A Polanyian Reflection on AI

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Introduction

What follows is both historically oriented discussion and an effort to suggest that Polanyi's thought can be a useful contemporary resource for philosophy of technology focusing on emerging digital culture. I bring together some of the ideas Michael Polanyi developed in the mid-20th century about living beings and machines—both are what he termed "comprehensive entities"—and some contemporary discussions about artificial intelligence. "Artificial intelligence" (AI) seems to be a broad and ambiguous area concerned with making smart machines which augment human abilities generally associated with human intelligence (Coombs).[1] AI is, of course, today played for all it is worth by popular media and it has a history that is complicated. Most of this interesting history unfolded after Michael Polanyi's life. I am interested in the "machine learning" area (also sometimes called "predictive analytics") of contemporary AI and, even more specifically, in work on "deep learning neural networks," which seems to be an area within machine learning (Coombs). I have no expertise about—or even any sophistication about—machine learning or neural networks. I am a curious novice. Nevertheless, I find interesting connections and disconnections between some of Polanyi's philosophical conclusions about living beings, machines and computers and some current discussion about deep learning neural networks. Society is already making extensive use of deep learning neural networks. Polanyi's framework for thinking about machines I believe is a useful general framework to recover. But I also think Polanyi's framework needs to be recast.

Deep Learning Neural Networks: A Very Brief Overview

So-called "neural networks" have been discussed in theory since 1943, a few years prior to the time Michael Polanyi first commented on computers in 1949 and by 1958 (if not before) Polanyi was aware of the famous McCulloch and Pitts paper on neural networks and very briefly commented on it in *Personal Knowledge* (PK 340—see discussion below). Although there were

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[1] I rely on two straightforward, non-technical orientational discussions: (1) Ted Coombs, *Artificial Intelligence & Cybersecurity for Dummies*.2018. John Wiley & Sons, available online at https://hosteddocs.ittoolbox.com/ai_cybersecurity_dummies.pdf, and (2) Skymind's A.I. Wiki, "A Beginner's Guide to Neural Networks and Deep Learning" available online at https://skymind.ai/wiki/neural-network#define. I also make use of Amy Web's recent book, *The Big Nine: How the Tech Titans & Their Thinking Machines Could Warp Humanity* (NY: Public Affairs,2019). References are noted simply in parenthesis in the text or in footnotes (and Polanyi titles are abbreviated); I acknowledge that my debts to Coombs, Skymind, and Webb go beyond the direct quotations and that I have read and learned from many other unacknowledged articles and internet sources about neural networks.

models and experiments in the twentieth century, “deep learning neural networks” have been widely implemented for all sorts of projects only recently. Basically, a “neural network” is an algorithm which is designed to “recognize” patterns. Such algorithms can interpret data with a “kind of machine perception” enabled through human labeling or the clustering of raw input (Skymind). The algorithms “recognize” patterns which are numerical and present in vectors. All real-world knowledge must, of course, be translated into machine-readable numerical data for any patterns to be discerned. First “shallow” neural networks (three or fewer levels) were developed, but now there are “deep learning” networks which have more than three levels. Each level has nodes where computation happens and levels can be fed into each other. The node combines input from data and coefficients or weights giving significance to inputs “with regard to the task the algorithm is trying to learn; e.g., which input is most helpful in classifying data without error” (Skymind). The signal then either does or does not “progress further through the network to affect the ultimate outcome.” (Skymind). That outcome is articulated in terms of a certain “confidence level” about work done by the deep learning neural network (Coombs).

Insofar as deep learning networks are involved in classification, they are software that makes sophisticated correlations. “Classification” by deep learning networks requires humanly labeled datasets: “. . . humans must transfer their knowledge to the dataset in order for a neural network to learn the correlation between labels and data.” If human beings can produce the labels, then “any outcomes that you care about and which correlate to data, can be used to train a neural network” (Skymind). “Clustering,” unlike classification, is grouping which is focused on finding similarities and anomalies. No labels are required and most data in emerging digital culture is unlabeled. The more “data an algorithm can train on, the more accurate it will be” (Skymind). Apparently, there are not necessarily a great many data sets ready to be used and “synthetic data” is on the market and its use may skew results (Webb, 182). Nevertheless, in emerging digital culture where there are already many accessible digital artifacts (e.g., the internet), so-called “unsupervised learning” (i.e., “learning without labels”) has broad potential and already is used in many applications such as searching (Skymind). Apparently, it is possible at times to put together classification and clustering and other machine learning strategies and this enhances pattern recognition. Deep learning neural networks work not only on digitized images and audio but also digitized written texts in natural languages.

Deep learning pattern recognition is much finer grained than humans can manage without the help of such tools. It seems to be done by algorithms that “tweak” themselves (see discussion below). That is, the tree structure and the way that levels feed into other levels makes such algorithms seem to “learn,” although the path to output is not always clear. Deep learning neural networks are a clustering and/or classifying layer with many connected working levels added to data that is electronically stored and managed and networks can “extract features,” which can be “fed to other algorithms” (Skymind).

Deep learning neural networks are a new generation of "contrivances," to use Polanyi's term (PK, 328, see the discussion below), which he broadly applied to all kinds of devices which humans have created to shape the bio-cultural niche in which we live. Contrivances are telic artifacts. Most of Polanyi's examples of contrivances were mechanical devices although he also included processes, digital devices and automata. Contrivances thus include contemporary computers running the kind of software identified as deep learning neural networks used to discern patterns. There are, of course, today all kinds of difficult new ethical and political questions about the development and use of deep learning neural networks. Such algorithms have been developed and quickly put to use in a market-driven environment rushing for profitability, and in some regions such as contemporary China deep learning neural networks are tools overtly used for social control.

Polanyi: A Very Brief Overview

Michael Polanyi was a polymath but his early work as an outstanding research scientist living in the tumultuous European culture of the early 20th century shaped his constructive philosophical ideas, which in fact evolve over the course of his life. It is a fair but somewhat narrow description to tag Polanyi, as he often is, a philosopher of science and an epistemologist. Polanyi did aim to reframe the dominant mid-century understanding of science and scientific knowledge and he focused on scientific discovery as the key to science. But discovery for Polanyi becomes the paradigm case of human knowing. Polanyi tried to reform the dominant positivist and Marxist accounts of science in his time and he did this, as he frequently notes, by developing Gestalt ideas into an account of knowing. Fundamentally, Polanyi's philosophical approach and outlook are anti-Cartesian, although his anti-Cartesian orientation is more like that of a figure such as the American philosopher Charles Sanders Peirce than European contemporaries such as Heidegger or Merleau-Ponty or others offering Marxist influenced accounts. Polanyi's Gestalt epistemology does not begin with presuppositions that separate mind and matter and he emphasizes belief and its role in promoting the growth of thought in communities of interpretation such as science rather than doubt as a royal road to truth. He focuses attention on knowing as a process, one in which a person embedded in a biosocial location integrates subsidiarily known elements to attend to a focal whole; persons make contact with reality and are capable of understanding real coherences. In sum, Polanyi aimed to re-frame the mainstream understanding of understanding and to emphasize the importance of ongoing human inquiry. Inquiry for Polanyi is a special human vocation, one that requires skillful participation and imagination and elicits our commitments; inquiry engages us in public conversation with social companions about what is real and has the potential, Polanyi argued, to make human beings again at home in the biosocial world we discover and shape.

Although Polanyi did take an interest in questions about computers and the human mind, he was a thinker who did not anticipate that the computer would be an epoch-making device that would reshape so much about late twentieth and twenty-first century culture.[2] He does not discuss the importance of the development and proliferation of digital media. He died in 1976 before emerging digital culture, now supplanting print culture, was broadly visible. Polanyi's philosophical reflection was primarily focused on re-orienting the troubled European culture that he saw developing in his own lifetime between World War I and his death in 1976. His constructive philosophical oeuvre (which is in part *Lebensphilosophie*) was woven inextricably with sharp philosophical critique directed at the late thought and culture of European modernity which he argued was a milieu in which nihilism, violence and totalitarianism predominated. Polanyi argued changes brought by the scientific revolution morphed into a dangerous misrepresentation of science (scientism), which sowed the seeds of the problems of late modernity. He aimed to heal the late modern mind and believed a reframed philosophy of science rooted in a new account of human understanding (i.e., his "postcritical" perspective) could be the key to this.

Polanyi on "Comprehensive Entities": Understanding Comprehensive Entities

In Polanyi's constructive philosophical thought, he introduces the innovative conception of what he terms a "comprehensive entity." A "comprehensive entity" is an understood coherence, a meaningful unity, which entails a subsidiary awareness of parts that are not altogether specifiable in detached terms. If the comprehensive entity is a living being such as an animal, this is a case in which there is an implicit acknowledgement of a particular comprehensive achievement of the individual. Polanyi emphasized that recognizing a molar function cannot be reduced to molecular particulars (PK 327).

Polanyi's ideas about comprehensive entities evolve from the early fifties until about the mid-sixties. He first used this term in his Gifford Lectures (1951 and 1952) and he modestly expanded his account in *Personal Knowledge* (1958), his magnum opus, which grew out of his Gifford Lectures. Most but not all of his PK uses of "comprehensive entity" (see PK, 64) are in the final division of PK, the "Knowing and Being" division (PK, 327-405, 3 chapters paralleling his final three Series II Gifford Lectures). Here the discussion moves from the more general problem of knowing to the matter of knowing living beings and the evolution of living beings. "Comprehensive entity," as Marjorie Grene notes in *The Knower and the Known* (223-224), is a term Polanyi used primarily in this section of PK to designate a known living being. Sometimes (but not consistently) Polanyi speaks of knowing "comprehensive biotic entities" (PK, 342) when discussing the matter of knowing life or particular living individuals. To study an amoeba or a complex bio-cultural creature like a human being requires a molar recognition of a coherent entity embedded in and active in a particular environment.

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[2] See J. D. Bolter's illuminating early discussion in *Turing's Man: Western Culture in the Computer Age* (Chapel Hill, UNC Press, 1984).

For Polanyi, molar recognition is a kind of participation of the knower in the known. Polanyi frequently characterized his effort to turn important Gestalt ideas into an account of knowing as an approach that emphasized participation. (PK x, xiii. 65, 379; SM, 26, 28-29, 32, 62). Molar recognition involves dwelling in subsidiaries (i.e., making them function in the special way parts of the body function when we use them to attend to what is of interest) and grasping their conjoint bearing in the meaning of a whole (i.e., integrating relevant subsidiaries). Polanyi argued that the predominant approach of much science was reductionistic insofar as it smuggled in but denied the importance of the molar and focused instead on least parts (usually fundamental elements recognized by physics and chemistry) which were assumed strictly to determine a whole. While this reductionism was not always harmful, it is grounded in Cartesian presuppositions which implicitly accept as a starting point a res cogitans/res extensa bifurcation.[3] It fails to acknowledge the knower's participation in grasping the known. This reductionism has inclined science (and broader culture which has been influenced by scientistic accounts of science) to favor one-level, predominantly materialistic explanations.

Machines and Comprehensive Biotic Entities-Two Kinds of Comprehensive Entities

In PK, Polanyi focused attention on not only known living beings but also on machines as recognized "comprehensive entities." He was deeply interested in similarities and differences between comprehensive biotic entities and machines and he explored this topic extensively in Part IV of PK. To know or understand a machine requires molar recognition of its coherence, just as does knowing a comprehensive biotic entity. Such a molar perspective is bound up with purpose. Just as an amoeba or a human being must be recognized as a directed or purposive living system acting within a niche where it flourishes or perishes, a machine must be recognized as a whole in terms of its purpose realized in a particular human socio-political and cultural context. The purposes of comprehensive biotic entities are realized in action initiated by or within the entity (i.e., in behavior or achievements within a niche) and living entities are reshaped in evolutionary history in interaction within a dynamic environmental niche. Similarly, the telic element of a machine is realized in action (i.e., its use) but it is designed by engineers and technologists, and fits into a certain socio-cultural economic and political niche. And machines, of course, become obsolete and are replaced or updated and improved by engineers and technologists.

The successful action or functioning of both a comprehensive biotic entity and of a machine can be understood only in terms of what Polanyi terms conformity to "rules of rightness" (PK, 329). Such rules are concerned with the appropriate way in which a defining operational principle is

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[3] This kind of ontological separation was spun out, in the modern philosophical tradition, into an objectivism which idealized a view from nowhere, a God's eye account. Objectivism informs the "scientism" which has pervaded many areas of inquiry. In Polanyi's more general account, objectivism and "scientism" (especially in the social sciences and cultural studies) eventually effectively undermine the traditions and ideals underpinning social stability and democracy as well as valuable endeavors such as scientific research.

situated and properly functions to realize achievements. The failures of both types of comprehensive entities must be located not at the "higher" defining level of an operational principle conforming to rules of rightness, but, Polanyi argues, at a lower level of control that Polanyi most frequently associated with physics and chemistry. This rather abstract structural approach to understanding comprehensive entities is one that emphasizes the two-level hierarchy of control in entities (see discussion below); it is an account which counters what Polanyi took to be the dominant kind of reductionism found in much of modern science whereby explanation overlooks wholes and focuses on least parts.

Living beings such as animals have many machine-like features, but they also have the capacity for originality not found in machines. Polanyi characterized comprehensive biotic entities in terms of the functioning of "two always interwoven principles, namely as machines and by 'regulation.'" While machine-like functions operate "by a fixed structure," regulation in an ideal case is an "equipotential integration of all parts in a joint performance," but "both kinds of performances are defined by rules of rightness" (PK 342). Polanyi held that the rules of rightness for machines and machine-like functions in comprehensive biotic entities can ideally be defined with analytical precision; however, "the rightness of regulative achievements in living beings can only be expressed in gestalt-like terms," since recognizing regulative achievements involves the kind of skillful appraisal in connoisseurship (PK 342).[4]

In Polanyi's philosophical writing after PK, some of his earlier discussions about "comprehensive entities" are further elaborated in books like *The Study of Man* (1959, hereafter SM) and Polanyi's lectures, essays and books in the sixties. In SM, Polanyi argues there are two "levels of reality" in personal knowledge (i.e., understanding), "that of a comprehensive entity and that of its particulars (in terms of which the entity is unspecifiable). . . " Between these levels there is "a peculiar logical relationship, derived from the distinction between subsidiary and focal awareness." Polanyi suggests that there are a "consecutively rising set of levels" in comprehensive biotic entities ascending toward "responsible human personhood" (SM 46). Polanyi thus posits what he calls "the stratification of reality" (SM 58) and he uses this conception to account for the complexity of human beings as peculiar comprehensive biotic entities that are embedded bio-cultural living beings with special talents (or tacit powers) and responsibilities.

In the sixties, Polanyi worked out more carefully his ideas about the relation of two levels of reality in terms of the dual control structure of comprehensive entities which he sometimes explained in terms of control of "boundary conditions" or "marginal control" (see the 1965

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[4] Polanyi suggests that comprehensive biotic entities, unlike machines, have certain "equipotential" (PK, 337) powers for achieving action and he understands this as the inventive initiatives found in living entities. In PK (PK, 337-339), he speculated about the continuity between heuristics and morphogenetic equipotentiality, relying on some now outdated biology, since both involve the operation of rules of rightness.

essay "The Structure of Consciousness," in *Knowing and Being* [hereafter KB], 216-17). In an unpublished interview in 1966, Polanyi suggested that in a 1962 essay ("Tacit Knowing: Its Bearing on Some Problems in Philosophy," KB 159-180) he reinforced what he regarded as his relatively weak critique of reductionist mechanism in PK (probably he had in mind PK 328-331, 343-346, and 381-382) and added a new argument ("the most decisive things which have come out since Personal Knowledge"[5]). Polanyi suggested that in PK he argued machines could not be represented in terms of physics and chemistry and this was a case based on his claims about molar recognition. But he later developed the stronger argument that levels of reality in comprehensive entities are irreducible because of the "principle of boundary control," which shows the structure in comprehensive entities through which such entities exist: thus "the same system can be under two or three or four or five fold control of different principles because each stratum has its boundaries controlled by another higher principle; and the case of the machine is now analyzed and properly established in these terms."[6]

The Logic of Contriving—Polanyi's Hierarchical Schema

Polanyi suggested in PK that what he termed the "logic of contriving" illumines the general nature of machines, although not only machines but such things as technical processes qualify as contrivances. Although for two millennia there has been serious study of the "logic of deductive reasoning" and philosophers have worked on the "logic of empirical inference" for centuries, the "logic of contriving" is a domain that has not been thoroughly explored because of the dominant modern philosophical effort, as Polanyi puts it, to "reduce all knowledge to strictly impersonal terms" (PK 328).

Polanyi contended that contrivances are "classes of objects that embody a particular operational principle" (PK 328). Tools, machines and technical processes are "characterized by an operational principle" which can, if new, be patented, and this differs fundamentally from an

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[5] The unpublished April 5 and 6, 1966 interviews of Polanyi by Ray Wilken (Wesleyan Interview Transcript 3 File, pp. 9-10 at http://www.polanyisociety.org/WilkenInterview/WslynIntrvw Apr5&6-1966-transcript-file3.pdf) provide the clearest discussion by Polanyi of what he takes to be a significant post-PK development in his ideas about boundary control. In this paragraph, I quote from the transcript of these interviews (accessed 10 May 2019).

[6] See the further discussion below of machines. Effectively, what Polanyi calls his "new argument" which pays attention to "levels of reality" (transcript-file 3, p. 10) moves from his PK epistemic focus on the irreducibility of conceptions to an account focusing on how such structures can exist. Polanyi's new insight is a prerequisite for his discussions, beginning in the same period, of the "ontological aspect" (TD 13) of tacit knowing and comprehensive entities. PK is focused on "the fiduciary program" (PK. Torchbook ix-x, 264-269) and does not discuss "ontology," although PK IV treats the problem of knowing comprehensive biotic entities. But Polanyi's writing in the decade after the publication of PK focuses on refining his epistemological model focused on his theory of "tacit knowing" (TD x; PK,Torchbook xi) and some of this post-PK writing does treat the "ontological aspect" and the "ontological claim" (TD 141; "The Logic of Tacit Inference"1964, KB 138-158) of tacit knowing.

"observational statement" which, if new, is a "discovery" but cannot be patented (PK 328). Patents, Polanyi noted, "attempt to cover all conceivable embodiments" of a particular operational principle and avoid mentioning physical or chemical particulars of any actual constructed artifact unless these are critical (PK 328-329). New contrivances embodying a particular operational principle, are, of course, used in a certain socio-economic context to realize certain human purposes.

In the few years soon after the publication of PK, Polanyi seems to have worked out more fully some elements of the "logic of contriving." Effectively, contrivances function in ways in part similar to comprehensive biotic entities insofar as both types of comprehensive entities have a hierarchical structure and this structure's operation can be described only in terms the intersection of two levels of control. The higher level of control definitively contours or realizes objectives and this level operates within boundaries left open by the lower level of control. Contrivances thus are classes of objects which embody a particular operational principle as a higher level in a hierarchical dual control structure. That is, the operational principle is instantiated as a top or defining level of a pair in an artifact, and this higher level we usually identify as the artifact's purpose. But a higher level operating principle must be recognized as always operating within certain constraints (or margins left open or set by a lower level of control) and Polanyi thus argues (as noted above) that failures of entities can be discerned only in terms of problems at the lower level of control.

All machines, in Polanyi's broader account, seem to be comprehensive entities that are contrivances in which human beings dwell (as we dwell in our bodies) and thereby understand (at least at some general level), use and improve; such contrivances are interesting and can be employed to change the human condition and human possibilities. Although Polanyi seems to have admired the intricacy and elegance of some machines and the ingenuity of engineers, he clearly distinguished machines as tools from living beings. All living beings—broadly speaking—are akin, as Plato also noted, and at least some living beings warrant profound respect in Polanyi's account.[7]

Although much of Polanyi's discussion in PK focuses on mechanical devices, he intended to include electrical or electrical and mechanical devices such as computers under his rubric "contrivances," since he likely saw digital devices as the newest generation of contrivances. Some machines, like comprehensive biotic entities, are complex artifacts in which there can be

[7] Polanyi apparently intentionally does not extend to contrivances the special vocabulary emphasizing "centres," "achievement" and "tacit powers" that he employs to characterize and distinguish different comprehensive biotic entities which are immersed in evolutionary history. While certainly machines are "real" entities, Polanyi does not suggest that the reality of this type of comprehensive entity has the resonant depth of potential meaning of some comprehensive biotic entities such as human beings or the complex problems studied by scientists, problems whose indeterminate future manifestations he emphasizes.

a hierarchy of "dual controlled" layers. Although he suggests that understanding the operational principle operating at a higher level in a machine is a matter of connoisseurship (PK 328), Polanyi holds that machines, unlike comprehensive biotic entities, have no inventive powers. They operate in terms of a fixed set of relationships (even if they are self-adjusting machines). Machines are contrivances manifesting a purpose and it is human beings who construct complex contrivances to achieve particular ends or purposes (although some other animals may contrive simple tools).

The Evolution of Comprehensive Biotic Entities and Technology-Two Kinds of Evolution

Polanyi argued that the account, in the Modern Synthesis, of the evolution of comprehensive biotic entities (narrowly emphasizing mutations and random selection) was inadequate since it diverted attention from important questions about the nature of life and the emergence and evolution of life. He emphasized the importance of the rise of higher beings from lower ones and particularly anthropogenesis. This approach to evolution was a part of his more general philosophical project aimed at reframing the understanding of modern human beings and promoting a sane and responsible political and cultural order. The biology of the mid-twentieth century, Polanyi contended, had generally ignored the agency of living entities as well as the pattern of deepening agency seen in evolutionary history. Polanyi was an emergentist who argued that after life originates, mutations and selection provide the conditions that release and sustain the action of new principles which come into operation and define major evolutionary achievements (PK 385).[8]

Although Polanyi focused philosophical attention on the evolution of comprehensive biotic entities and on the evolution (i.e., growth) of thought in human society, he did not extend his emergentist account to address matters concerned with the growth of technology (although he seems to have assumed that technology changes or evolves). In part as a reaction against Marxist views, he sharply distinguished pure scientific research and applied science and technology. Although, he emphasized how applied science and technology are definitively shaped by economic factors, he resisted any type of technologically- determinative account of history and society. He recognized that applied science and technology develop in relation to knowledge generated in broader theoretical scientific inquiry, but he construed the connection between these areas as somewhat indirect.

Although Polanyi never put matters this way, it seems appropriate to suggest that he viewed human beings as very sophisticated bio-cultural social animals who excel in niche-construction. Human beings are inquisitive and inventive and have a rich set of traditions in our articulate culture which we can re-appropriate with our tacit powers to expand articulate culture and reshape our human lives. Applied science and technology are very important elements employed in human niche-construction and they are, of course, deeply woven with and

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[8] See also my 2017 discussion (13-19) in Mullins, "Michael Polanyi's Approach to Biological Systems and Contemporary Biosemiotics," *Tradition and Discovery* 43 (1): 6-31.

dependent on cultural and political components bearing on niche-construction. I believe that Polanyi's philosophical framework can be extended to illumine further the use and changes in machines in society. In particular, the emergence and wide scale use of digital contrivances and their role in re-shaping human habits and thought seems important, or, more generally, in reshaping biocultural human niches and the activity of niche-construction. Interestingly, Polanyi was perhaps on the front edge of such an extension of his philosophical framework in some of his early comments about computers in the late forties and fifties. He was involved in important early discussions with others in this era and and his comments in his philosophical writings reflect this and perhaps hint at some elements that are important in a philosophy of technology grounded in Polanyi's postcritical thought.

Polanyi's Interest in the Computing Machine: The Historical Narrative

In October of 1949, Polanyi was a participant in a University of Manchester "Mind and the Computing Machine" seminar which included not only Alan Turing, but Max Newman, Maurice Bartlett and Bernhard Neumann (also mathematicians), Dorothy Emmet (a philosopher), the neurologists Geoffrey Jefferson and J. Z. Young, and others yet unidentified.[9] Wolfe Mays, then a young philosopher, was also a participant and in 2000 wrote about the seminar (see note 9, see also his April 1952 "Can Machines Think," in *Philosophy* 27[101]: 148-162), focusing his article on Polanyi's views and what seemed to be differences in views put forward by Polanyi and Turing.[10] Mays also provided his summary of what he regarded as the relevant

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[9] In his October, 2000 article, "Turing and Polanyi on Minds and Machines" (*Appraisal*, 3 [2]: 55-62), Wolfe Mays identifies the seminar as "Mind and the Computing Machine"(55) but Polanyi in PK (261, n.2) calls the event a "Symposium held of 'Mind and Machine.'" Paul Richard Blum (35-36) in "Michael Polanyi: Can the Mind Be Represented by a Machine? (*Polanyiana* 2010, no 1&2 (19): 35-60) provides the most extensive list of who likely was involved in the seminar but it is not altogether clear. Blum's Polanyiana article with his summary, analysis and archival documents is online at http://www.polanyi.bme.hu/folyoirat/2010-01/2010-1-2-03-Blum.pdf (accessed 5 April 2019).

[10] Mays (1912-2005), like Emmet, was a Manchester University philosopher, and sometimes is described as a phenomenologist but with diverse interests; he not only attended the seminar but seems to have taken a lively interest in Polanyi's philosophical ideas during his career. In the sixties, Mays was involved in establishing the British Society for Phenomenology and edited its journal, *The Journal of the British Society for Phenomenology*, for many years. See Joanna Hodges informative obituary at https://www.radicalphilosophy.com/obituary/wolfe-mays-1912-2005 (accessed 6 April 2019). An issue of *JBSP* devoted to Polanyi's thought (vol. 8, no. 3, 1977) was published soon after Polanyi died (see polanyisociety.org). Although his role in not altogether clear, Mays was also involved in the late sixties and early seventies in the later stages of the work of the multi-year Ford Foundation-funded Study Group on the Unity of Knowledge (SGUK). Because of failing health and other interests, Polanyi eventually dropped out of the SGUK and Grene and figures like Charles Taylor and Hubert Dreyfus managed the project. But Polanyi and Marjorie Grene (with important help from some other figures both inside and

components of a sketchy archival set of incomplete but redacted notes (see discussion below) on the seminar (Mays, 2000, 61-62). As Mays points out, some primary documents and his work have now been picked up by some scholars interested in Turing. More recently, Paul Richard Blum (see note 9) has published a set of archival materials related to the 1949 Manchester seminar and his own summary and analysis (Blum, 2010, 35-44) of these materials. The archival materials include: (1) a set of sketchy, incomplete notes made at the seminar that Blum titles "Discussion on the Mind and the Computing Machine" (Blum, 2010, 45-51),[11] and these notes identify some speakers and their seminar questions and responses (available in Box 22, Folder 19 of the Michael Polanyi Papers [hereafter MPP] and this document apparently is what Mays loosely summarizes); (2) Polanyi's short statement "Can the mind be represented by a machine?" (subtitled "Notes for discussion on 27 October 1949," but dated 13 September 1949, from Box 32, Folder 6 of MPP), a document prepared before the seminar that makes Polanyi's position clear (Blum, 2010, 52-55); (3) a set of what are perhaps Polanyi's notes on a February 1952 lecture by the neurologist Jefferson (titled "Jefferson's last lecture 11.2. 1952, The Workings of the Human Mind," from Box 24, Folder 1 of MPP) and these notes touch on some of the issues in the earlier seminar in which Jefferson participated.

Polanyi's involvement in this 1949 Manchester seminar was an occasion in which he considered differences between the human mind and a digital computer and his involvement was important for his developing philosophical ideas. In 1951, he published "The Hypothesis of Cybernetics," a 3-page comment that was part of a broader discussion of cybernetics by several philosophers in the *British Journal for the Philosophy of Science* (2[8]: 312-315). His comment focuses on "the question whether the operations of a formalized deductive system might conceivably be considered equivalent to the operations of the mind" (1951, 312). His answer is a clear "no." Polanyi's brief *BJPS* discussion grew out of his personal pre-conference prepared notes titled "Can the mind be represented by a machine?" (subtitled "Notes for discussion on 27 October 1949") and what were apparently his oral comments outlined in the sketchy notes on the actual discussion in the Manchester seminar. Polanyi argues in his published comment that it is "logically fallacious to speak of a complete elimination. . . [of] 'unformalised' elements

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outside the Ford Foundation) were the principle figures who originally set up this multi-year, multi-dimensional Ford project, one in which Polanyi's cultural criticism and constructive thought were to serve as a catalyst for philosophical renewal and one in which Mays was involved. Interestingly, some of these much later SGUK conferences focused on topics concerned with the digital computer.

[11] Blum's summary of this document differs in interesting ways from that of Mays. Blum suggests that Polanyi and Turing agree that "a mathematical interpretation of human thought is not all there is;" nevertheless, Turing's approach and comments in discussion "tries to find in thinking as much mathematical procedure as possible, while Polanyi aims at capturing with philosophical precision that what [sic] remains" (Blum,2010, 40). Mays' account suggests Turing held "mind is unspecifiable because it has not yet been specified" (Mays,2000, 56) but seems to entertain the possibility that mind might eventually be specifiable. He notes that Turning seems to regard "mind" and "brain" as identical, but Polanyi clearly does not.

of deductive systems" (1951, 312). He discusses the importance of the function of "unformalised supplements" provided by any human being using a deductive system, designating these the "'semantic operations' of the formalized system" (1951, 313).

Not long after the 1949 conference Polanyi gave his Gifford Lectures (1951-52)—which he already was preparing in 1949—and many elements in his lectures reflect his interest in accrediting the importance of unformalized elements in science and, more generally, in human knowing. Particularly Polanyi's ideas about "inarticulate performances" (381) in his November 1952 sixth Series II Gifford Lecture "Skills and Connoisseurship" are reminiscent of and complement ideas about the importance of unformalized elements involved in using a formalized deductive system.[12]

Most of Polanyi's earlier discussions of the importance of unformalized and skillful elements (often linked to beliefs and commitments) are re-presented in PK. Polanyi's involvement in this 1949 seminar and work soon after thus helped shape what Polanyi, more generally, called his postcritical philosophy articulated more fully in PK (whose subtitle is "Towards a Post-Critical Philosophy") and refined in the remainder of his life. As noted above, Polanyi focuses on the knowing process and emphasizes subsidiary and focal components and comprehensive entities in PK; he compares two kinds of comprehensive entities, living beings (i.e., comprehensive biotic entities) and machines and carefully identifies their similarities and differences. In publications after PK, Polanyi continued to work on matters concerned with similarities and differences between living beings and machines and eventually refines his ideas about the hierarchical, dual control structure of comprehensive entities. In later publications, Polanyi continued to develop ideas about the importance of unformalized and unformalizable elements

[12] The Gifford Lectures are online at http://www.polanyisociety.org/Giffords/Giffords-web-page9-20-16.htm (consulted 16 May 2019) along with my introduction. In "Skills and Connoisseurship," Polanyi notes the pervasiveness of connoisseurship and human skills, which are "inarticulate performances." Human commitment is "inherent in the structure of these performances." This "necessarily makes us both participate in their achievement and acknowledge their results" (381). Not only this Gifford Lecture is relevant to this topic but also other lectures (see my introduction's more general discussion). Polanyi apparently gave a version of this Series II, sixth Gifford lecture as a paper in December of 1952 at a methodological studies conference in Italy and published this in *Atti del Congresso di studi methodological promosso dal Central di studi methodologi* (381-394; cited on PK xvi). Much of this is incorporated in the "Skills" chapter of PK (as Polanyi acknowledges--xvi identifies PK 49-57 is drawn from his 1952 publication). See also my discussion (53-56) in **"**Michael Polanyi on Machines as Comprehensive Entities," in *Essays in Post-Critical Philosophy of Technology* (Mihály Héder and Eszter Nádasi [eds.]. Wilmington, Delaware: Vernon Press, 2019: 37-61).

in knowing in his theory tacit knowing which emphasizes the importance of tacit coefficients in the living action of all comprehensive biotic entities.[13]

Polanyi's Early Comment on Neural Networks

In PK, Polanyi references the "McCulloch-Pitts theory of the neural network," which he suggests many contemporary scientists insistently contend shows that "all intelligent behavior is based on a machine which in organisms possessing a nervous system operates on the principles of digital computers" (PK 340), This account "shows that a suitable linkage of neural circuits can account for the responses given by an intelligent person to the stimuli impinging on his sensory organs" (PK 340). On first blush, this seems a somewhat odd account of neural networks, at least in terms of the contemporary discussion of deep learning neural networks as complex digital tools for pattern recognition. But Polanyi's comment should be seen in the general context of his rejection of the equation of human minds and digital computers. What Polanyi says next suggests that he thinks this equation in ideas about neural networks as advanced by figures like Lorenz is incredible: "Adherents of this theory go so far as to assert that even the discoveries of Kepler and Darwin (and presumably also Shakespeare and Beethoven) as automata is, according to K. Z. Lorenz who puts forward this view, imperative for 'the inductive research worker who does not believe in miracles'" (PK 340, and there is a footnote to a 1951 Lorenz publication).Clearly, this remark is a *reductio ad absurdum*. Polanyi indicates he has addressed this view in the previous section of the chapter discussing originality in animals. In the previous section, essentially Polanyi argued that animals, (as figures like Kohler have shown), have inventive powers. Animals show machine-like traits, but an altogether machine-like conception of animals is not sufficient (PK 336). There is a center "operating unspecifiably in all animals" (PK, 336). Polanyi affirms that he wants to link "the unformalizable powers of originality to the whole range of tacit, often passionate, coefficients which account for all the powers of an articulate intelligence" (PK 336). He summarizes his account by confirming there are

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[13] In the mid-sixties, Polanyi's writing begins strongly to emphasize the importance of the imagination in the process of tacit knowing as it operates in both science and in generating the meaningful artifacts found in art, symbol, ritual, myth and religion. In the scientist's pursuit of discovery, Polanyi says the "force of imagination" is combined with "spontaneous integrations" which he calls "intuition." Polanyi stresses the link between "imagination" and human "powers of anticipation" which he sharply distinguishes from his ideas about the operation of digital computers: "The imagination does not work like a computer surveying millions of useless alternatives, but by producing ideas guided by a fine sense of their plausibility, which contains aspects of the solution from the start" ("Works of Art," p.93 in the 1969 Meaning: A Project Lectures published in *Polanyiana*, 2006 (http://www.polanyisociety.org/Meaning-a-Project-pg-6-25-16-adobe.pdf --accessed May 16, 2019). Polanyi thus suggests digital computers have no imaginative capacities and human being do and this is important.

> two principles at work in animals namely . . . (1) the use of machine-like contrivances and (2) the inventive powers of animal life. Accordingly, while the animal's machinery embodies fixed operational principles, this machinery would be impelled, guided and readapted by the animal's unspecifiable inventive urge—even as rigid symbolic operations are accredited and steadily reinterpreted by the tacit powers that affirm them (PK 337).

In sum, Polanyi suggests that what he regards as a neural network account for the intelligent behavior of animals—including human beings— is too mechanistic an account that does not appreciate the inventive powers of animals.[14]

Applying Polanyi in Emerging Digital Culture

The following points summarize, comment on, and extend Polanyi's mid-century discussions of the digital computer.

1. Before his death, Polanyi likely recognized that the computer would be important in pure scientific research. However, it seems not to have been this matter that caught his attention. In writing reaching back to 1949, Polanyi argued that the human mind and its operation should not be confused with the operation of a digital computer.[15] And on this point he may have differed with Turing and others in the 1949 Manchester seminar in which he participated, as he certainly did with some later commentators equating minds and digital computers. Polanyi contended his "theory of knowledge" implied a certain "ontology of mind" (PK 264). He articulated his perspective distinguishing human minds from computers by arguing that formalized deductive systems rely on unformalized supplements which human users of such formalized deductive systems supply. These Polanyi called "semantic functions" which are "performed by a person" using a formal system; he also identifies such semantic functions as an "unformalized process which constitutes a commitment" of the user of a formalized deductive system (PK 258). Human minds, unlike a formalized deductive system, can operate

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[14] Polanyi's suggestion that "equipotential processes are a primordial form of originality" (PK 343) is followed up in his speculative discussion of morphogenesis (PK 354-359).

[15] Polanyi's PK discussions focus on "formalized deductive systems," but he makes clear that he holds the "operation of digital computers as machines of logical inference coincide with the operations of symbolic logic." Therefore, it is permissible to "identify the formalization involved in the construction and the use of machines, operating in this particular way, with the procedure governing the construction of a deductive system" (PK 257). Human minds, in Polanyi's account, are the highest level of control in the human comprehensive biotic entity. Polanyi seems to have anticipated the early move in AI work attempting to construct knowledge-based systems that simulated human experts and wished to resist philosophical presuppositions embedded in this move.

independently of a digital computer and Polanyi sets forth this seemingly obvious claim as much more important than is normally recognized:

> This is the difference between machine and mind. A man's mind can carry out feats of intelligence *by aid of* a machine and also *withou*t such aid, while a machine can function only as the extension of a person's body under the control of his mind" (PK 262).

Although this is perhaps a somewhat odd argument, it is clearly one that points to Polanyi's broader philosophical effort to re-conceive the nature of "knowledge" in his post-critical perspective.

It is worth noting that Polanyi seems to have regarded the Turing test as irrelevant to the more serious issue concerned with distinguishing the operation of the human mind and the operation of a formalized deductive system. Deception, Polanyi points out, does not "justify us in accepting as identical two things known from the start to be different in nature" (PK 263). In a footnote, he comments, more pointedly, "I dissent from the speculation of A. M. Turing (*Mind*, N.S. 59 (1950), p. 433) who equates the problem 'Can machines think?' with the experimental question, whether a computing machine could be constructed to deceive us as to its own nature successfully as a human being could deceive us in the same respect" (PK 263 n. 1).[16]

2. The digital computer (an electronic formalized deductive system, in Polanyi's account), is, of course, built upon a base two number system, on binary opposition taken to be an adequate (or at least a useful) representational option. Embedded in ideas about an electronic computing contrivance there are suppositions about the nature of "knowledge" and its representation in propositions or rules built into a formal deductive system. Polanyi's writing makes it clear that he dissented from many of the mainstream philosophical and scientific assumptions about

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[16] In his broader discussion of automation in PK, which moves beyond logical inference machines, Polanyi contends the "necessary relatedness of machines to persons does essentially restrict the independence of a machine and reduce the status of automata in general below that of thinking persons" (PK 261-262). His following discussion of neurology and psychology (PK 262-263) argues that a human being with a mind can know things either focally or subsidiarily, but a machine cannot do this. Human beings with minds "can be said to think, feel, imagine, desire, mean, believe or judge something" (PK 263), but machines cannot, although they may simulate such human actions and may deceive human beings. The mind of a human being, in Polanyi's account, is "not an aggregate of its focally known manifestations, but is that on which we focus our attention while being subsidiarily aware of its manifestations" (PK 263). A machine is a comprehensive entity, which operates in terms of the dual control strategy outlined above. Its higher level of control is usually identified with its purpose (e.g., to recognize patterns). But the machine as a comprehensive entity fits into a socio-political-cultural niche and it is either improved or replaced by human beings so that its purpose (or we more likely say function) remains relevant to human life as human communities evolve.

these matters dominant in the first half of the 20th century.[17] Polanyi's larger post-critical philosophical project recasts modernist notions of "knowledge" by distinguishing subsidiary and focal awareness and explicit and tacit knowledge. He focused attention on the from-to dynamics of the knowing process in living agents who always already are embedded. Logicians, of course, have long studied not only deduction but also induction. Charles Sanders Peirce, an innovative logician, integrally links deduction and induction with abduction (sometimes termed retroduction and hypothesis) in human beings; Peirce describes the cooperative operation of deduction, induction and abduction in ordinary human perception and reasoning as well as in the method of science. Polanyi's general approach to logic, to science and to personal knowledge is like that of Peirce insofar as he does not focus narrowly on deduction and induction in his writing (although he treats both), but on what he later terms "the logic of tacit inference."(KB 138-158). That is, he focuses attention on knowing as an embedded agent's integrative process relying on subsidiary elements that serve the focal interests of an imaginative person engaged in a community of interpretation such as is found in one or another neighborhood of science and society.[18]

3. Polanyi regards the digital computer as an electrical "contrivance," which has a hierarchical structure that can be described in terms of a sequence of "dual control" levels, like other purely mechanical contrivances and like living beings or "comprehensive biotic entities." The lower level has boundaries within which a higher operating principle functions to give further definition to results. Today this hierarchical "dual control" structure in digital computers might be unpacked, loosely speaking, at the hardware level in terms of refined silicon chips and the transistors that are etched on them. This is a lower and higher-level pair in which the higher-level functions in the margins left open by the lower level. So also is this duality of linked levels found in the way in which hardware sets the boundary conditions within which higher level software operates so that a digital contrivance can provide further definitive manipulations. Like Polanyi's early emphasis on the "semantic function" involved in the use of digital devices functioning as formalized deductive systems, Polanyi's emphasis on the "dual control" structure of digital contrivances is a way to make clear his radically anti-Cartesian philosophical stance which embraces new notions of knowledge and a form of participative realism.

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[17] This dissent simply pervades Polanyi's writing after 1946 and is central to his Gifford Lectures (1952 and 1952) and PK, but also is sharply articulated in later essays such as his 1966 "The Logic of Tacit Inference" (KB 138-158). In this late essay Polanyi bluntly says "claims of cybernetics represent a revival of logical positivism in its original insistence on strictly explicit operations of the mind. Hence my rejection of a cybernetic interpretation of thought and of behaviourism which are based likewise on the assumptions that the data and operations of mental processes are explicitly specifiable" (KB, 156-157).

[18] See my "Peirce's Abduction and Polanyi's Tacit Integration," (*Jou. Speculative Philosophy* 16:3 [2002]: 198-224) for a discussion of similarities in approaches of Peirce and Polanyi.

4. Polanyi was in principle not an opponent of formalization, although his anti-Cartesian philosophical perspective emphasized the limits of formalization. Polanyi's postcritical account emphasizes the legitimate purpose of formalization and he likely saw the emergence of computers and their use in science and technology in connection with the expansion of formalization. Although some of Polanyi's discussion makes use of Gödel and Tarski's work, his conclusions can be stated independently of complex mathematical and logical proofs, which he simply regarded as very elegant ways of making his point about the necessary limits of formalization. But this recognition of these limits of formalization also should be linked to a proper understanding of the purposes of formalization and Polanyi's appreciation for the expansion of formalization in modern societies shaped by science and technology. Computing devices have initiated a new stage in the development of mechanization, a stage which is closely tied to the growth of formalization. Formalization reduces human tacit coefficients involved in human endeavors, although it does not eliminate human "personal participation" and should not aim at total elimination (PK, 259). Formalization functions within the context of human being-in-the world which marks the way human beings are always already bound up with a particular bio-cultural niche. Polanyi suggested that mechanization in general is an important component of late modernity and produces valuable "consistent results" in human endeavors. Digital mechanization contributes to the growth of "articulate knowledge" in the modern human world and such knowledge is valuable since it is more diffusible than unspecified human knowledge.[19] In his 1964 essay "The Logic of Tacit Inference," Polanyi put his careful conclusions about formalization this way:

> Formalization of tacit knowing immensely expands the powers of the mind, by creating a machinery of precise thought, but it also opens up new paths to intuition; any attempt to gain complete control of thought by explicit rules is self-contradictory, systematically misleading and culturally destructive. The

[19] "The legitimate purpose of formalization lies in the reduction of the tacit coefficient to more limited and obvious informal operations; but it is nonsensical to aim at the total elimination of our personal participation" (PK 259). In the published version of Polanyi's Series II sixth Gifford Lecture, "Skills and Connoisseurship" (cited above), he discusses the importance of developing "consistent results" in cotton grading. "Measured grading" produces more consistent results in different hands and this mechanization of grading was based at least indirectly on scientific research on cotton. Polanyi's interest in cotton grading likely grew out of his research on cotton at the Kaiser Wilhelm Institutes early in his career. Better grading realized through the expansion of machine grading required expanded formalization which is a part of the growth of "articulate culture." Polanyi discusses "articulation" and "articulate culture" in the chapter titled "Articulation" following his fourth chapter of PK, "Skills," which is built on his Series II sixth Gifford Lecture In sum, formalization for Polanyi is an important value in complex modern society with a rich and growing articulate culture which makes significant use of sophisticated technology.

pursuit of formalization will find its true place in a tacit framework (KB 156).

5. The above four points can perhaps be summarized as follows. The account in PK (see especially PK 257-263) of the usually unnoticed, unformalized elements that surround the operation of a digital computer understood as a formalized deductive system—elements necessarily supplied by a person(i.e., Polanyi's "semantic function")— is not a trivial point but a good starting point for any contemporary philosophical and cultural discussion treating the nature of and use of digital computers**.** Human beings do dwell in computers, just as we do other tools or our bodies, although this may not be so obvious to us. This is a kind of participation according to the logic of indwelling, which we have not yet adequately explored. But Polanyi's starting point vis a vis the use of digital computers needs to be seen in relation to Polanyi's broader criticism of the modernist tradition—a narrative about the rise and spread of objectivism in science, technology and culture—and Polanyi's effort to fashion a post-critical alternative philosophical perspective. Polanyi's post-critical turn is grounded in his account of tacit knowing and personal knowledge. Responding to the large questions about the proper grounds for modernity that Polanyi was posing remains an important project. Polanyi's message to contemporary digital culture is one that suggests that we today need both a clearer understanding of the limits of formalization and the grounds for and importance of expanding formalization with the digital computer as a primary tool in contemporary society.

6. Polanyi's early account of the digital computer as an operating formalized deductive system is not a sufficient characterization. His account does not consider the unfolding history of AI including the development of machine learning which occurred primarily after his death. It now appears that the development of machine learning strategies for computer use has redirected much of the energy in early approaches devoted to the development of knowledge-based systems.[20] Computers are operating formalized deductive systems and dual controlled electronic contrivances as Polanyi suggested, but the development of approaches to machine

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[20] See Satinder Gill's discussion in *Tacit Engagement, Beyond Interaction* (Springer, 2015, 44-47). Her book, using Polanyi and others, treats the complex matter of re-conceiving the interface on digital tools and, more generally, the socio-cultural and bodily dimensions of communication. Gill articulates an important counter to some of the assumptions about knowledge, formalization and interfaces that historically have been dominant among sophisticated theoreticians and computer scientists and perhaps remain dominant. She remains skeptical about the more contemporary AI conversations about "Big data" which have replaced early conversations about expert systems. She fears that the "legacy" (2015, 73) of early AI work on expert systems (i.e., presuppositions about "knowledge" and its reprsentation) is being uncritically transferred into more contemporary work on large scale databases. She outlines a "person-centered perspective" (2015, 67) that appreciates the temporal, socio-personal and performative constituents of human knowledge. Clearly, she recognizes the operating parameters of digital contrivances. I applaud Gill's use of some Polanyi material, but also believe Polanyi's early discussion of the computer and his account in PK is a valuable resource.

learning, including deep learning neural networks, now focuses attention on generated outcomes in terms of "confidence levels" (see discussion above). Probability is thus at the center of things.[21] That is, what is "discovered" by deep learning neural networks, based upon classification and/or clustering strategies (and anything combined with such approaches) is a prediction about a pattern. As Kuang notes, a machine learning algorithm can "tweak itself" by employing a large variety of new techniques: "Machine learning is not just one technique. It encompasses entire families of them, from 'boosted decision trees,' which allow an algorithm to change the weighting it gives to each data point, to 'random forests,' which average together many thousands of randomly generated decision trees." Thus deep learning neural networks employ techniques "for letting machines find their own patterns in data" (Kuang, 2017, 49) and a new field, "explainable A.I. or X.A.I.," has begun to emerge with the goal of making "machines able to account for the things they learn" (Kuang, 2017, 48) in ways human beings who use the algorithms can understand. [22]

7. The way in which Polanyi, in the late forties and fifties, thought about the digital computer as a logical inference machine seems not much akin to the way in which today most people think about contemporary digital computers and their use. Everything about computer hardware and software not to mention the development of networking has improved since the mid-20th century. In the early 21st century, many live in a networked world overrun with digital artifacts; digital tools and the skills for using such tools have proliferated.

The manifestations of computer use are everywhere and growing and this use shapes not only the many tangible aspects of the biocultural niche which human beings inhabit but also our minds and habits. Intellectuals should today be assessing the impact of the computer—and particularly AI tools such as neural networks—on the evolving social imaginary in digital culture and the implications of this imaginary.[23]

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[21] This statistical approach somewhat more resembles human induction (and perhaps it emulates induction) than straightforward deduction.

[22] C Kuang. "Can A.I. Be Taught to Explain itself?" *New York Times Magazine* (26 November 2017): 46-53. See also David Gunning, "Explainable Artificial Intelligence (X.A.I.)" at https://www.darpa.mil/program/explainable-artificial-intelligence (accessed 12 June 2019). Gunning, who apparently works on X.A.I. for Defense Advanced Research Projects Agency, suggests "new machine-learning systems will have the ability to explain their rationale, characterize their strengths and weaknesses, and convey an understanding of how they will behave in the future."

[23] In the mid-20th century, Polanyi noted that the main influence of science was not through advancement of technology but through the influence of the objectivistic, materialist account of science upon the modern human imagination (see "Works of Art," p. 98 op. cite); the scientistic imaginary, in Polanyi's account, produced the ideologies and disasters of the 20th century and the loss of human capacity to find meaning and be at home in the world. Polanyi's post-critical philosophy, of course, aimed to counter this scientistic imaginary with a

Print (a technology which itself evolved) was the dominant memory technology shaping cultural development for about 500 years. But digital technology has now become the dominant memory technology and, with the development and widespread use of machine learning and neural networks, contemporary digital technology seems to be stepping forward particularly as a technology of discernment. The domain of predictive analytics is a new face of the digital contrivance which particularly needs scrutiny from a philosophy of technology informed by Polanyi's constructive postcritical perspective. Polanyi's clear distinction between functioning human minds and digital contrivances is an important starting point. Today we need to clarify how Polanyi's "semantic function" is central to the design, adjustment and use of neural networks. We need to analyze and explore more fully how human users "dwell in" these new digital contrivances which discern patterns. A better understanding of this "indwelling"—and a serious effort to disseminate this understanding in society— can help society avoid confusing minds and machines. It should re-open large questions about the nature of "knowledge" and help human beings recognize more clearly that the output of discerning digital devices is not human knowledge. Formalization and the growth of formalization will remain important in complex modern societies. Insofar as much of the extension of formalization in contemporary digital culture seems likely to be driven primarily by digital tools using machine learning approaches, a postcritical philosophy of technology needs more carefully to study the patterns of formalization which pattern recognition software presently are and, in the future, should be used to discern. Such patterns primarily at present appear to be habits of consumption and information that can be used for social control. Society needs both to set limits upon predictive analytics and to recognize better the potential of predictive analytics to promote the good society.

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fundamentally different account of science, one whose imaginary would again make human beings at home in a meaningful world.