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MICHAEL POLANYI (1891-1976): THE LIFE OF THE MIND

INTRODUCTION

Michael Polanyi was a polymath widely acclaimed for his work in areas as diverse as physical chemistry, economics, patent law, sociology of science, and philosophy, as well as for his activism as a public intellectual. He left behind a legacy that has been examined in countless articles published in the periodicals of the three Polanyi societies[1] and elsewhere as well as in over a dozen monographs.

Even Polanyi's work in physical chemistry alone had an uncommonly broad scope, ranging from the study of the structure of cellulose (whose macromolecular character Polanyi anticipated in 1921) to the structure and properties of crystals (in particular crystal defects) to adsorption of gases (physisorption) to heterogeneous catalysis (the Horiuti-Polanyi mechanism of hydrogenation) to chemical kinetics, his foremost preoccupation. With his mutually "trusting but critical"[1] team of young theorists, which included Eugene Wigner, Fritz London, and Henry Eyring, see Figure 1, Polanyi laid the foundations for kinetic theory consistent with quantum mechanics and foreshadowed chemical reaction dynamics, which would only see the light of day in the early 1960s in North America.

Among the protagonists of chemical reaction dynamics were Polanyi's son John Polanyi as well as Dudley Herschbach who, along with Yuan Lee, would share the 1986 Nobel prize in chemistry "for their contributions concerning the dynamics of chemical elementary processes."

Here is how John Polanyi characterized his father:[2] "Michael, in his intellectual endeavors, cultivated the position of an outsider. He worked for years as an amateur [scientist], in the spare time from his profession of medicine. Later he would be an amateur economist, an amateur on patent law (on which subject he published, and testified before a Committee of the House of Lords in the UK) and, most conspicuously, an amateur philosopher. What did all this amateurism mean? Many things. A gentlemanly disdain for the professional. A belief in the special ability of the outsider to see beyond cant and convention. Perhaps a romantic admiration for the lonely cow-boy."

And Eugene Wigner, Michael Polanyi's former PhD student, noted in his own Nobel presentation:[3] "[Michael Polanyi] taught me, among other things, that science begins when a body of phenomena is available which shows some coherence and regularities, that science consists in assimilating these regu-

Fig. 1: Michael Polanyi and the members of his "trusting but critical" team of theorists at the KWI for Physical Chemistry and Electrochemistry in Berlin. From left to right: Michael Polanyi, Eugene Wigner (1902-1995), Fritz London (1900-1954), and Henry Eyring (1901-1981).

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[1] *The Polanyi Society* publishes *Tradition & Discovery* (since 1972); *The Michael Polanyi Liberal Philosophical Association* publishes *Polanyiana* (since 1992); *The Society for Post-Critical and Personalist Studies* was formed in 2004, and took over the publication of *Appraisal* (in 1996).

larities and in creating concepts which permit expressing these regularities in a natural way. He also taught me that it is this method of science rather than the concepts themselves (such as energy) which should be applied to other fields of learning."

Recently, Dudley Herschbach, who had met Michael Polanyi on about half a dozen occasions, added the following characterization:[4] "No one else impressed me as living 'the life of the mind' so intensely [as Michael Polanyi did]."

Below I aim to outline how much worth-living Michael Polanyi's life of the mind had been.

BUDAPEST: 1891-1913

Michael Polanyi was born on 12 March 1891 into a well-to-do Jewish family in Budapest at a time when its emancipated Jewish community was thriving.[2] His father, Mihaly Pollacsek, was an ETH-educated railroad engineer who became one of the major players in the development of Hungary's advanced railroad system. His mother, Cecile, nee Wohl, was the daughter of the chief rabbi of Wilna (Vilnius). The couple moved to Budapest in 1890 and in 1904 Magyarized the family name of their five children (but not their own) to Polanyi.[3] The father declared bankruptcy in 1899 after a flood washed away a railroad line he had developed and died in 1905, leaving the family in a precarious financial situation. However, despite the odds, the mother was able to hold a weekly salon frequented by Hungary's leading poets, novelists, painters, and scholars. Michael, who was a student at the elite Minta Gymnasium[4] was contributing to the household budget by tutoring his fellow students. He graduated from Minta in 1909 and entered the medical school in Budapest the same year, earning his medical diploma in 1913. A timeline of Michael Polanyi's life and work is shown in Figure 2.

As the historian and journalist Paul Ignotus put it:[1] "From his background [Michael Polanyi] inherited the limitless liberality of mind, the simultaneity of personal and technical interests and the ability to coordinate them in behavior as well as in philosophy." Eugene Wigner and R.A. Hodgkin add:[1] "Perhaps there was another quality which Polanyi acquired from those early years – the capacity to reflect on the workings of his mind and body, to make sense of his actions and what befell him."

Polanyi himself would say late in life that it was science that was the pole star that had been inspiring him since his childhood.[5]

[2] Jews in Hungary were equal before the law to Christians since 1867. In 1900, about 5% of Hungary's population was Jewish. However in Budapest, a city of 733,000, the fraction was about 20%. There was no ghetto in Budapest. Ref. 5, pp. 4-5.

[3] The mother spoke German to her children.

[4] About 35% of high-school (*Gymnasium*) students in pre-WWI Budapest were Jewish. Cited in Ref. 5, p. 107.

Fig. 2: Timeline of Michael Polanyi's life and work.

EN ROUTE TO BERLIN: 1913-1920

Michael Polanyi wrote his first scientific papers (on thermodynamics) when he was a high-school student. His first three published scientific papers dealt with medical topics and the first of them was written during his first year at the medical school when he was nineteen. However, the subsequent three papers that Polanyi wrote before receiving his medical degree were on thermodynamics and quantum mechanics and elicited the attention of, among others, Albert Einstein. It was also in 1913 that he entered the Technische Hochschule in Karlsruhe as a student of chemistry under Georg Bredig, whom he had visited already a year earlier and who had encouraged him to publish his scientific ideas. In Karlsruhe, Polanyi expanded his range of interests to include adsorption and chemical kinetics.

Following the outbreak of World War I, Polanyi was drafted by the Austro-Hungarian military where he served as a medical officer until his invalidation in 1916. While on a sick leave, he wrote a PhD thesis on the theory of adsorption of gases on solids, which he defended at the University of Budapest in 1919. The post WWI turmoil in Hungary that included the Bela Kun-led communist revolution and the anti-Semitic Miklos Horthy-led counter-revolution forced Michael Polanyi to leave Hungary in 1919, whence he returned to Karlsruhe.

WEIMAR BERLIN: 1920-1933

In September of 1920 Polanyi landed a position at the Kaiser Wilhelm Institute (KWI) for Fiber Chemistry in Berlin-Dahlem, whose director was the Austrian biochemist Reginald Oliver Herzog. At that time Herzog's KWI was still housed primarily in rooms rented from Fritz Haber's KWI for Physical Chemistry and Electrochemistry.[5] Although Herzog offered him considerable freedom in choosing topics of research, Polanyi's interests fit better in Haber's institute. Following negotiations about funding, the transfer from Faradayweg 16 to Faradayweg 4 became official in September 1923.[6] In the Spring of the same year, Polanyi completed his *Habilitation* at the Berlin University[1] and received an appointment as *Privatdozent* at the Technische Hochschule Chralottenburg (today's Technische Universität Berlin), which was upgraded in 1926 to *Extraordinarius*.[6]

When he joined Haber's KWI, as head[7, 8] of the Department of Chemical Kinetics, Polanyi was in the midst of writing a series of articles on the use of X-ray diffraction relevant for the understanding of plasticity, crystals under stress and crystal defects. However, Polanyi divided his attention between multiple lines of research, including industrial research and consulting that helped him supplement his salary from the KWI and the Technische Hochschule. Notably, Polanyi kept returning to the topic of his dissertation research, gas adsorption. He even gave a presentation of his work on this subject at Haber's Colloquium in 1921. Later he said:[7] "Professionally, I survived the occasion only by the skin of my teeth." In attendance were Fritz Haber, Albert Einstein and numerous experts on adsorption who at that time all opposed Polanyi's model of adsorption. Polanyi's ideas on adsorption differed markedly from those of the American physical chemist, Irving Langmuir, who would later receive the Nobel prize for his work in surface chemistry. While Langmuir modeled adsorption on the basis of molecules attaching to individual and equivalent adsorption sites and forming a layer no more than one atom or molecule thick, Polanyi posited an attractive force between the adsorbate molecules and the surface, characterized by an empirically derived potential function, and not necessarily saturated by the adsorption of a single layer of atoms or molecules. Polanyi commented:[8] "Whose fate is better, mine or Langmuir's? My theory is absolutely right but not accepted. Langmuir's theory is wrong but very famous ... Langmuir is better off." However, in 1930, Fritz London was able to show that the hypothetical attractive potential that Polanyi had posited was the result of dispersion forces,[9] a corollary of quantum mechanics. In subsequent years, Polanyi's description came to be favored for many cases of physisorption; whereas, Langmuir's model remains relevant for many cases of chemisorption.

Within a year of his arrival at Haber's institute, Polanyi also returned to working on chemical kinetics, a topic that had occupied his attention intermittently but deeply since at least 1920 and that would earn him enduring scientific recognition. Over the next nine years, Polanyi and his collaborators at Haber's KWI would advance both the experimental and the theoretical study of reaction kinetics. In his 1920 paper,[10] Polanyi noted that existing kinetic theories could not be quite correct, as the ratio of forward to backward reaction rates failed to yield the equilibrium constants obtained from thermodynamics. At this time, Polanyi also conceived of the idea of studying chemical reactions rates via collisions in atomic or molecular beams.[1] However, instead he developed, in collaboration with Hans Beutler, and later with Stefan von Bogdandy and Hans von Hartel, the highly-dilute flame technique, pioneered by Haber and Walter Zisch,[11] into a powerful tool for studying reaction rates via chemiluminescence.[12]

On the theoretical side, Polanyi collaborated with Eugene Wigner, who completed a dissertation ("Formation and Decay of Molecules, Statistical Mechanics, and Reaction Rates"[13]) at the Technische Hochschule Charlottenburg under Polanyi's supervision in 1925. Wigner first joined Polanyi while the latter was still at the KWI for Fiber Chemistry, where Wigner also worked with Hermann Mark and later as an assistant to Karl Weissenberg, pursuing research on the use of symmetry groups in crystal structure analysis, but continued working with Polanyi on chemical kinetics as well. In addition, the Polanyi group was aided in its theory endeavors by Fritz London,[9] whose many con-

[5] An X-ray apparatus was set up in the basement of Haber's directorial villa next to the KWI for Physical Chemistry and Elecrochemistry.

[6] Polanyi occupied rooms on the 3rd floor of the main building.

[7] Wigner and Hodgkin, Ref. 1: "[Haber] directed his Institute somewhat from a distance; one rarely saw him and he rarely attended the scientific conferences. Hence the departmental heads had to make most of their decisions by themselves."

[8] Michael Polanyi: "Few scientists can do good work with more than a dozen personal collaborators," Ref. 5, p. 204.

[9] Fritz London was Erwin Schrödinger's assistant at the Berlin University at the time.

tributions to physics included developing one of the first quantum mechanical accounts of the covalent chemical bond,[14] in collaboration with Walter Heitler. Wigner and London, together with Hans Beutler, brought to the reaction kinetics research a facility with quantum mechanics, especially its more advanced mathematical methods, that Polanyi lacked.

In 1925, in a rejoinder to a paper in which Max Born and James Franck argued that it would be nearly impossible for a collision of molecules to trigger a chemical reaction, Polanyi and Wigner succeeded to resolve the discrepancy between forward and reverse reaction rates for the case of two-body capture and its reverse, one-body decay, by invoking an argument that bore an uncanny similarity to the uncertainty relation between energy and time.[15][10] The Polanyi-Wigner article was followed by a series of papers by Hans Beutler examining in detail the quantum mechanics of inelastic collisions of gaseous atoms and molecules that lead to electronic excitation; these were written in part in collaboration with Polanyi and in part with Eugene Rabinowitsch. Starting from a general study of atomic collisions by Hartmut Kallmann and Fritz London, Beutler and his colleagues treated in detail the kinds of collisions they thought most likely to contribute to chemical reactions and chemiluminescence.[16] But the most enduring theoretical achievement of the Polanyi group would depend pivotally upon the help of one of the KWI's many visiting foreign scholars.

In 1929, Henry Eyring, arrived in Berlin with a National Research Council Fellowship to work with Max Bodenstein at the Berlin University; however, because of Bodenstein's absence (he was attending a meeting overseas), Eyring, on the recommendation of a savvy colleague,[11] joined Polanyi instead.[17] Eyring was a graduate of the University of California, Berkeley, and had spent the preceding two years as a junior faculty at the University of Wisconsin. Eyring initially worked with Polanyi on the highly-dilute flame experiments, but Polanyi soon invited Eyring to work with him on the problem of chemical activation energy from the perspective offered by London's recent work on the dynamics of chemical reactions.

In their landmark 1931 paper on the subject,[18] Eyring and Polanyi relied upon the research of Karl Friedrich Bonhoeffer, Paul Harteck and Adalbert and Ladislaus Farkas on the simplest chemical exchange reaction, $H + H_2 \Leftrightarrow H_2 + H$, which Adalbert Farkas had posited as the mechanism for the interconversion of ortho- and para-hydrogen.[19] Eyring's and Polanyi's paper established a visual metaphor for looking at the process of making and breaking of chemical bonds which, for thermal and hyperthermal reactions, prevails until this day: a ball, representing the configuration of the constituent atoms' nuclei, rolls on the potential energy surface, given by the eigenenergy of the atoms' electrons. En route from the valley of the reactants to the valley of the products, the ball follows a path restricted by the reaction's energy disposal. Or, as Eyring and Polanyi put it: "... the chemical initial and final state are two minima of energy which are separated by a chain of energy mountains. [...] Among all possible paths [across the mountains], the reaction path is the one which leads over the lowest pass, whose energy elevation determines the activation energy of the reaction."[18] This view of the reaction entails a separation between the nuclear and electronic motions, known today as the Born-Oppenheimer approximation.[20] Thus London's tackling of the H_3 system breathed new life into Svante Arrhenius's 1889 concept of activation energy, by reinterpreting it as the summit-to-be-conquered between the electronic eigenenergy valleys of the reactants and products, see Figure 3.[21] The rate at which the ball makes its transit over the summit – and hence the rate of the reaction – was evaluated in 1932 in Polanyi's group by Hans Pelzer and Wigner,[22} who made use of statistical mechanics and the London-Eyring-Polanyi semi-empirical potential energy surface.[12] This was the first take on the "transition-state" or "activated complex" theory of chemical reactions, which would be developed by Eyring and his collaborators at Princeton and Polanyi and Meredith Evans at Manchester in 1935, and later refined by others.[23]

Another prominent visitor-turned-key-collaborator of Polanyi's was the Tokyo-University-trained physical chemist Juro Horiuti. In the spring of 1933, Horiuti joined the Polanyi group from Arnold Eucken's laboratory, where he had been doing research on Raman spectra. When he arrived at Haber's KWI, he began research with Polanyi on heavy water. Their collaboration then turned to studies of hydrogen exchange reactions and eventually resulted in the first descriptions of the Horiuti-Polanyi mechanism of hydrogenation of alkenes. This research marked the beginning of Horiuti's life-long interest in catalysis and electrochemistry, and to date the Horiuti-Polanyi mechanism remains a preferred model for the hydrogenation of hydrocarbons at solid surfaces. But the culmination of this research came only in 1934 after Horiuti followed Polanyi to Manchester in August of 1933.[24]

A farewell photo of the members of Polanyi's department taken shortly before its dissolution is shown in Figure 4.

MANCHESTER AND OXFORD: 1933-1976

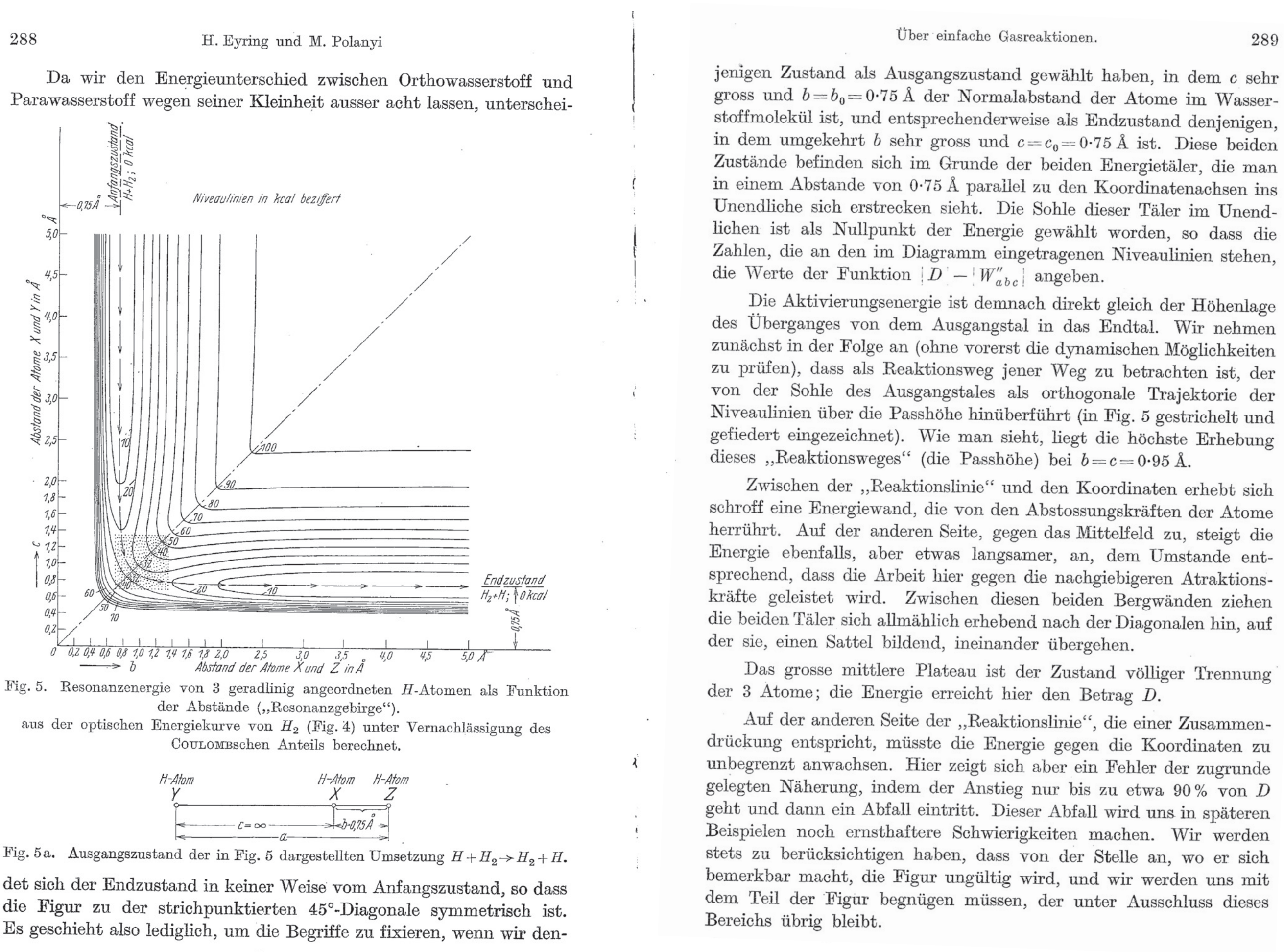
In the late 1920s and early 1930s, before the rise of the Nazis to power, Polanyi received several attractive offers, most notably from the German University in Prague (in 1928), the University of Szeged (in 1929) and the University of Manchester (in 1932). In particular the last offer, which came at a time when the Great Depression was taking a devastating toll on Germany,[13] proved tempting, as it entailed a start-up fund, a new building, and commitment to support eight to ten personnel. In a letter to Polanyi from June 1932, Haber advised:[25] "[I]f I received this call in

[10] Wigner and Hodgkin: "It is characteristic of Polanyi's modesty that it required considerable persuasion to induce him to have his name associated with the article." Ref. 1.

[11] Alexander Frumkin, a visitor from Moscow at the University of Wisconsin.

[12] The pragmatic semi-empirical method, introduced by Polanyi and Eyring, made use of spectroscopically determined dissociation energies of the constituent diatomic molecule (i.e., H_2 in the case of the $H+H_2$ exchange reaction) in order to boost the accuracy of the potential energy surface.

[13] The national funding for the Kaiser Wilhelm Gesellschaft was cut by 30% between 1930-1931 and 1932-1933. The personnel at Haber's institute had been reduced from sixty five in 1931 to forty two in January 1932 and would be cut further to thirty six in April 1932. Ref. 5, p. 67.



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Da wir den Energieunterschied zwischen Orthowasserstoff und Parawasserstoff wegen seiner Kleinheit ausser acht lassen, unterschei-

Fig. 5. Resonanzenergie von 3 geradlinig angeordneten H-Atomen als Funktion der Abstände („Resonanzgebirge“). aus der optischen Energiekurve von H_2 (Fig. 4) unter Vernachlässigung des Coulombschen Anteils berechnet.

Fig. 5a. Ausgangszustand der in Fig. 5 dargestellten Umsetzung $H + H_2 \rightarrow H_2 + H$.

det sich der Endzustand in keiner Weise vom Anfangszustand, so dass die Figur zu der strichpunktierten 45°-Diagonale symmetrisch ist. Es geschieht also lediglich, um die Begriffe zu fixieren, wenn wir den-

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jenigen Zustand als Ausgangszustand gewählt haben, in dem c sehr gross und $b = b_0 = 0{\cdot}75$ Å der Normalabstand der Atome im Wasserstoffmolekül ist, und entsprechenderweise als Endzustand denjenigen, in dem umgekehrt b sehr gross und $c = c_0 = 0{\cdot}75$ Å ist. Diese beiden Zustände befinden sich im Grunde der beiden Energietäler, die man in einem Abstande von 0·75 Å parallel zu den Koordinatenachsen ins Unendliche sich erstrecken sieht. Die Sohle dieser Täler im Unendlichen ist als Nullpunkt der Energie gewählt worden, so dass die Zahlen, die an den im Diagramm eingetragenen Niveaulinien stehen, die Werte der Funktion $|D| - |W''_{abc}|$ angeben.

Die Aktivierungsenergie ist demnach direkt gleich der Höhenlage des Überganges von dem Ausgangstal in das Endtal. Wir nehmen zunächst in der Folge an (ohne vorerst die dynamischen Möglichkeiten zu prüfen), dass als Reaktionsweg jener Weg zu betrachten ist, der von der Sohle des Ausgangstales als orthogonale Trajektorie der Niveaulinien über die Passhöhe hinüberführt (in Fig. 5 gestrichelt und gefiedert eingezeichnet). Wie man sieht, liegt die höchste Erhebung dieses „Reaktionsweges“ (die Passhöhe) bei $b = c = 0{\cdot}95$ Å.

Zwischen der „Reaktionslinie“ und den Koordinaten erhebt sich schroff eine Energiewand, die von den Abstossungskräften der Atome herrührt. Auf der anderen Seite, gegen das Mittelfeld zu, steigt die Energie ebenfalls, aber etwas langsamer, an, dem Umstande entsprechend, dass die Arbeit hier gegen die nachgiebigeren Atraktionskräfte geleistet wird. Zwischen diesen beiden Bergwänden ziehen die beiden Täler sich allmählich erhebend nach der Diagonalen hin, auf der sie, einen Sattel bildend, ineinander übergehen.

Das grosse mittlere Plateau ist der Zustand völliger Trennung der 3 Atome; die Energie erreicht hier den Betrag D.

Auf der anderen Seite der „Reaktionslinie“, die einer Zusammendrückung entspricht, müsste die Energie gegen die Koordinaten zu unbegrenzt anwachsen. Hier zeigt sich aber ein Fehler der zugrunde gelegten Näherung, indem der Anstieg nur bis zu etwa 90% von D geht und dann ein Abfall eintritt. Dieser Abfall wird uns in späteren Beispielen noch ernsthaftere Schwierigkeiten machen. Wir werden stets zu berücksichtigen haben, dass von der Stelle an, wo er sich bemerkbar macht, die Figur ungültig wird, und wir werden uns mit dem Teil der Figur begnügen müssen, der unter Ausschluss dieses Bereichs übrig bleibt.

Fig. 3: Excerpt from Ref. 18 (1931) showing the potential energy surface of the H + H_2 ⇔ H_2 + H reaction for a collinear collision geometry as considered by Henry Eyring and Michael Polanyi (the London-Eyring-Polanyi potential energy surface). The arrow follows the minimum energy path from the reactant valley via a saddle point area (dashed) to the product valley.

Fig. 4: Farewell photo of the already reduced department of Michael Polanyi at the KWI for Physical Chemistry and Electrochemistry, 1933. First row from the left: Herr Hille, Irene Sackur, unknown, Akexander Szabo. Second row from the left: Michael Polanyi, Juro Horiuti (?). Third row from the left: Frau Gehrte (janitor), Frau Weissenberg (secretary). Fourth row from the left: Kurt Hauschild (lab assistant), Erika Cremer.

your situation, which I see as extremely honorable and advantageous, I would accept it.” But, on January 13, 1933, Polanyi declined. In a draft letter, he wrote:[26] “Although I first arrived in Germany in my later years, I nonetheless am rooted here with the greater part of my being. Even if I wanted to leave here, in order to secure greater latitude in my professional work, this decision would be especially difficult for me at the present moment when Germany endured such hard times. One would reluctantly give up a community which finds itself in such difficulties, when one has shared earlier in the good times.”

However, Polanyi’s Berlin years, of which Wigner said,[27] “I doubt [Polanyi] was ever again as happy as he had been in Berlin,” did come to an end once the Nazis rose to power, on 30 January 1933, and Polanyi was forced to emigrate from Germany; he left in August of 1933. He found a new academic home at the University of Manchester after all, however under conditions much less advantageous than spelled out in the declined 1932 offer.[14] In Manchester, where he held the chair made famous by John Dalton, Polanyi published about forty

[14] There was also a brewing opposition in the senior ranks of the English academia to hiring a foreigner instead of an Englishman.

percent of his overall scientific output, including his "activated complex" theory, see Figure 5. This despite the modest working conditions there; as Polanyi once jokingly explained to a visitor, his "laboratory's floor … was so weak and unstable that they had to make instrument readings by first standing on the right foot, then on the left foot, and then taking the average."[28]

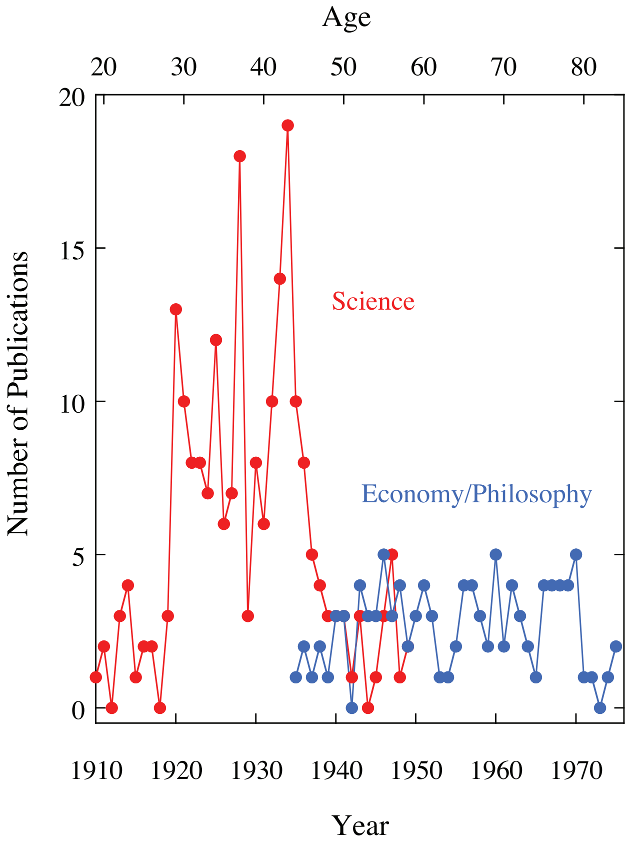

Fig. 5: Timeline of Michael Polanyi's publication activities (resulting in a total of 356 publications). Over a half of his science papers were produced with collaborators (about sixty of them). Based on Ref. 1.

With the deterioration of the political climate in the 1930s Europe, the "twice-exiled" Polanyi embarked on a mission which would gradually claim most of his attention: standing up for political and economic freedom in general and for academic freedom in particular. Mary Jo Nye notes that[29] "the freedom of research that [Polanyi] had experienced in a tightly networked community of world-class colleagues within the tree-lined precincts of Dahlem [a.k.a. 'the German Oxford'] became an induplicable but idealized memory that formed the foundation for his later writings on the nature of scientific life and scientific achievement. The loss of his Berlin scientific community and gradually of his own scientific productivity led to later reflections on the social conditions of scientific work and on the difficulty of transplanting established traditions in new terrain." The University of Manchester, "was not deterred by suspicions that Polanyi could never be more, academically speaking, than an amateur philosopher. … Was not Polanyi, in the strict academic sense, an amateur in everything except his early skills in medicine? And could anyone quarrel with the result?"[30] and created a chair in "Social Studies" for him in 1948. What made this appointment even more audacious was that Polanyi would need ten more years to write his first major work outside of physical chemistry. Aided by philosopher Marjorie Grene,[15] see Figure 6, Polanyi toiled on *Personal Knowledge*, his philosophical *magnum opus*, at least since delivering his 1951-1952 Gifford Lectures. Interestingly, the University of Chicago, under its liberal president Robert Maynard Hutchins, was interested in Polanyi the philosopher and public intellectual as well and offered him in 1951 a chair in social philosophy. Polanyi decided to accept, but couldn't because he was denied a U.S. visa, based on absurd McCarthyite allegations of his association with communists. In 1959, Polanyi moved from Manchester to Merton College, Oxford, as a Senior Research Fellow.

Fig. 6: Michael Polanyi in Manchester and his two key collaborators there: Meredith Evans (1904-1952) and Marjorie Grene (1910-2009).

By Polanyi's own account, "The principal purpose of [*Personal Knowledge* (1958)[31] and of its abridged and more accessible variant, *The Tacit Dimension* (1966)[32]] is to achieve a frame of mind in which I may hold firmly to what I believe to be true, even though I know that it might conceivably be false. … I'm trying to convince myself."[33] The starting point of Polanyi's project, conceived ambitiously as a new epistemology, was that "*we can know more than we can tell*" and that "all knowledge is grounded in [such] tacit knowing."[34] Polanyi's favorite example is the "art of recognizing a characteristic appearance by unspecifiable particulars … We practice it every day when watching the delicately varied expressions of the human face, and recognizing its moods without being able to identify, except quite vaguely, the signs by which we do so."[35] And Polanyi adds that the most "striking concrete example of an experience" that relies on tacit knowing is simply "the experience of seeing a problem, as a scientist sees it in his pursuit of discovery." He also notes that "If we succeeded in focusing our attention *completely* on the elements of a skill, its performance would be paralyzed altogether."[35]

Another, more sociological element of Polanyi's philosophy, is concerned with the transfer of scientific knowledge from teacher to pupil:[36] "the master chooses the problems, selects a technique, reacts to clues and difficulties, and keeps speculating all the time. It is a system of apprenticeship rooted in tacit knowledge that often cannot be articulated and constitutes a tradition passed from mentor to apprentice."[16] At the same time, personal knowledge is not subjective, as it establishes contact with reality in "anticipating an indeterminate range of yet unknown true implications."[37] Polanyi spoke of "intellec-

[15] Marjorie Grene was Polanyi's assistant in 1951, funded by the Rockefeller Foundation.

[16] Cf. Erwin Chargaff: "[modes of scientific thought and practice] live in the womb of a particular language and civilization." Cited in Ref. 5, p. 84.

tual passions" as constituents of the personal engagement that is needed for scientific work.

Personal Knowledge is permeated with historical examples none of which, however, came from Polanyi's own research. One of the examples stands out, namely Einstein's work on special relativity: from the fact that Einstein did not cite in his 1905 paper on the subject the Michelson-Morley experiment, Polanyi concluded that Einstein's theory was conceived "on the basis of pure speculation, rationally intuited by Einstein before he had ever heard about [the experiment]." In 1992, summarizing his research under the heading 'An Experimental Proof of Tacit Knowledge,' the physicist and historian of science Gerald Holton showed that Polanyi had been essentially right.[38]

Polanyi's philosophical writings have not become as well known as those of his contemporaries, Karl Popper (whose logical empiricist characterizations of science as a system of detached objectivity were anathema to Polanyi) or Thomas Kuhn (with whom Polanyi agreed on key issues and whom he inspired). Stefania Ruzsits Jha points out that "Polanyi's choice of language seems to be the greatest barrier to understanding his works, especially his philosophy of science."[39] Mary Jo Nye aptly adds that,[40] "When Polanyi abandoned his work in physical chemistry in order to launch a crusade on behalf of a liberal and humane science in a free society, he did so without having experienced the apprenticeship and mentorship in social science and philosophy that he knew were necessary for membership in a discipline."

As Mary Jo Nye further showed in her Polanyi biography,[41] "Polanyi's truly original ideas in philosophy of science occurred in [his] explicitly political writings that appeared well before the publication ... of [*Personal Knowledge*]." Polanyi developed his views on science policy and economics, his first non-chemical interests, through intense discussions with other scientists and economists, including his older brother Karl, a noted socialist political economist. Appalled by the inefficiency of Soviet central planning and by John D. Bernal's 1939 Marxist appeal to introduce central planning in science, Polanyi extolled the virtues of the Keynesian capitalist market system and likened the coordination by mutual adjustments within the scientific community to a free market guided by a "hidden hand." The analogy between the workings of the scientific community and a free market economy was the subject of a 1942 draft titled "The City of Science," which would become, once refined and published twenty years hence, one of Polanyi's best know essays, "The Republic of Science."[42] It ends with Polanyi's redefinition of the scientific community as a "Society of Explorers." Mary Jo Nye points out that,[43] "Polanyi's argument against Bernal that science requires the structure of a liberal republican framework in order to thrive is a clearly political argument and one that was common among natural scientists and social scientists in the West and especially in the United States."

Michael Polanyi died on 22 February 1976 in Northampton, England.

EPILOG

As Mary Jo Nye has pointed out,[44] Polanyi "and other natural scientists and social scientists of his generation – including John D. Bernal, Ludwik Fleck, Karl Mannheim, and Robert K. Merton – and the next – notably Thomas Kuhn – arrived at a strong new conception of science as a socially based enterprise that does not rely on empiricism and reason alone, but on social communities, behavioral norms, and personal commitments that ultimately strengthen rather than weaken the growth of scientific knowledge."

Polanyi's last student, Paul Craig Roberts, who joined Polanyi at Merton College, strengthens Nye's argument by pointing to the centrality of Polanyi's concerns for the intangibles, in particular for "thought as an independent, self-governing force," banished, in Polanyi's view, by modern skepticism.[45] This is, according to Polanyi, where positivist empiricism and the moral skepticism of the 20^{th} century met to spell disaster. Polanyi's remedy, which echoes his maxim "The freedom of a subjective person to do as he pleases is overruled by the freedom of the responsible person to do as he must,"[46] articulated in Personal Knowledge, is a "Western Commonwealth" in which "all people of the West will have to undergo some assimilation towards a more uniform type of man." Its basis will be the "rule of law, equal citizenship and a religion rather similar to early Christianity with its admixture of Greek philosophy."[47] Against the backdrop of WWI, in 1917, Polanyi argued that[48] "national sovereignties must be eliminated, and a European state established that is united by a system of law and order and by a European army." Does all this ring a bell? Are we there yet or at least getting there? If so, it may be another experimental proof of Michael Polanyi's theory of knowledge.

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