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MICHAEL POLANYI'S INTEGRATIVE PHILOSOPHY

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CHAPTER 5

Integrative philosophy - an evaluation

5.1 What is meant by a Polanyian Integrative Philosophy?

In the above chapters I have explicated the major aspects of Polanyi's conception of integration and analyzed how his sources may illuminate the problem of tacit knowing as Polanyi approached it. I have also drawn on supplementary material to clarify Polanyi's formulations. Here I will synthesize what I believe Polanyi meant by Integrative Philosophy.

Primarily, Polanyi meant his work to offer a principle of explanation of the process of scientific discovery, focusing on the stages of problem-finding and initial insight, that is on originality. Secondly, he meant to correct the notion that creative scientific activity takes place in a deterministic world. Thirdly, he meant his work to be an effort to rejoin scientific knowing to knowing in general.

The three goals just mentioned made it necessary for Polanyi to rejoin logic and psychology, to take into account understanding, belief and judgement, and to give an account of "relief from puzzlement by the spreading of coherence ... [because to] define the explanation of an event as its subsumption under a general law leaves unexplained its capacity to relieve puzzlement Explanation must be understood as a particular form of insight." [1] That is, Polanyi redefines 'explanation' by saying that relief from puzzlement is not by employing an explicit rule of classification or definition, but by tacit knowing.

Polanyi's clearest presentation of his thought as Integrative Philosophy is made in his 1966 book *The Tacit Dimension*. In this work the mainspring of tacit knowing is no longer couched overwhelmingly in terms of 'belief', but in terms of its 'logical structure.' In the introduction to this book he says:

"Viewing the content of these pages from the position reached in *Personal Knowledge* and *The Study of Man* eight years ago, I see that my reliance on the necessity of commitment has been reduced by working out the structure of tacit knowing. ... [Thinking] has a *from-to* structure." [2] We attend from the proximal to the distal, from the subsidiary to the focal, "thus achieving an integration of particulars to a coherent entity to which we are attending." [3] This *from-to* logical structure is experienced as

interiorization and manifested as understanding.

... if we now regard the integration of particulars as an interiorization, ... [it] now becomes a means of making certain things function as the proximal terms of tacit knowing, so that instead of observing them in themselves, we may be aware of them in their bearing on the comprehensive entity of which they constitute. It brings home to us that it is not by looking at things, but by dwelling in them, that we understand their meaning.[4]

As I have shown earlier in discussing Polanyi's formalization[5] of *from-to* into the 'tacit triad,' by 'bearing on' Polanyi means tacit inference, his logic term for integration.

For Polanyi, integration is anchored in and evoked by the significance of the focus of attention, as it became clear in his notion of Intellectual Passions in science. In his ontology, where 'integration' of levels of comprehension is transformed into 'emergence' of levels of entities, he notes:

My analysis of consecutive operational levels necessitates the assumption of a principle which works in the manner of an innovation achieved by integration. The assumption that this process is evoked by the accessibility of the higher levels of stable meaning which it eventually achieves, seems compelling to me. The tension generated by such a potentiality might then be triggered into action either by accident or by the operation of first causes. It seems, furthermore, consonant with the conceptual framework of quantum mechanics on the one hand and of problem-solving on the other hand to assume that these creative releases are controlled, and yet never fully determined, by their potentialities.[6]

For Polanyi, the property of indeterminacy of potentiality does not preclude the achievement of meaning in integration, rather, it opens meaning up to richer possibilities --- as he noted, it is the tension generated by the potentiality which triggers the action. What holds his whole scheme of knowing and being together, is the organizing principle of integration:

It is the image of humanity immersed in potential thought that I find revealing for the problems of our day. It rids us of the absurdity of absolute self-determination, yet offers each of us the chance of creative originality, within the fragmentary area which circumscribes our calling. It [potential thought, tacit knowing] provides us with the metaphysical grounds and the organizing principle[7]

'Integration' in the sense Polanyi developed it for his systematic philosophy in *The Tacit Dimension*, is an organizing, living, directed, self-transforming act of meaning-seeking, whose goal is truth.

The 're-definitions' of these terms are to be understood as elucidated in the previous chapters. In all his works, Polanyi believed he explained his redefinitions carefully. To understand his approach, at this point we need to examine his method of explanation, and what he meant by 'explanation.' A 'teasing out' of his method is necessary because his method and his content are thoroughly intertwined.

5.2. On Polanyi's method: how does Integrative Philosophy `explain' scientific insight?

Here it is necessary to examine how Polanyi redefined `explanation' and what he could have meant by `explanation is a particular form of insight.'

In correspondence with the psychologist John Beloff, Polanyi was exploring what the materialist-positivist view of explanation may mean to working scientists. Beloff replied:

You ask me what I mean by `theoretical reduction'[8] without `logical reduction.' I mean quite simply what any scientist means by explanation, namely a theory which enables one to infer the properties of some complex system from the properties of its parts together with the laws of their interaction.

To this you would no doubt retort that no explanation is possible of any phenomena unless one has already grasped the concept of the comprehensive entity that one is trying to explain, hence there can be no question of a reduction.

I do not dispute this if we are using reduction in an epistemological sense but fail to see that this has any relevance to the question of an ontological reduction. And what the materialist asserts is that ontologically speaking a gas is nothing over and above its component mechanisms and, in particular, mind is nothing over and above the brain and body. ...

I cannot agree with you ... that a theory of knowledge can have any ontological implications whatever (except, as Descartes pointed out, with respect to the knower himself). Hence, I cannot agree that your arguments have any bearing on the validity of materialism as a philosophical position.[9]

Beloff summarized the prevailing notion amongst scientists on the conception of `explanation' --- it is precisely the notion that does not allow for tacit knowing, and which does not admit the ontological foundations the scientist assumes but does not explicitly state. It is this prevailing notion of explaining by defining properties and connections of elements only, that Polanyi aimed to correct. He found the holders of this view exceedingly difficult to persuade of the validity of his view.

Another attempt at clarifying the confusion over `explanation' can be made from seeking to answer Bar-Hillel's charge, that (in the essay `The Logic of Tacit Inference') Polanyi did not explain the problem of tacit knowing, only restated it.

Bar-Hillel's objection stems from Polanyi's use of analogy between perception and tacit inference as an explanatory device. Bar-Hillel interprets Polanyi's device as a one-to-one analogy. According to such use of analogies, perception should contain elements which are contained in tacit inference, that is

elements which can be called 'logical,' and conversely, "it is harmful to use such terms [borrowed from perception] as 'the logical relation of the subsidiary and the focal' ... [it is harmful epistemologically because it is] misdirecting our attention."[\[10\]](#)

As I explained earlier, use of the perception analogy was for the purpose of pointing out a *relation* between two different levels of awareness, and the analogy is drawn to a *relation* between two different logical levels in tacit inference (that between 'premise' and 'conclusion,' the quotation marks mean that these levels *can be taken as* premise ...). So the point of the analogy is to highlight that the relation is between different levels, not the properties of the levels.

As noted earlier, according to Polanyi, the analogy has four aspects: phenomenal (part---whole relation borrowed from Gestalt-perception), functional (the logical premise---conclusion aspect to which Bar-Hillel objects), ontological (the claim that the result of tacit knowing is an aspect of reality whose truth may be revealed in yet unknown ways, that is, it is open-ended), and semantic (the elements of tacit knowing point to their meaning, that is, meaning lies in the performance of the knowing act).[\[11\]](#)

In a sense, Polanyi is pointing out a relation of a relation, a move which can lend itself to confusion. It is the internal vector in each member of the analogy which is the point here, a point Bar-Hillel ignores. Clearly defined one-to-one analogies of the kind Bar-Hillel demands are frequently used in models --- however Polanyi is not building a model this way. His 'model building' is elucidated at length in my previous chapters.

This leads back to Bar-Hillel's charge:

You believe that you somehow furthered the inquiry into the nature of 'tacit knowledge' and you are in a position to 'explain' this phenomenon better than others are able to do. I would insist that you do nothing of the kind, that you at most restate the problem, and moreover, in my opinion, in a way which is more misleading than revealing.[\[12\]](#)

This necessitates explaining 'explanation.' Keeping in mind, on the one hand, Beloff's definition of explanation and Bar-Hillel's insistence on adhering to strict analogies as a means of explanation, then on the other hand, remembering Polanyi's idea as presented in these chapters, we may come to the following:

Beloff and Bar-Hillel are demanding an explicit statement (*Erklärung* in Dilthey's terms), an analysis, a breaking apart of 'tacit knowing.' As Dilthey noted, analysis without synthesis kills the phenomena. If Bar-Hillel is asking for explicit logic, tacit inference will not supply it. Polanyi's 'tacit triad: from-to' is implicit, and the 'logical structure' is as it is attributed by analogy. An analogy in Polanyi's usage points to an essential similarity, it does not give a one-to-one correspondence. The essential similarity here is the vectorial nature of understanding, not a correspondence in propositions.

If, as Bar-Hillel said, Polanyi only restated the problem, the question is, did the restatement put the

problem in a better light for understanding it? Or, to put it differently --- how far did Polanyi go beyond Kant? Briefly, he expanded the concept of scientific knowing from theoretical knowing to include a redefined practical knowing, a move which allowed him to include Intellectual Passions as the source of creativity and open-endedness in science.

But what may Bar-Hillel mean by 'restating the problem'? In the context of the letter, it meant that Polanyi did nothing to further understanding. On the other hand, to 'restate' (*neue Darstellung*, i.e. a new representation, showing, portrayal), for Polanyi, is a combination of Dilthey's meaning of reproduction (*das Nachbilden*) and his meaning of hermeneutics (*die Hermeneutik*): the first, the conscious process in my mind by which I re-experience someone else's mental process and thereby it is possible for me to understand its reality; the second, the art and science of interpreting enduring expressions of mind.^[13] 'Restate' in this sense is a series of integrative acts which may subsume analysis where needed, however the overall process is integrative. As Polanyi said, explanation is a form of insight.

Therefore, to answer Beloff and Bar-Hillel, Polanyi's explanation is not a definition, it is a new interpretation. These "heterodox ideas on the philosophy of science"^[14] were the working out of his alternative epistemology, that is, what he saw as the 'logical structure of Personal Knowledge' with its organizing principle of integration. If Polanyi 'restated the problem,' his restatement is a reinterpretation, a reconception, illuminated by previously unexplored connections and offering new principles.^[15] It may be said, that he employed a combination of 'reduction to the familiar' (analogies, examples) and 'concepts and principles of novel kinds,' rather than offer a definition.^[16]

In a letter to Charles C. Gillispie of Princeton University, Polanyi's understanding of his heterodox philosophy of science is stated as the concern with the logic of how all the various levels of sciences 'hang together.' This is a logic, which as I presented earlier, must include the logic of tacit knowing, and a logic which can be explained not by definitions, but by showing (informal logic).^[17] In this same letter to Gillispie, Polanyi points out what he considers to be the errors of 'scientific explanations,' that is reductionism, by way of saying why he felt the need to develop his alternative philosophy of science:

Biologists speak of explaining living beings in terms of physics and chemistry, but they never actually realise what this means. They assume that to explain life *in terms of a mechanism based on physics and chemistry is to explain it in terms of physics and chemistry, and this is false*. Thus misconceived, the claim to explain life by physics and chemistry comes to stand for the claim of explaining life by mechanical models, and this claim has much truth in it [since models are 'as if' conceptions]. ...

Though the claim to explain all living processes mechanically is absurd, *all* life has a *mechanical aspect* which is truly explained by a mechanism. Now suppose that this appears to be as much as we can achieve at this time. It would be a sound policy then to restrict enquiry to the mechanical aspects of life as if they explained life altogether. And consequently, scientists --- being primarily concerned with the advancement of science --- may come so firmly to uphold this fiction that they will regard it as 'the scientific view' of life and condemn anyone challenging this fallacy as

an anti-scientific obscurantist. ...

When manifest truths are obscured in the interest of advancing scientific research, we must disregard this interest, if we are to vindicate these truths. The Universe is not determined by one single set of principles, but by a number of them. ... [We] have a hierarchy of biological principles, in which each higher principle controls the boundary conditions left open by the principles below it Science can study this hierarchy on each level. ... [morphology, embryology, ...] But neither of these sciences is concerned with the kind of logical criticism which shows how all these levels hang together. Such comprehensive enquiries, extending over the whole universe and including the very grounds on which we reflect on the universe, are the task of philosophy. This, at least, is what I understand by philosophy.[\[18\]](#)

This letter indicates that Polanyi's overriding concern throughout is the commitment to search for what he believes to be the 'true' face of reality, and the effort to understand how various levels of explanations of this reality 'hang together.' He was searching for an overall view, and explanatory principles which could encompass complex systems (such as biological phenomena), which could illuminate the function as well as the ontological underpinnings of these systems. He was not willing to accept reductionist models as a replacement for 'as if' conceptions. Although the language he employed in his works makes it difficult to see, he wanted to keep all uses of analogies clearly in view, with the warning that analogies are but pointers. This holds for 'the scientific view' he criticized, as well as for his own alternative explanation of the "Dynamic Order"[\[19\]](#) in scientific thinking and the relations between science, ideals and society. The above letter would indicate that the 'scientific view' he criticized is reductionist, which tends not to view models as 'as if' models. He spent the last thirty-five years of his active life on explanation and clarification.

Polanyi's Integrative Philosophy explains scientific insight by showing how an expansion of the foundations of explanation would be more in keeping with the actual facts of how scientists arrive at insights. He claims that this expansion to include tacit knowing is not only possible but necessary to avoid fallacies of reduction which may have, as he insisted in the preface to *Personal Knowledge*, a deleterious effect on the human sciences.

5.3 Examples of Polanyi's use of Integrative Philosophy in scientific insight: An analysis

For Polanyi, the most significant use of Integrative Philosophy for science was for the examination of selective and heuristic functions in scientific originality. These functions and their personal elements can be separated only artificially: the personal element in the selective function is an aesthetic response, and in heuristic function it is a goal-directed striving.

According to Polanyi, "scientific originality works informally and irreversibly, whether it operates in symbols or on immediate experiences. This will be our clue to understanding of [intellectually exhilarating] beauty as a token of reality in science, by contrast to mere elegance which has no such significance."[\[20\]](#)

Polanyi's use of 'intellectual beauty' has made scientists, though not mathematicians in general, suspicious of imported Platonism. According to Polanyi, the originality of the discovery can be assessed by the degree of surprise, of shock, which measures the discontinuity between the old and the new --- the leap which traversed the logical or heuristic gap.[\[21\]](#) The gap measures the irreversibility, the self-transforming act, the change of framework. For example, in response to M. Fierz's (Professor of Physics University of Basel) question on the similarity of Polanyi's notion of traversing the logical gap to the quality of beauty in Plato's theory of science, Polanyi responded: "There is an element of the Platonic view included, but with the intention of avoiding the possibility of having Platonic ideas laid up somewhere and looking at them in a detached manner. For these 'Platonic ideas' of mine exist only in our acceptance of them."[\[22\]](#) So, for Polanyi, intellectual beauty is both that which is found by traversing the heuristic gap, and the connotive act --- in this sense, beauty is an integrator of the understanding.

5.3.1 Example from Mathematics

The mathematician G.H. Hardy had no difficulty accepting Platonic theories of intellectual beauty. Polanyi refers to him[\[23\]](#) in the context of beauty of mathematical discoveries tacitly understood: since the convincing power of a mathematical proof operates through our tacit understanding of it, the acceptance of a proof may also involve radical conceptual innovations --- the intellectual beauty of a theorem seen by its discoverer needs to be seen also by those who want to understand it. The intellectual beauty is the revealer of the radical conceptual innovation for both persons:

There are beautiful theorems in the "theory of aggregates" (*Mengenlehre*) such as Cantor's theorem of the "non enumerability" of the continuum',[\[24\]](#) writes G.H. Hardy, "the proof [of which] is easy enough once the language has been mastered, but considerable explanation is necessary before the meaning of the theorem becomes clear". Cantor's proofs traversed a logical gap across which those willing to enter into their meaning and capable of grasping it could follow him.[\[25\]](#)

In this quote, Polanyi points out, that the proof which the mathematician tacitly understands, would require extensive explicit explanation, which still does not guarantee understanding. It is the seeing of the beauty of the proof which seems to make understanding so simple. The recognition of Beauty is the integrator of understanding.

Hardy's beliefs about the role of beauty as integrator are better expressed in his book *A Mathematician's Apology* where he talks about the context of discovery as well as of the context of verification (proof). Here, he calls a mathematician a maker of patterns:

A mathematician, like a painter or a poet, is a maker of patterns. If his patterns are more permanent than theirs, it is because they are made with *ideas*. ... The mathematician's patterns, like the painter's or the poet's, must be *beautiful*: the ideas, like the colours of words, must fit

together in a harmonious way. Beauty is the first test: there is no place for ugly mathematics. ... It may be very hard to *define* mathematical beauty, but ... that does not prevent us from recognizing [it][26]

Hardy's idea of standards[27] for recognizing beauty as revealing mathematical reality are very similar to Polanyi's selective function of intellectual passions, i.e. seriousness, significance, depth, generality, unexpectedness, inevitability. For Hardy also, the reality thus discovered is 'outside the knower' (not subjective), although he distinguishes a physical reality in the ordinary sense and a mathematical reality which is undefinable and is a metaphysical problem:

I believe that mathematical reality lies outside us, that our function is to discover or *observe* it, and that the theorems which we prove, and which we describe grandiloquently as our 'creations', are simply our notes of our observations. This view has been held, in one form or another, by many philosophers of high reputation from Plato onwards[28]

According to Polanyi's scheme then, for Hardy a theorem is an integration revealing a mathematical reality whose significance is recognized from experience. Beauty functions both as a selector and as the attractor, the revealer of reality in the mathematician's heuristic self-transforming act as 'maker of patterns'; furthermore, a mathematician believes in the universal validity of his patterns because mathematical reality is not subjective --- he sets out on his discovery act with universal intent.

All four aspects of tacit knowing are exemplified and integrated in this example. The phenomenal aspect of part-whole relation is the mathematician's way of 'seeing' the situation; the functional aspect of premise-conclusion, on several levels, but specifically in the relation of the mathematician's background knowledge to the achieved solution; the ontological aspect in the mathematician's claim that the results are mathematically real; and the semantic aspect in that meaning lies in the performance of the finding of the solution.

5.3.2. Example from Biology

The zoologist Pantin, quoted by Polanyi,[29] spoke of the role of beauty in revealing reality as 'aesthetic recognition,' a whole impression made by the organism in the researcher's mind in his work in taxonomy. [30] He described his work of identification of a newly discovered species in the field in contrast to a systematic recognition (by a deductive process) based on key features in classification in the museum. In the living animal, he noted, the internal features used for correct identification are invisible, yet Pantin was able to identify living specimens in the field. According to him,

... in the museum I seek a collection of definite 'yes or no' characters, those used in a key. ... This sort of selection is not to do with the organism: it is to do with my logical processes. After we have selected the 'yes or no' characters, a very great deal of the impression which the organism makes upon us still remains 'unused'. This residue is undoubtedly important in our recognition of species even though it cannot be analysed in just this way. This residue, and indeed the whole

impression made by the organism, is used when we recognize a species in the field. Field recognition cannot easily be translated into accurate analytical description. But it can be communicated to others. It can often be conveyed vividly by metaphor, simile and association, in fact by the ordinary modes of poetic expression.[\[31\]](#)

Pantin's notion of aesthetic recognition, this whole impression of the object which can be conveyed by poetic expression, seems to him to be an instantaneous apprehension of many kinds of relationships at the same time. He admits to the risk of error in aesthetic recognition, since it involves personal judgement. This judgement must be used with a quality Pantin calls honesty. In spite of the risk of error, the zoologist does recognize something real: an individual of a species not seen before.

In lecture notes for the Meaning Project of 1969 on 'Kinds of Self-centered Integration'[\[32\]](#) Polanyi affirms that Pantin's notion of 'aesthetic recognition' shows that "integration relies subsidiarily on a number of somewhat indeterminate particulars, which include a contribution of more or less specifiable items. ... [This recognition] is the hidden skill Kant speaks of ..."[\[33\]](#)

Aesthetic recognition in the biological sciences also, is an aspect of the integrator in scientific discovery --- it provides the 'hunch' in the context of discovery. The reality perceived in biology is a physical reality, unlike the mathematical reality spoken of above. However, the physical reality perceived is a relation not a sensory datum --- it is a 'whole impression ... a recognition of species,' a recognition of the meaning of what is seen. Pantin speaks about functions as the set of elements in subsidiary awareness organized by the scientist's imagination and skill of 'guessing right' to yield the 'recognition of species' in focal awareness.

The two most prominent aspects of tacit knowing in this example are the phenomenal aspect of the parts merging into the whole of the appearance as in Gestalt-perception, and the functional aspect with its intentional directedness from the 'parts' to the 'whole,' that is directedness from the 'residue' to 'recognition of the species.' The ontological claim is an aspect of recognition, of affirmation that what was recognized is indeed a particular species not explicitly or fully described as yet. The semantic aspect, which 'gathers up' so to speak the clues into the meaning 'this is species X!' in this example is the end-point of Pantin's aesthetic recognition process.

[Next part](#)

Notes

1. Polanyi, 'Logic and Psychology' p. 37.

2. *TD*, p. x.

3. TD, p. 18.
4. TD, p. 18.
5. By formalization Polanyi does not mean reduction. Significantly, he means a setting of a problem, more like a decision-making rather than a solving of the problem. `Notes made in July 1962' Polanyi Papers (21:1).
6. TD, p. 90.
7. TD, p. 91. For `potential thought,' see Blanshard, *The Nature of Thought*, vol.2, pp. 261-2. Excerpt filed in Polanyi Papers (23:3).
8. For a discussion of theoretical reduction, see Carl G. Hempel, *Philosophy of Natural Science*, pp.101-110. In summary Hempel's statements are: at the present state of theoretical development, mechanists claim that biology is reducible to physics and chemistry. The `thesis of the autonomy of biology' denies this claim. But, `mechanism' is best construed as a heuristic maxim for guidance of research, not as a principle of biological process. --- In general Polanyi would agree with this interpretation: see his letter to Gillispie below.
9. John Beloff, Department of Psychology, Univ. of Edinburgh. Letter to Polanyi dated 21 August 1963. Polanyi Papers (6:3).
10. Yehoshua Bar-Hillel, Department of Linguistics, Univ. of California. Letter to Polanyi, dated April 25, 1966. Polanyi Papers (6:8).
11. `The Logic of Tacit Inference,' *Knowing and Being*, pp. 141-145.
12. Bar-Hillel's letter to Polanyi, April 25, 1966.
13. Paraphrased from H.A. Hodges, *Wilhelm Dilthey: An Introduction*, p. 160.
14. which were given in a paper at the Congress in Jerusalem but not published in the *Proceedings for the 1964 International Congress for the Logic, Methodology and Philosophy of Science*. See: letter of Bar-Hillel to Polanyi dated Dec. 30, 1964, The Hebrew University of Jerusalem. Polanyi Papers (6:6). From the correspondence it is not clear if a re-write was requested for publication. This paper subsequently appeared as `The Logic of Tacit Inference,' *Philosophy*, 41, (Jan. 1966), pp. 1-18.
15. TD, p. 90.
16. See Hempel's *Philosophy of Natural Science*, p. 83. Although Hempel's discussion is of scientific

theories, Polanyi seems to have employed these techniques in working out his epistemology.

17. *Logic and Psychology* p. 27.

18. Polanyi's letter to Charles C. Gillispie, dated 30th June, 1966, Polanyi Papers (6:8). [Italics in original.]

19. Letter to Toni Stolper, dated 3rd October 1943. Polanyi Papers (4:10): 'Science, ideals and society' became the 1946 book *Science, Faith and Society*. Some of the earlier ideas he refers to were published in *The Logic of Liberty*, esp. chapter 10. Here he does not mention a 1937 attempt at working out the dynamic order between truth, reason, justice, ideas and beliefs with regard to science and learning, in which he explored the concept of hierarchies and frameworks. See his essays 'On Truth', 'On Reason', 'Truth & Justice', 'Ideas & Belief', and 'Notes on the Position of Science'. Polanyi Papers (25:11).

20. Michael Polanyi, 'Beauty, elegance, and reality in science', in *Observation and Interpretation: A Symposium of Philosophers and Physicists*, ed. by S. Korner (New York: Academic Press Inc., 1957). This article has been later partially used in *Personal Knowledge*, Chapter 5.

21. This surprise, according to Polanyi, is part of the selection process for the granting of new patents: "When we acknowledge that a skillful performance is coherent and ingenious in itself, we appeal to standards of coherence and ingenuity to which we attribute universal significance. The operation of the patent law relies successfully on our capacity for appreciating the presence or absence of a certain degree of ingenuity in a new practical procedure." Michael Polanyi, 'On the Introduction of Science into Moral Subjects,' *Scientific Thought and Social Reality: Essays by Michael Polanyi*, ed. by Fred Schwartz. (New York: International University Press, Inc., 1974) p. 93.

22. Polanyi, 'Beauty, elegance, and reality in science' p. 118.

23. *PK*, pp. 186, 190.

24. For an accessible form of this theorem, see Edward Kasner and James Newman, *Mathematics and The Imagination* (New York: Simon and Schuster, 1940) pp. 27-53, but especially p. 53.

25. Polanyi, quoting Hardy in *Personal Knowledge*, pp. 189-190.

26. G.H. Hardy, *A Mathematician's Apology* (Cambridge: Cambridge University Press, 1941) p. 24. [Italics in original.]

27. Hardy, *Apology*, pp. 39-53.

28. Hardy, *Apology*, p. 63. Quote filed in Polanyi Papers (23:14).

29. *PK*, p. 351.

30. In biology, taxonomy means the application of principles and laws of classification of plants and animals into distinct kinds according to certain sets of characteristics. Kinds with a specified set of distinguishing characteristics are given a name in common. There are several levels of division.

31. C.F.A. Pantin, *The Relations Between the Sciences* (Cambridge: Cambridge University Press, 1968). pp. 112-113.

32. Polanyi, 'Kinds of Self-centered Integration', *Polanyi Papers* (21:10). These notes were reworked by Prosch and published as their joint book *Meaning*, Chapter 5.

33. Polanyi, 'Kinds of Self-centered Integration', p. 10.

[Next part](#)

[Back to Contents](#)

Polanyiana Volume 5, Number 2, 1996, pp. 36-65

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