

MICHAEL POLANYI AND TECHNOLOGY: A POST CRITICAL APPROACH TO INNOVATION

Eduardo Beira¹

Natural science is an expansion of observing; technology, of contriving;
mathematics, of understanding. PK184

1. *Technology and Science. Innovation and Discovery*

Sections 1, 4 and 6 of this paper are based on my introductory chapter to the new book *Technology and Science. Innovation and Discovery* (Beira, 2026). For this book I tried to extend the coverage by compiling a new selection including unpublished texts and other less known papers. The selected texts and papers are organized by chronological order as described in the table attached (annex 1). The last chapter of the book (chapter 15, “Genius in Science”) was Polanyi’s last significant synthesis on the philosophy of science, originally written in the end of sixties. Chapters 2 (“Rights and Duties of Science”), 7 (“Science: academic and Industrial. Ways of Cooperation”), 9 (Pure and Applied Science and their Appropriate Forms of Organization”) and 10 (“Science: academic and Industrial”) are reprints of essays that are less frequent in the literature. It is worth noting that chapters 7 and 10 have similar titles but different contents that reflect the changes in Polanyi’s sophistication about the same issue, from 1947 (last year of his chemistry period in Manchester) to 1962 (Terry Lectures at Yale University). A brief summary of each chapter in T&S is provided in the annex 1.

The annex 2 lists the texts and papers in T&S (the left side of the table) and also lists, on the right side, the majority of papers by Polanyi about science (and technology) in the same period according to Polanyi’s bibliography provided by Scott and Moleski². These papers are identified by their code in this bibliography and by their chapter numbers in Polanyi’s *The Logic of Liberty* (1951) (column LL), and in the anthologies *Knowing and Being* (1969), edited by Marjorie Grene (column KB) and *Society, Economics and Philosophy* (1997) (column SEP), edited by R. Allen. Polanyi’s more popular papers about science and technology can be found in these anthologies.

¹ Senior Research Fellow, IN+ Centre for Innovation, Technology and Policy Research, Instituto Superior Tecnico, Universidade de Lisboa, Portugal.

² Scott and Moleski (2005), Bibliography, p. 327-350

Polanyi's bibliography has over 200 entries¹³. The word "technology" does not appear in any of their titles, nor does "engineering" or any related word, although "science" appears in more than 150 titles. Yet technology had a key place in Polanyi's life and in his insights about knowledge and science. Polanyi had important ideas not only about pure science but also about the development of technology. This book seeks to balance the importance of technology and science in Polanyi's work. Polanyi's framework was centered on a hermeneutics of scientific life as an inspiration or model for knowing and for the creation of knowledge, but his ideas about technology was also very rich and also based on his own experience. He deserves to be recognized as an insightful "philosopher of technology."

Polanyi was more than a leading scientist: he was also an brilliant technologist in (the chemical) industry and a formidable, creative and skilled experimenter in the laboratory, developing new, complex technological devices and apparatus for scientific research. He was an insider in the field of science, but also deeply involved in technological development. Polanyi's work with technologies is a less known facet of his biography, particularly before he moved to Manchester, in 1933, but also during his first years there. Polanyi was co-owner of several patents that are not included in his current bibliographies. He was also a critical contributor to other important industrial patents (such as the Krypton lamp patent)⁴. Curiously, Polanyi did not mention those activities in technological and industrial research in the curriculum vitae he sent to the University of Manchester as part of his admission process in 1932⁵. In any case, he was applying for a chair in Physical-Chemistry (pure science, not industrial technology) and was perhaps afraid that his previous industrial work could compromise the perceived purity of his application for a pure science chair. But when Polanyi arrived in Manchester in 1933 he had a rich experience both in technological development in industrial corporations and at the Kaiser Wilhelm Institute in Berlin, and as a scientist driven by technological challenges⁶.

³ Scott and Moleski (2005), Bibliography, p. 327-350

⁴ See discussion on chapter 12 of TS. See also note 13.

⁵ Cf. RPC(02,10)0626-0627, "14 juni (sic!) 1933, curriculum vitae."

⁶ Polanyi's innovative research on metals is a good example. Later, in Manchester, his research (with P. Plesch) on polymerization of isobutene, discussed in TS, chapters 7 and 15, is another good case. See also note 9, chapter 7.

2. Patents

Two chapters about patents are included in TS (chapter 6 and 7). The work of Polanyi about patents is something seen as an “outlier” in his “episodic” interest about economics and social theory. It is not true. Polanyi had lived in a world of patents before arriving to Manchester. He discussed some of those stories in “Innovation” (TS, chapter 12). And Polanyi’s interest on economics, where his interest in patents fitted, was very far from episodic.

The following quote was written by Polanyi as an introduction to a chapter about patent reform for a book on *Economic Planning* drafted from November 20, 1943 to April 15, 1944 and then abandoned. On April 20, 1944 a new start was made on a book *Full Employment in Theory and Practice* (later published as *Full Employment and Free Trade*)⁷, . The chapters about patents were not included in *Full Employment and Free Trade*. A shorter version of that chapters about patents was later integrated in the Polanyi (1944) essay about patent reform. In that introduction Polanyi wrote⁸ that he intended to refresh the intellectual atmosphere in which industrial research:

I decided to include this essay here, in spite of its somewhat disparate subject, firstly in order to give further currency to a project in the advantage of which I continue to believe strongly. I believe that the reform which I advocate would release considerable productive forces; but even more do I look forward to the possibility that it might pervasively refresh the intellectual atmosphere in which industrial scientists spend their lives. Though this hope is barely mentioned in the paper, it was actually my main motive in formulating the proposals put forward here.

Moreover, the inadequacy of the existing methods for exploiting inventions vividly illustrates a theme which recurs frequently in the subsequent essays. It gives a clear example of a well defined task which society has long tried to solve, without much success, and thus demonstrates it in a nutshell that social institutions are essentially imperfect instruments.

Polanyi was very confident about his proposed reform of the patent laws. In a letter to the London School of Economics and to the National Institute of Social and Economic Research (both in London) dated 1944, he wrote:

⁷ Cf RPC(28,1)0009

⁸ Part of unpublished manuscript, typed, cover (“PATENT REFORM. Pages 227/250, 30.3.1944”) plus 24 pages edited by hand, RPC(29,9)0648-0671.

My article⁹ deals in some detail with a new idea for the elimination of patent monopoly, and I would be glad if you would read the manuscript before its publication which may be delayed for another two or three months or even longer. I have been in touch with a certain number of authoritative people among economists, engineers and patent lawyers (including Mr. Potts with whose ideas I am in general sympathy) and it seems that they are prepared to give serious consideration to my proposals.

Patents are discussed in *Personal Knowledge* associated with invention and operational principles of machines¹⁰:

A patent has two functions, namely, publicly to disclose its subject matter, and to grant a monopoly in respect to its use. If applied to new knowledge its first function would preclude the second: once such knowledge is publicly disclosed it can no longer be anyone's monopoly. But the patent can grant and enforce a monopoly for the practice of any new operational principle; it can restrain unauthorized persons from using the new invention which it makes generally known. Invention has in common with discovery that it can claim to be what it is only if it is surprising. It must be separated from its antecedents by a considerable logical gap. I have mentioned already that in case of doubt the courts undertake to assess whether this logical gap is wide enough to warrant the acknowledgment of an invention. This width measures the ingenuity of the invention. ...

... in addition to the disclosure of a new operational principle, technology requires that an invention should be economic and thus achieve a material advantage. ... The law [of patents] endorses thereby once more the sharp distinction between a knowledge of the facts of nature (achieved by discovery) and the knowledge of an operational principle (achieved by invention).

Personal Knowledge: From Early Polanyi to Late Polanyi

TS selection of unpublished texts and less known published papers by Michael Polanyi, written from 1937 to 1971, covers his thoughts about technology and science, both in the “early” (before *Personal Knowledge*, published in 1958) and “late” Polanyi periods (after *Personal Knowledge*, the decade of 1960’s). The collection covers the origins and roots

⁹ Polanyi (1944)

¹⁰ Polanyi (1958), p. 177

of Polanyi's ideas and their refinement and transformation over the years. They highlight Polanyi's contributions as a philosopher of technology and as a modern philosopher of science (his better known reputation) through the incorporation of his epistemology of tacit knowing.

Polanyi always knew how to draw a clear distinction between science and technology, yet he consistently built bridges between them by integrating both into his broader philosophical framework. TS includes some of Polanyi's contributions to the organization of research in technology and science, as well as to his theory of innovation (in technology) and discovery (in science).

A summary of the main topics about technology and machines in *Personal Knowledge* follows:

(a) **Indefinable tacit knowledge and skills in technology:** Technology relies on “unspecifiable know-how” and “indefinable knowledge” that are essential for the efficiency and quality of labor, even in modern industries.

- Even in the modern industries the indefinable knowledge is still an essential part of technology (PK52)
- Primitive technology may be regarded as a mere extension of bodily skills employed for the satisfaction of bodily appetites. And even in highly complex and predominantly articulate branches of technology, like the manufacture of cloth or the production of steel, there is involved a measure of unspecifiable know-how which is essential to the efficiency of labour and the quality of its product. PK175

(b) **Operational principles as distinctive of technology** (versus science and arts): A technology is defined by a set of rules about how to make it and how to use it, its “operational principle,” which acts as a “rule of rightness” or a “conditional command” teaching people how to act to secure the desired advantages. The concept of operational principle is central in Polanyi's understanding of technology. There is no “operational principle” in science.

- Operational principles will be taken to include here the constructional principles which tell us the way technical devices, like machines or houses, are to be built. ... As implements are defined and understood in terms of an action which they serve, they are defined and understood likewise in terms of the operational principle which tells how to perform such an action PK176
- We have seen that a tool, a machine or a technical process is characterized by an operational principle, which differs altogether from an observational statement. The

former, if it is new, represents an invention and can be covered by a patent; the latter, if it is new, is a discovery, which cannot be patented. Contrivances are classes of objects which embody a particular operational principle. PK328

- the contriving of a machine, built of a number of parts, each of which has a function of its own within a coherent, rational operation. There is a specifiable reason for every step of the procedure and every part of the machine, as well as for the way the several steps and the various parts are linked together to serve their joint purpose. This chain of reasons is set out in the operational principles of the process or of the machine. Since physics and chemistry ignore operational principles, they are blind also to the reasons which justify the successive steps of an operation. PK331

(c) **Technology as distinct from science:** While science is an expansion of “observing” aimed at discovering the laws of nature, technology is an expansion of “contriving” aimed at creating inventions (innovations) for acknowledged material purposes. PK184

- The difference between scientific knowledge and an operational principle of technology is recognized by patent law, which draws a sharp distinction between a discovery, which makes an addition to our knowledge of nature, and an invention, which establishes a new operational principle serving some acknowledged advantage PK176
- This sharp division between science and technology is entirely compatible with the existence of domains which in one respect or another form a transition between them. ... a technical process is an application of scientific knowledge it contributes nothing to science, while empirical technology, which is itself unscientific, may well offer - for this very reason - important material for scientific study PK178-179
- a technical process is an application of scientific knowledge it contributes nothing to science, while empirical technology, which is itself unscientific, may well offer-for this very reason - important material for scientific study it may happen that some parts of pure PK178
- science offer such exceptionally ample sources of technically useful information that they are thought worth cultivation for this reason, though they would otherwise lack sufficient interest PK178

(d) **Economic requirements:** Unlike scientific discovery, a technological invention must be “economic” and demonstrate a “material advantage” to be acknowledged as such by technology and patents law.

- All technology is equivalent to a conditional command, for it is not possible to define a technology without acknowledging, at least at second hand, the advantages which technical operations might reasonably pursue. PK175
- collecting clues and pondering perspectives, the technologist must keep in mind a whole panorama of advantages and disadvantages which the scientist ignores. PK177

(e) **Incommensurability of technology with physics and chemistry:** pure sciences such as physics and chemistry ignores operational principles and cannot explain or specify a machine's function; a complete physico-chemical specification would “dissolve altogether” our knowledge of the machine.

- A physical and chemical investigation cannot convey the understanding of a machine as expressed by its operational principles. In fact, it can say nothing at all about the way the machine works or ought to work. PK329
- Their operational principles can then be specified further by technological investigations. Physics and chemistry can establish the conditions for their successful operation and account for possible failures, but a complete specification of a machine in physico-chemical terms would dissolve altogether our knowledge of the machine. PK359

Technology as subject of analysis did not appear in *Science, Faith and Society* (1946). But it appeared in *The Logic of Liberty* (1951):

- The distinction between technology and pure science can be sharply defined by economic criteria.... An invention designed to produce practical disadvantages cannot be regarded as an invention, either in the light of common sense or in the eyes of patent law. Pure science, on the other hand, cannot be affected in its validity by variations of supply or demand. LL74
- the nature of the task clearly determines the proper conditions under which it has to be pursued. There are many classes of inventions and technical improvements, but in no case has the inventor to immerse himself entirely in one branch of scientific knowledge, while it is indispensable that he should remain intensely aware of a certain set of practical circumstances. An inventor who lacks a keen sense of practical profitability will produce inventions which work only on paper. That is why inventions do not thrive on academic soil. LL75
- Admittedly, some branches of engineering which have a systematic structure can be cultivated at universities and engineering science, understood in that sense, rightly

relies for its advancement on technical schools and other academic institutions. But a far greater part of applied science consists of more or less disjointed solutions to problems which can be properly sensed and appreciated only by those struggling daily in the dust and heat of practical life LL75

- Technology as a polycentric problem: polycentric problems that can be mathematically formulated, such as are commonly presented to the engineer and also occur all over the field of science, for example as the many-body problems of astronomy and atomic physics. In a wider sense, however, we may consider every problem of balancing a large number of elements as a polycentric task. LL176

The concept of dual control already appeared in *The Study of Man* (1959), but yet without the “dual control” label:

- Technology alone reveals the true nature of a machine by defining it in terms of successful working, while physics and chemistry determine only the material conditions in which this success can be achieved and the shortcomings which may cause the machine to break down. The true knowledge of a machine which we have on the upper level is the understanding of a purpose and of the rational means for achieving it; while the knowledge of its physical and chemical topography is by itself meaningless, for it lacks any conception of purpose or achievement. It becomes meaningful only when orientated towards establishing the material conditions for the success or failure of a machine SM51

“Operational principles” of machines also appear in *The Study of Man* (1959) with the extension of the concept to the biological world:

- operational principles have the same structure as those of pure engineering: they analyse the joint functioning of different bodily organs in the successful achievement of certain purposes. No physical or chemical analysis of the body can ascertain by itself any of these operational principles, since the conceptions of purpose and of successfully functioning organs cannot be expressed in terms of physics or chemistry. SM53

3. What is Technology?

In one of the Merton College lectures¹¹ (in the first months of 1960) Polanyi addressed the question “technology: what is it?”. His answer: “The *sum of profitable operational principles*, plus the knowledge of conditions for using them”. Technological device results from a “sound technical problem: a feasible and remunerative operational possibility” that “must include estimate of rival uses of resources”. Polanyi recognises that problem solving in technology have a structure similar to problems like “find X such that” where there is “vaguely perceived operational principle to be realised effectively and economically”. The achievement is evoked by a passionate pursuit that evokes means of achievement with a “purposive re-organisation of given particulars” that shows the “heuristic power of known operational idea”. A good problem is a “feasible possibility”. The job of the research director of a corporate laboratory is precisely to find and screen the feasibility of these foreseeable possibilities.

The (future) idea of dual control appeared in a revised version of the first Terry lecture:

the testing of a machine does not verify any laws of nature, except in the way in which we all test these laws every moment by relying on their continued operations. What is being tested when a machine is tried out, is its practical feasibility. To claim an invention in the technical sense, is to say that all the difficulties of its realisation and development, including its commercial exploitation, will be overcome; this has to be tested in practice¹².

And also the role of imagination in the invention of a machine:

What faculties are at work in the invention of a machine? A technical problem is a line of action. More precisely: it defines a line of action in general terms; if it is a mechanical problem, its line of action may include the invention of machinery. Suppose then somebody has decided to take up such a problem: he will know fully what it signifies. He will be aware of the kind of means needed to solve the problem - both of those that are specifiable and those that are not - in the terms of his decision to

¹¹ Lecture 2, “Originality”, RPC(34,2)0035--0041

¹² RPC(35,13)0717. In “Tacit knowing, Chapter One” (35,8,9,10) Lecture 1 (with 1963 revisions) of Terry Lectures as delivered at Yale University, October 31-November 3, 1962.

solve the problem. The means for this solution are mobilised by the imagination, which integrates them to serve the intention on which the imagination fixes attention. Because the intention is conceived in general terms its execution is known to require the making of an invention, and the imagination therefore speculates in this direction. Any success of this effort will narrow down the problem by specifying to some extent its mode of operation. By successive stages, the mode of operation will be completely specified and the problem be solved¹³.

4. The Lectures in America, 1960s: Discovery, Problem Solving and Knowledge

T&S includes new materials about innovation and discovery from Polanyi's unpublished lectures from the sixties. The timeline of the most important series of lectures was as follows:

- 1962: Terry Lectures, Yale University (The Modern Mind: Its Structure and Prospects) (3 lectures)
- 1964: Duke Lectures (Man in Thought) (5 lectures); Jerusalem Congress 1965: Wesleyan Lectures (Man's Place in the Universe) (5 lectures) 1966: Publication of The Tacit Dimension
- 1968: Chicago Seminars (Committee on Social Thought) 1969: Chicago Lectures (Meaning: a project) (4 lectures)
- 1970: Nuffield Lectures (Loyola University) (5 lectures)
- 1971: Austin, Texas Lectures (4 lectures)

In these important series of lectures Polanyi explored the metaphysical ramifications of his tacit epistemology for new areas of inquiry¹⁴. But until now only part of the manuscripts of those lectures has been published¹⁵. *The Tacit Dimension* is based on the Terry lectures, but only part of them. Harry Prosch organized *Meaning* with materials from some of the Chicago and Austin lectures from 1969 and 1971.

Chapters 12, 15 and 16 of TS are unpublished materials from the Terry lectures (chapter 12, "Innovation", 1962), the Duke lectures (chapter 15, "Commitment to Science", first delivered in 1964 and revised in 1965) and the Wesleyan lectures (chapter 16, "Notes to

¹³ RPC(35,9)0446. Idem.

¹⁴ In December, 1962 Polanyi committed to explore "A major new theme: to trace back my philosophy to the corresponding ideas of the existentialist movement, Dostoevski, Nietzsche, nihilism, Sartre." RPC(21,07)0273 "Notes made on the journey (to Guatemala) December 27, 1962 to January 10, 1963". See also Beira (2023).

¹⁵ Some of the lectures have several versions because lectures of one series were reused, retitled, edited for other series, which complicates the issue.

theory of innovation”, 1965). These three chapters cover important material about discovery (in science) and innovation (in technology) understood as forms of problem solving and they deserve more attention.

They are also good examples of Polanyi’s intellectual efforts in the first half of the 1960s as he outlined in a letter to the British philosopher Mary Hesse¹⁶. On February 6th, 1967 Polanyi sent a letter¹⁷ to Mary Hesse, then editor of *The British Journal for the Philosophy of Science*, thanking her for accepting his submission and “outlining a picture” of his current work. The paper was “Science and Reality”¹⁸. Polanyi also sent her a copy of “Sense-Giving and Sense-Reading”, a paper published in the same year that “develops the ideas of *Personal Knowledge* a few steps further”, as Polanyi added. In the letter he stated:

I feel today more certain than ever of the ideas first mooted more than twenty years ago, of the essential identity of perception, conceptualisation, the seeing of a problem and its pursuit, all the way to discovery and its verification. They have all the same structure and present the same question of meaning and justification.

And he added:

To me it seems manifest that all stages of knowing, from perception to the verification of discovery, operate by the integration of two levels, one subsidiary the other focal.

Polanyi was aware of his sharp differences with Mary Hesse's opinions, although their positions may have been drawing closer. Hesse insisted “on the pursuit of an explicit logic of empirical knowledge” and ignored Polanyi’s view “even as a possibility”. Nevertheless, Polanyi regarded “her efforts and mine as parts of the same pursuit”.

A good summary of Polanyi’s views about innovation and discovery can be found in his paper “Science and Reality” (1967) where he discussed “how the actual process of discovery is performed”:

¹⁶ Mary Hesse (1924-2016) was a professor at the University of Cambridge, Department of History and Philosophy of Science, which is housed alongside the Whipple Museum of the History of Science. Her philosophical approach is known as “post-empiricist.” She argued that scientific theories are not just literal descriptions of facts but “imaginative structures” deeply reliant on metaphor and analogy to make sense of the world.

¹⁷ RPC(6,9)0701-0702, Letter from M. Polanyi to M. Hesse, January 9, 1967.

¹⁸ Polanyi (1967).

To see a good problem is to see something hidden and yet accessible. This is done by integrating some raw experiences into clues pointing to a possible gap in our knowledge. To undertake a problem is to commit one-self to the belief that you can fill in this gap and make thereby a new contact with reality. Such a commitment must be passionate; a problem which does not worry us, that does not excite us, is not a problem; it does not exist. Without such passionate commitment no supporting evidence will turn up, no failure to find such evidence will be felt, no conclusions will be drawn and tested, no quest will take place. Evidence is cast up only by a surmise, a hope of the truth which as such, necessarily seeks its own fulfilment. This is how the anticipatory powers I have shown at work in a historical perspective, arouse and guide individual creativity. [In these lectures] I want to define the mental powers by which coherence is discovered in nature. This will establish the theoretical grounds of scientific enquiry, guided by anticipations of reality.

Chapters 12 to 16 of T&S cover this topic, which was central to Polanyi's later work. Chapters 13 and 14 are related to the same theme and they consist of unpublished notes that Polanyi organized for a congress in Jerusalem (1964).

Around 1970, the issue of discovery and knowledge continued present in Polanyi's interests, and he still hoped that mainstream academic philosophers of science could recognize and integrate his contribution. In a hand-written note¹⁹ to the Executive Secretary of the Study Group on the Unity of Knowledge, Polanyi said that:

I wish to have an exploratory meeting on Discovery and Knowledge in Science. A discussion I recently had with Herbert Feigl showed that he would like to reconsider the relation of positivism with personal knowledge. Other workers like Harré, Holton, Margenan, Scheffler, Chomsky hold intermediate views. Ernest Nagel and Carnap might be inclined to revise their position. Qine remains fixed but he too seems interested. Serious progress might be made by a discussion with writers of this kind.

5. Dual control, Boundary Conditions and the Principle of Marginal Control

In his later work, Polanyi developed the concepts of dual control and marginal control to describe the organizational structure of technical systems:

¹⁹ RPC(16,8)0523-0524, March 9, nd, in letterhead of "The University of Chicago. Committee on Social Thought".

- Dual Control: An inanimate system, such as a machine, is subject to two levels of control: the operational principles (upper level, provided by engineering) and the laws of inanimate nature (lower level, provided by physics and chemistry).
- Boundary Conditions: The operational principles are artificially embodied in the boundary conditions of the lower-level inanimate system.
- Principle of Marginal Control: This principle states that the organizational principle of a higher level (e.g., a machine's successful function) exercises control over the particulars (its physical components) forming its lower level.

These concepts of dual control, boundary conditions and the principle of marginal of marginal control appear later, after the cycles of lectures in America during the 1960's, and they are discussed on the first chapter of *The Tacit Dimension*:

- Engineering and physics are two different sciences. Engineering includes the operational principles of machines and some knowledge of physics bearing on these principles. Physics and chemistry, on the other hand, include no knowledge of the operational principles of machines. TD39
- The operational principles of machines are embodied in matter by such artificial shaping. These principles may be said to govern the boundary conditions of an inanimate system—a set of conditions that is explicitly left undetermined by the laws of nature. Engineering provides a determination of such boundary conditions. And this is how an inanimate system can be subject to a dual control on two levels: the operations of the upper level are artificially embodied in the boundaries of the lower level which is relied on to obey the laws of inanimate nature, i.e., physics and chemistry. We may call the control exercised by the organizational principle of a higher level on the particulars forming its lower level the principle of marginal control. This principle of marginality could be recognized already in the way I described some hierarchies of human performances. TD40

But these ideas began to appear in the Terry lectures, early 1960's:

- Engineering and physics are two difference sciences. Engineering includes the operational principles of machines and some knowledge of physics bearing on these

principles of operation. Physics and chemistry, on the other hand, include no knowledge of the operational principles of machines. Hence a complete physical and chemical topography of an object would not tell us whether it is a machine, and if so, how it works, and for what purpose. Physical and chemical investigations of a machine are meaningless, unless undertaken with a bearing on the previously established operational principles of the machine. But there is an important feature of machines, which its not entirely operational principles do not reveal; they can never account for the failure and ultimate breakdown of machines. And here physics and chemistry effectively come in. Only the physical-chemical structure of a machine can explain its failures. Liability to failure is, as it were, the price paid for embodying operational principles in a material the laws of which ignore these principles²⁰.

- These principles may be said to govern the borderline conditions of an inanimate system--a set of conditions that is explicitly left undetermined by the laws of nature. Engineering provides. A determination of such borderline conditions. And this is how an inanimate system can be subject to a dual control on two levels: the operations of the upper level are artificially embodied in the lower level which is relied on to obey the laws of inanimate nature, i.e., physics and chemistry. We may call the control exercised by the organisational principle of a higher level on its particulars forming its lower level, the principle of marginal control. This marginal principle could be recognised already in the way I described some hierarchies of human performances²¹.

In *Meaning* the emphasis is on coherence and the integration of objects and processes through imagination:

- Modern engineering has invented innumerable new coherences in the shape of contrivances.M 84
- The practical advance of engineering and technology consists primarily in the invention and construction of devices that will work. This too is an integrative pursuit.

²⁰ RPC(35,11)0555. Terry lectures, Lecture 2, "Comprehensive Entities" (with 1963 revision entitled "Emergence")

²¹ RPC(35,11)0555. Idem.

It skillfully combines specially devised objects and processes to form a useful mechanism. The task is conceived in the imagination and is completed by actually producing the mechanism and making it work. M141

6. Technology and Science: Common Grounds

A lot of the content of T&S' selection of texts and papers is about making sense, exploring coherences and finding meanings based on knowing. Polanyi organized his thoughts about the mysteries of knowing the unknown (or contriving the non-existent) around his epistemology of tacit knowing by indwelling. This is the fundamental common ground shared by technology and science although driven by different "passions."²²

There is a single undated and unnumbered page from the archives a Very substantive commentary by Polanyi, at the top margin. It looks like a summary of Polanyi's thought, especially during the 1960's. There are two copies of the page in the archives²³. One of them was largely annotated by Polanyi with new underlines, marks and comments on the margins:

We begin to see now that the paradox to which Meno called attention is not merely our capacity to know things we cannot tell, but the fact that tacit knowledge has powers of innovation which appear absurd in the light of a conception of thought as an explicit operation. I have said that all innovation takes place in tacit thought; we can say also, conversely, that every acquisition of tacit knowing is an innovation, because it modifies our existence. Every time we dispose of ourselves we do something that we cannot fully account for in terms of our previous state of existence: we have made an existential come to choice. When we come to know something we

²² Not only: the same mechanisms of innovation and discovery are also common ground with other areas like mathematics, arts and social sciences (beyond natural sciences).

²³ A "clean" copy is RPC(35,13)0634. Box 35 contains materials dated from 1962 and 1963. Folder 13 (and 14) are dated 1963 and labelled "*Tacit Knowing* (a version of the first Terry lecture revised for publication," according to the "Guide to the Papers of Michael Polanyi" (Cash, 1996). The copy itself is neither dated nor numbered, suggesting an addition to the original version of the Lecture. The other copy is RPC(22,18)0730. Box 22 contains "Notes" (by subjects) but folder 18 is about "miscellaneous notes and fragments" with no specific topic assigned. A lot of them are single pages, handwritten or typed. This copy has a lot of annotations by Polanyi's hand. In the top of the page he wrote "Very substantive" and underlined it. He marked large parts of the text in the left margin. Some of the marks are very intense and he manually underlined parts of the typed text that were not previously underlined. He also added large exclamation points at the bottom margin. The original must have been typed in early 1960's but the annotations seem to be added later. My guess, based on Polanyi's calligraphy at the top of the page, is that the annotations are from early 1970's (or end of 1960's). It seems that Polanyi may have rediscovered the page, around ten years after the first copy, and found it "Very substantive" and significant. Underlined words in the original were made italics in the transcription.

cannot tell, this is due to the fact that we have done something we did not know and which yet was deliberate in terms of our focal intention to which that tacit act has contributed. Our focal intention has evoked, mobilised, particulars that are subsidiary to itself. It has *produced a problem by converting things into clues*, from which we *attend to their potential meaning*. Thereby it mobilises further clues which serve to consolidate a further stage of this emergence. By such stages we organise every further set of tacit particulars in support of our *focal insight*. (*“Insight” includes both intellectual and practical comprehension*). *To gain an insight is to create knowledge within a new expanse of indwelling*. Insight appropriates subsidiary elements which support what it discovers or contrives.

We may put the matter more clearly by describing *discovery* as making sense. *Tacit knowing makes sense focally of particulars known subsidiarily*. The effort of making sense is alerted by the presence of events which seem to have a meaning of some kind. By straining our *attention towards this meaning we intensify the significance* (that is, diagnostic character) of the clues which pointed to it and bring into action further clues pointing to a yet deeper insight into the problem.

7. Towards a Post Critical Theory of *Personal Innovation*

Upon his return from India, Polanyi gave a series of eight lectures on "Unspecifiable Elements of Knowledge" at Oxford during the Hilary term, January to March 1961.¹³ These lectures were a considerably expanded version of the single lecture he had delivered in Crombie's seminar²⁴.

Polanyi intended these lectures to be a “logical backbone in a series of theses and connection with some traditional problems and contemporary philosophy”²⁵. He planned for six lectures: Art of Seeing, Art of Knowing, Art of Discovery, Levels of Existence, Knowing Life, Evolution, The Growth of Thought in Society and Ultimate Commitments.

The notes for the third meeting²⁶, about “The Art of Discovery”, include a discussion of discovery, innovation and invention and a section (section IV) about “theory of innovation”. Before that Polanyi began the lecture with a recapitulation: “The act of knowing relies on two not fully specifiables (clues and coherence) to achieve something essentially indeterminate (contact with reality)” and “the processes of discovery and

²⁴ Scott and Moleski (2005), p. 244

²⁵ RPC(22,144)0492

²⁶ RPC(22,14)0497-0500

invention are *necessarily unformalisable*. They reveal the powers of *originality*, which are assessed by the *surprise* they evoke and the *importance* of their result. The surprise defines a *logical gap*.” Let’s review the section IV (“Theory of Innovation”) and part of the following sections²⁷:

A theory of innovation should be comprehensive, including all forms of scientific innovation, from primordial level to intellectual peaks and from dawn of discovery to final holding. Such is (a theory of) *heuristics*.

The conception of a *good problem* is the key to heuristics. it is the *knowledge of hidden knowledge* that is *accessible* and *worth the trouble* of searching for it.

But it must be known to be accessible only by a *major effort* so as to be *puzzling* and *exciting*.

Problems are prefigured in trying to make out what we see (Art of Seeing) or in diagnosing, or skilfully testing (Art of Knowing), more generally in awareness of unspecifiable clues and in awareness of incomplete comprehensions. The search for particulars serving comprehensive objectives predominates in technology and acquiring skills; the search of comprehension of given clues is more common in science and maths. But problems may prove false (perpetual motion, elixir of life, astrological prediction) or remain dubious (causal analysis of quantum mechanics, perhaps also the proof of Fermat's theorem²⁸). ...

First conclusion of heuristics: a good problem is important foreknowledge, true and practicable and it is an indispensable motive of scientific innovation. ...

Look at the unknown. Look at the conclusion. Plato in Meno: we cannot seek what we don't know, for we would not know what we are looking for. *Solution*: we know the unknown in terms of clues which suggest its existence and accessibility, as we sense the presence of clues yet to be found which will confirm a surmised comprehensive entity.

By straining our attention to see the unknown we evoke its hidden elements, we feel our way to it and correct our direction by eliciting new clues towards it.

Many of these clues or particulars we shall never know in themselves.

²⁷ Original manuscripts are organized by points in a simplified structure. I tried to organize the sentences in a structured way for more easier reading. Italics were used for the underlined words in the manuscript.

²⁸ "Fermat's theorem" states that there are no three positive integers (a, b, and c) that satisfy the equation $a^n + b^n = c^n$ for any integer value of n greater than 2. The original problem, proposed by Pierre de Fermat in 1637, stumped mathematicians for over 350 years. It was famously proven in 1994 by British mathematician Sir Andrew Wiles (along with his former student Richard Taylor).

In the effort to discover how to ride a bicycle we evoke the practice of [formula] without ever knowing it focally (model of empirical technology). ...

There is a *gradient of proximity*, a chain of consecutive steps in a discovery like stones put in successively to form an arch. But each step is stabilised by sense of approaching success. This remember the effort of recollection: to searches for something we do not know, but then we can feel when we are approaching it (Plato's mistake). ...

Some see a problem where others dont, get fascinated where others pass on, find their bearings where others get lost, can sense what is plausible and beautiful in science hence make a series of discoveries while others try a in vain. This faculty is rooted in *innate ability* (originality). ...

A problem is puzzling, promising and engrossing and research carries on this excitement which triumphs in discovery. If the procedure could be defined by rules, discovery would be denatured into surveying, beset by no problems, excited by no dawning discovery, experiencing no triumph and causing no surprise.

Epistemological reflection: The process of discovery shows a passionate and uniquely personal action that is intrinsically universal in its intention, because it is goaded and guided throughout by the intimation of a hidden reality. This reflection transforms my psychological description of discovery into a justification of knowledge acquired by this process.

These fundamental ideas are explored again and with more detail in Polanyi's unpublished "Notes to theory of innovation" (1965)²⁹ where the role of alertness is emphasized: "Alertness in man has the faculty for discovering problems, whether intellectual or practical. ... *If alertness is an anticipation of problems, problems them- selves are anticipations of discovery or invention.* They are, at first, vague surmises. *To start an enquiry into a problem is to pass from vague to definite surmises.* ...All anticipation of feasibility and intelligibility is a foreknowledge of reality". And he added:

The participation of a person in the effort of discovery is comprehensive and the satisfaction felt by its achievement pervades the whole person. ... The unfinished task, unsolved problem, remains worrying us, wasting our peace, exhausting us. The moment the task is done, we triumph, we are elated, feel a calm joy of life. It is not effort, but disappointment that wears us out; it is not idleness but achievement that

²⁹ TS, Chapter 16

brings rest to us. Yet it is precisely the inspirational success, coming to us from nowhere, that we most fully acclaim as our own. This suggests that it is in fact our own performance, though not a *focal action* but an *existential reform*, a recuperation of the mind from the blight of disorder, incoherence striving for coherence.

To sum up the cycle of innovation. Alertness expressing our whole existential situation, first arouses our imagination in search of a problem and senses possible feasibilities. The imagination probes these and may launch a sally of surmises into one. This starts off the enquiry. The second phase consists in the ransacking of mental resources to substantiate our surmises, which command during this stage. If the problem can be solved by a single sally, the enquiry will be completed by the integrative powers, rooted in our whole situation. They would make good our surmises by integrating the fragments loosened up by their ransackings and put forward the discovery which solves the problem. These cycles may be repeated, following repeated thrusts of the imagination.

Imagination, intuition and coherence entered as fundamental ideas of the theory of innovation. Polanyi organized the “three stages of creative work” by intuition and imagination in a table³⁰:

Intuition	strategic anticipation	guiding the imagination	concluding idea
Imagination	embodying intuition	thrusting forward	contemplative outlook

Polanyi’s approach can be described as a *post critical theory of personal innovation*.

³⁰ RPC(35,9)0359

Annex 1

Summaries of the texts and papers by Michael Polanyi in TS

(*) indicates previously published material

1. *NOTES ON THE POSITION OF SCIENCE: SCIENCE AND INDUSTRY* (1937, unpublished): Scientific development is often theoretical and independent of practical applications. The usefulness of science is difficult to explain because a specific discovery rarely results in a specific invention.
2. *RIGHTS AND DUTIES OF SCIENCE* (1939, 30) (*): Discussion and refutation of the Marxist claims (Bernal, et al) for a reconsideration and reorganization of science based on Marxist philosophy and its social function.
3. *NOTE ON THE REASONS PREVENTING COMMERCIAL REWARD OF SCIENTIFIC PRODUCTION THROUGH SALE OF SCIENTIFIC PAPERS* (1939, unpublished): The commercial sale of pure scientific papers is impossible because the value of a discovery cannot be assessed until the knowledge is acquired. The suggestion for technological studies is to fund them by collecting money from benefiting industries and distributing it as prizes, while making secrecy contracts illegal.
4. *NOTE ON INTUITION* (1940, unpublished): Intuition is guessing guided by sound judgement, not “mere guesswork”: it involves putting forward ideas before the full reasons for them are apparent, and therefore plays a role of intuition in discovery, planning and leadership.
5. *SCIENCE - ITS REALITY AND FREEDOM* (1944) (*): Defends the independent reality and freedom of pure science (freedom as a basis for progress) against demands that all scientific work be centrally planned and subordinated to visible social interests, therefore denying the value of pursuing knowledge for its own sake.
6. *MONOPOLIES FOR PIONEERS* (1944, unpublished): Examines why monopolistic powers, particularly patents, are necessary for the commercial justification and reward of “pioneer enterprises” that introduce new or significantly cheaper products. Suggests an alternative to prevent the abuses of the patent system.
7. *PATENT REFORM* (1944, unpublished): Proposes a reform of patent law to replace the commercial process of earning profits from inventions with a system of government-funded public rewards, thereby eliminating the monopolies that patents currently grant.
8. *SCIENCE: ACADEMIC AND INDUSTRIAL. WAYS OF COOPERATION* (1947) (*): Outlines the divergence between academic science and industrial technology and proposes

solutions for collaboration. Universities should not be reproached for neglecting technology or asked to provide full technical training, as they cannot run on-site factories. Doing so would neglect their own primary task.

9. *PURE AND APPLIED SCIENCE AND THEIR APPROPRIATE FORMS OF*

ORGANISATION (1955) (*): Establishes a clear distinction between pure science and technology, arguing for different organizational structures for each. Refutes the view that all research should be centrally directed based on practical needs. Pure science must be organized as a polycentric system of spontaneous coordination (like the “invisible hand” of the free market). But technological tasks within a corporate body are often subordinate and organized under a pyramid of authority.

10. *SCIENCE: ACADEMIC AND INDUSTRIAL* (1960) (*): Explores the necessary distinction between pure science and technology, arguing that each must be cultivated on its own motivations. Technology is associated with an “industrial science” guided by economic criteria, meaning that its validity is tied to prevailing market valuations and is therefore different from that of pure science.

11. *FOUNDATIONS OF SCIENCE AND DISCOVERY* (1962, unpublished): Argues against the positivist notion that scientific theories are accepted merely for their usefulness or predictive power, asserting instead that science operates on the belief that its explanatory theories are substantially true.

12. *INNOVATION* (1962, unpublished): Asserts that innovation and discovery are fundamentally rooted in tacit knowing, therefore offering a solution to Plato’s Meno paradox (the absurdity of searching for the unknown). Innovation begins with the personal act of seeing a hidden problem, based on an intuition of coherence. It requires commitment and personal judgment.

13. *SCIENCE, TACIT AND EXPLICIT* (1964, unpublished): Presents a sustained argument against the residue of logical positivism by centering on the principle of tacit knowing merely of explicit logical relations. Rejects the adequacy of formal rules and strict falsifiability, asserting instead that scientific advancement depends on the intuitive capacity to see coherent patterns in nature, a process akin to perception and based on informal procedures.

14. *NOTES FOR JERUSALEM SECOND HALF OF THE TALK* (1964, unpublished): The grounds of scientific authority and public funding of pure science must be re-examined. Scientific understanding arises from resolving puzzles and is rooted in a theory of discovery and meaning, a process largely driven by “tacit understanding”, understood as the integration of intellectual powers involving skills, imagination, intelligent perception, and the forming of

new conceptions, a foundational matrix for all explicit explanation. Theories of scientific explanation and discovery must acknowledge this tacit matrix.

15. *COMMITMENT TO SCIENCE* (1964, unpublished): Scientific discovery is fundamentally a process of tacit inference and a tacit effort to achieve coherence, rather than the formal, explicit testing of tentative hypotheses. The imagination guides the discovery through a sequence of “sallies,” or purposive thrusts, along a “gradient of deepening coherence,” mobilizing all of the scientist’s experience and resources. Scientists must rely on intuitive judgment to assess the “ripeness of a problem” and their own capabilities.

16. *NOTES TO THEORY OF INNOVATION* (1965, unpublished): Innovation is a process originating from a general state of alertness, an active and attentive mood that serves as the internal drive for exploratory activity and the discovery of problems. Problems, which are initially vague surmises anticipating discovery or invention, lead to a focused enquiry. Successful innovation results in a transformation of the person, permanently enlarging their intellectual powers and establishing new values and presuppositions through a process of emergence.

17. *GENIUS IN SCIENCE* (1969, 22 pages) (*): All natural sciences are inexact and fundamentally rely on the scientist’s personal judgment. This reliance on personal judgment is essential and contradicts the orthodox hypothetico-deductive model. Science is grounded in personal judgment, like an act of deliberate integration. This rejects the supremacy of the exact sciences and applies the same principles to all stages of inquiry.

Annex 2

SELECTED TEXTS AND PAPERS (this book)	year	LL	KB	SEP	SM	PUBLISHED PAPERS (Scott and Molesky, 2005)
	1929					
	1930				1930b	Förderung der Wissenschaft [Promotion of Science]
	1931					
	1932					
	1933					
	1933					
	1934					
	1935					
	1936				1936c	The Value of the Inexact
1 NOTES ON THE POSITION OF SCIENCE: SCIENCE AND INDUSTRY	1937					
	1938					
2 The Rights and Duties of Science	1939				1939d	The Rights and Duties of Science
3 NOTE ON THE REASONS PREVENTING COMMERCIAL REWARD						
4 NOTE ON INTUITION	1940				1940b	Science in USSR
	1941				1941a	Cultural Significance of Science
	1942				1942b	Revaluation of Science
	1943	4			1943d	The Autonomy of Science.
					1943f	Research and Planning
5 Science - Its Reality and Freedom	1944				1944a	Science - Its Reality and Freedom
6 MONOPOLIES FOR PIONEERS					1944c	Science and the Decline of Freedom.
7 PATENT REFORM					1944d	Reflections on John Dalton
					1944e	Patent Reform
	1945	5			1945a	The Planning of Science
					1945c	Science and the Modern Crisis
					1945d	Reform of the Patent Law in Britain.
			1		1945f	The Value of Pure Science.
	1946				1946m	Science: Academic and Industrial
					1946f	Can Science Bring Peace?
					1946g	Foundations of Freedom in Science
					1946h	Social Message of Pure Science
8 Science: Academic and Industrial. Ways of Cooperation	1947			15	1947b	Science: Observation and Belief.
					1947f,g	Organization of Universities
		3			1947j	The Foundations of Academic Freedom
	1948				1948b	The Universities Today
			6		1948f	Ought Science to be Planned?
	1949		2		1949c	The Nature of Scientific Conventions
	1950				1950b	Freedom in Science
	1951					
	1952				1952c	Science and Faith
9 Pure and Applied Science and Their Appropriate Forms of Organization	1953				1953a	Pure and Applied Science and Their Appropriate Forms of Organization
	1954					
	1955				1955b	From Copernicus to Einstein
					1955c	Words, Conceptions and Science
					1956b	Passion and Controversy in Science
	1956				1956c	Ethics and the Scientist
	1957				1957a	Scientific Outlook: Its Sickness and Cure
					1957c	Problem Solving
					1957f	Science and Morality
	1958				1958d	The Impact of Science
	1959				1959e	The Organization of Science and the Claim to Academic Freedom.
					1959f	Commentary on 'The Genesis of the Special Theory of Relativity
	1960					
10 SCIENCE: ACADEMIC AND INDUSTRIAL	1961				1961b	Science: Academic and Industrial
			8		1961c	The Unaccountable Element in Science
11 FOUNDATIONS OF SCIENCE AND DISCOVERY	1962		4		1962b	THE REPUBLIC OF SCIENCE: ITS POLITICAL AND ECONOMIC THEORY
12 INNOVATION					1962e	My Time with X-Rays and Crystals." In Fifty Years of X-Ray Diffraction,
	1963		6		1963a	Science and Religion: Separate Dimensions or Common Ground
					1963b	The Potential Theory of Adsorption: Authority in Science Has Its Uses and Dangers.
13 SCIENCE, TACIT AND EXPLICIT	1964					
14 NOTES FOR JERUSALEM SECOND HALF OF THE TALK						
15 COMMITMENT TO SCIENCE	1965					
16 NOTES TO THEORY OF INNOVATION						
	1966			17	1966b	The Creative Imagination.
	1967		5		1967a	The Growth of Science in Society
				16	1967c	Science and Reality
	1968					
	1969					
	1970					
17 Genius in Science	1971				1971	Genius in Science
	1972					
	1973					
	1974				1974b	Discoveries of Science
	1975					

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³¹ International distribution through the Amazon network