Knowledge*, to rules of rightness.

17. The judgment itself is of course another achievement.

18. R. Semon, *Die Mneme als erhaltendes Prinzip im Wechsel des organischen Geschehens*, 3d ed. (Leipzig: W. Engelmann, 1911).

19. Schrödinger, *Mind and Matter*, p. 9.

20. As Polanyi has pointed out, even if we could imitate on a computer the generation of novelty, we could only recognize our success by comparing the output of a

machine known to be deterministic with the behavior of an organism known to be creative (*Personal Knowledge,* pp. 261–63).

21. Ibid., pp. 120–31; M. Polanyi, "The Creative Imagination," *Psychological Issues* 6, no. 2, monograph 22 (1969):60.

22. M. Polanyi, "The Body-Mind Relation," in *Man and the Science of Man,* ed. W. Coulson and C. Rogers (Columbus, Ohio: Charles E. Merrill Publishing Co., 1968), pp. 85–102; see also Polanyi, *Knowing and Being,* pp. 211–24, 238.

23. Christopher Longuet-Higgins, "The Seat of the Soul," in *Towards a Theoretical Biology,* ed. C. H. Waddington (Edinburgh: Edinburgh University Press, in press), vol. 3.

24. John Ziman, *Public Knowledge: The Social Dimension of Science* (Cambridge: Cambridge University Press, 1968).

25. Polanyi, *Personal Knowledge,* chap. 7; Polanyi, "The Republic of Science: Its Political and Economic Theory," in *Knowing and Being,* pp. 49–72.

26. Polanyi, *Personal Knowledge,* pp. 374–79.

27. Rudolf Otto, *The Idea of the Holy* (Oxford: Oxford University Press, 1950).

28. *Theologica Germanica,* trans. S. Winkworth (London: Macmillan & Co., 1874, and later editions), also called *Theologia Deutsch.*

29. Polanyi, *Personal Knowledge,* chap. 13.

30. An earlier but considerably more detailed version of the material in this essay is contained in W. T. Scott, "A Course in Science and Religion Following the Ideas of Michael Polanyi," *Christian Scholar* 47 (Spring 1964):36–46.