SCIENTIFIC CREATIVITY IN HUNGARIAN CONTEXT

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Comparing with the population, many Hungarians achieved outstanding success in natural sciences in the 20th century. From this fact, the conclusion can be drawn that Hungarians are very creative. In analyzing this conclusion, a simple general model of creativity is used which distinguishes between the approaches of the genious theory and Zeitgeist theory. By applying the Zeitgeist theory, the paper concludes that some elements of the Hungarian culture significantly contributed to the success of the Hungarian scientists, although all of them left Hungary at a certain point of their career. Migration was a key element of their success because they could find relevant problems and meritocratic scientific community in the scientific centers.

Keywords: scientific creativity, scientific migration, Hungarian Nobel Prize Winners

Creativity for Hungarians often appears to be a consolation for the political and economical miseries that have occurred from time to time since the early twentieth century. After the general collapse caused by Hungary's defeat in the First World War lead to a great loss of territory and population Count Kuno Klébelsberg, Minister of Education in the 1920s, based his policy on the "cultural superiority" of Hungary. He aimed at building up a new system of education, science and culture that would provide possibilities for the emergence of Hungarian "genius", which was assumed to be the most important asset the country had after its severe losses. Cultural superiority, this policy supposed, could help to regain the traditional authority of the country within the region.

Similar argumentation appeared around the mid 1980s. Hungary's economic conditions and the future of the Soviet style socialist system became uncertain, resulting in a kind of frustrated and pessimistic feeling in the citizens about the country's future chances under the changing international circumstances. Socialism had no future, industry looked like industrial museums, and agriculture could not compete with its Western counterparts. Hungary had no mines, no seas, no oil wells, no diamonds, nor any particularly valuable natural resources. Politicians

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could only rely on one natural resource: the human factor. Their logic was the following: Hungary had produced many extremely successful intellectuals, including Nobel Laureates, wonderful musicians and businesspeople. This appeared to show that Hungarian life was fertile when it came to producing gifted people. An article published in *Nature* by a non-Hungarian author enhanced this feeling. In an important scientific journal one could read that scientists from Budapest had made the whole twentieth century.[1] In the modern age knowledge has become more important than any natural resource, and scientific knowledge is assumed to be applicable to practical problems. Therefore, one can conclude that the bright future of a country lays in the hands, or heads, of gifted people, primarily scientists.

In addition, the Nobel Prize winners, or musicians, such as Béla Bartók, George Solti or businesspeople, such as George Soros and many others were assumed to be so successful because of their unique way of thought and originality. A similar idea was also expressed by the brilliant nineteenth-century mathematician János Bolyai, who invented non-Euclidean geometry: "I created a new, different world from nothing". Hungary really needed a new, different world.

The importance of creativity in Hungarian life may explain the historic fact that quite a few Hungarian thinkers contributed significantly to the research field of creativity. Although Arthur Koestler, George Polya, Michael Polanyi, Imre Lakatos or Mihály Csikszentmihályi worked out different approaches, their theories have been cited as most relevant contributions.[2]

Precisely because of its importance in 2000 a group of scholars in Hungary launched a research project aiming at mapping and interpreting the supposed Hungarian creativity as it developed during the last two centuries, analyzing its characters and sources. The research (resulted in a series of books) extended to many different fields of intellectual life, including science.[3] Scientific creativity will be analyzed here as it was manifested in the Hungarian context. First, the problem will be precisely defined. This will be followed by a general model for scientific creativity. Finally, this model will be applied to the case of successful Hungarian scientists.

The Hungarian Phenomenon

The idea that through its population Hungary has a special natural resource relies, largely, on the relatively high number of very successful Hungarian scientists. According to this argument, the per capita number of the Hungarian Nobel Prize winners is very high. However, even this number is disputed. *Table 1* shows some basic data on the Nobel Prize winners.

Table 1

Hungarian Nobel Laureates

Name	Dates	Field	Places of activity	Nobel Prize
George von Békésy	1899–1972, Budapest	physics, physiology	Hungary, Sweden, USA	1961 medicine
Dennis Gabor	1900–1979 Budapest	engineering, physics	Germany, Hungary, UK	1971 physics
John Harsanyi	1920–Budapest	economy, pharmacy, mathematics	Hungary, Australia, USA	1994 economy
George de Hevesy	1885–1966 Budapest	chemistry, physics, biochemistry	Hungary, Germany, Denmark, Sweden	1943 chemistry
Philipp Lenard	1862–1947 Pozsony (Bratislava)	chemistry, physics	Germany	1905 physics
George Oláh	1927– Budapest	chemistry	Hungary, Canada, USA	1994 chemistry
Albert Szent-Györgyi	1893–1986 Budapest	medicine, biochemistry	Netherlands, UK, Hungary, USA	1937 medicine
Eugene Wigner	1902–1995 Budapest	chemistry, engineering, physics	Hungary, Germany, USA	1963 physics

Table 2

Hungarian Origin Nobel Prize Winners

Name	Dates	Field	Sites of living	Nobel Prize
Robert Barany	1876–1936	medicine	Austria, Sweden	1914 medicine
Richard Zsigmondy	1865–1929	chemistry	Austria, Germany	1925 chemistry
Milton Friedman	1912–	economy	USA	1976 economy
Carleton Gajdusek	1923–	biology	USA	1976 medicine
John C. Polanyi	1929–	chemistry	Germany, UK, Canada	1986 chemistry
Avram Hershko	1937–	biochemistry	Israel	2004 chemistry

Many authors, however, add other names to this list based on the origin of some Nobel Prize winners *(Table 2)*.

The difference in the list of names is explained by the incongruity of the definition of being Hungarian used by the various authors.[4] I use a somewhat lose definition based on the socialization process. Accordingly, I consider a scientist Hungarian, if he was socialized in Hungary, grew up in Hungarian language and culture, received his basic education, social skills, taste, basic human networks and the like in Hungary. The people shown on the second list do not meet these requirements as they were born and educated outside Hungary.

On the other hand, some additional scientists reached a similar level of respect or gained the same high esteem as the Nobel Prize winners although for some reason they never received the prize. Harriet Zuckerman calls them "uncrowned kings".[5] We can list many Hungarian scientists pertaining to this category but the best known of them are shown in *Table 3*.

Table 3

Some Uncrowned Kings

Name	Dates	Field	Places of working
Theodor von Kármán	1881–1963 Budapest	mechanical engineer, physicist, mathematician	Budapest, Germany, USA
John von Neumann	1903–1957 Budapest	chemist, mathematician, physicist	Germany, USA
Michael Polanyi	1891–1976 Budapest	medical doctor, chemist, philosopher	Budapest, Germany, UK
Leo Szilard	1898–1964 Budapest	engineer, physicist, biologist	Germany, UK, USA
Edward Teller	1909– Budapest	chemist, physicist	Germany, UK, USA

Many other names could be mentioned, including mathematicians who were successful for a long period, such as Paul Erdős, George Polya, Gábor Szegő, Paul Halmos, Peter Lax, Cornelius Lanczos and some mathematicians who remained in Hungary, such as Lipót Fejér, Frigyes Riesz, Béla Szőkefalvy-Nagy, Pál Turán, Alfréd Rényi, and others. Nevertheless, my goal here is not to prove that many excellent Hungarian scientists worked in various fields of natural sciences in the twentieth century, rather to analyze the sources of their success.

The impressive length of the list could serve as an argument for the existence of a special scientific gift. However, the fact that, except some mathematicians, all of the listed Hungarian scientists left Hungary and became successful outside the country makes the case more complicated.[6] The relatively large number of important scientists who left the country can be considered as a particular Hungarian phenomenon in the twentieth-century history of science.

Models of Creativity

Scientific creativity can be interpreted by a simple input-output model as shown in *Figure 1.* Some kind of processing module (brain, intellect, mystic illumination, or whatever, depending on the approaches) converts input information into output information, which is considered as a scientific result.

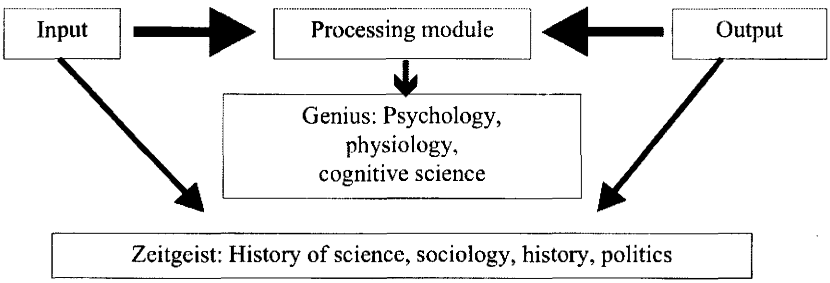

Figure 1. Creativity model

Based on this simple model, two kinds of theories can be distinguished. The first, the genius theory, looks at the mechanism of scientific creation from the point of view of the processing module. This theory supposes that a scientific result is the creation of a wonderful mind, and creativity is a feature of individuals with particular innate abilities working in a strange, mysterious way. The genius approach, the most popular one even today, was vividly expressed around the late 19th, early 20th century by the followers of Francis Galton or Cesare Lombroso.[7] The potential of the exceptional genius minds can supposedly be measured by some psychological tests, as, among many others, Paul Torrance did, who in his popular methods distinguished creativity from intelligence.[8] Robert Sternberg studied the factors influencing the individual's creativity in the fields of science and technology.[9] The psychometric investigations find components of the individual creativity, such as the work of intelligence, lateral and divergent thinking and the like.[10] The genius theory relies on biological, psychological or cognitive arguments.

The second kind of theory, called Zeitgeist theory, explains creativity rather by the input and output knowledge than by the work of the processing module, although accepting the role of individual abilities as a precondition. Robert Merton, sociologist showed that a large number of scientific results were born simultaneously and many were anticipated. From these facts he concluded that the problems of science at a given period and the accumulated knowledge at its premises, the Zeitgeist, had decisive impact on scientific creativity.[11] Dean Keith Simonton, while systematically investigating the impact of Zeitgeist,[12] applied the logic of evolution psychology. He held that the scientific views are selected and screened by a complex mechanism resulting in the survival of some ideas and death of others.[13] Mihály Csikszentmihályi apparently accepts the evolutionary Zeitgeist approach but he does not limit his studies to the relationship between the individual and his results. Csikszentmihályi focuses on the process of screening. He shows the selection mechanism, the complex influencing factors in many fields of human activity, including science.[14]

Following the logic of Merton, Simonton and Csikszentmihályi, a sociological approach to scientific creativity can be worked out. In spite of the genius theory and not denying the large differences existing in the creative potential of individuals, scientific activity seems to be a collective enterprise, rather than isolated work of outstanding individual minds. The collective character, represented by the Zeitgeist, appears both on the input and output side of the model. On the input side, being informed about the scientific knowledge produced previously by the scientific community is one precondition for creating new results. The scientist also needs an idea about the accepted methodological rules of research and a large background knowledge serving as an association base in his research work, not to mention the technical and social skills provided by his local culture.

The screening process of the results takes place on the output side. An output of scientific research is considered a result, only if it has been communicated and in this way has some influence on the field. (An interesting idea, a new observation, or an invention that had no influence on the field, had not become an accepted or debated part of science could only be an attractive subject for historians.) Consequently, the existence of a scientific audience, an institutional system able to evaluate the output, able to give credit to the author, and able to transmit the output to the wider professional and non-professional community is an indispensable component of scientific creativity.

Creative Hungarians versus Hungarian Creativity

In analyzing the Hungarian phenomenon from the point of view of creativity, both the genius and the Zeitgeist model can be applied. When considering the high number of excellent scientists, we rely on an individualistic, biological, psychological approach and refer to the brain, the quality of "the gray cells", as the most important factor. I call this the creative Hungarians approach, relying solely on the fact that the number of creative Hungarians is exceptionally high. In this approach the occurrence of a high number of extremely able brains could be attributed to some genetic causes. These causes are formed either by the long tradition of intellectual work in some, mostly Jewish, families, or by the beneficial effect of mixing the genes of the many ethnic groups traditionally living in Hungary. When applying the genius model, we consider the Hungarian creativity as a biological, psychological or cognitive scientific event related to individuals. Because this argument is based on statistics, on the number of the very successful scientists, the advocates of this theory list more names as Hungarian scientific geniuses than those, who do not approve the theory. The advocates list fourteen Nobel Prize winners, instead of eight, considering Barany, Zsigmondy, John Polanyi or Hersko to be Hungarian because they were descendants of families that had lived in Hungary. The supporters of the genius theory imply that although some Nobelists were not socialized as Hungarians, they were Hungarians "by birth", as if to be a Hungarian would constitute a genetic fact, the same way as in the case of a scientific genius. In this way the problem who is a Hungarian and who is not becomes a crucial point pertaining to the core of the creative Hungarians argument.

Underlying the genius theory of the Hungarian phenomenon, a particular shift should be assumed to take place in the distribution of the gift in the population. The probabilistic distribution of any features, including the gift for doing science, whatever way this quality is defined, in a large population is described by a bell curve shown by the thin line in *Figure 2.*[15]

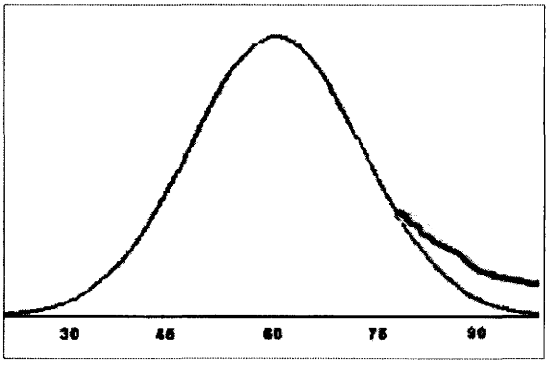

Figure 2. The probable distribution of "gift" in population

The horizontal axis shows the growing gift, the vertical the number of people. Accordingly, very few people belong to the extremely ungifted and the genius category. Most people belong to places between the extremes, having some gift though not very big or very small. According to the creative Hungarians theory, in Hungary instead of the normal distribution of the narrow line, somewhat more people belong to the very gifted or genius category, as the thick line shows. Such a shift in the distribution, however, needs to be proved by measurements and explained by events that changed the probabilistic distribution. However, no such kind of measurement exists, and no events of biological significance have been detected. Therefore, the thick line seems imaginary. Consequently, there is no rational basis for accepting the creative Hungarian theory, to think that in the Hungarian population the rate of scientifically extremely gifted people is higher than in any other large enough national population.

The statistical argumentation shows that a certain part of the population is always particularly gifted in any time, even if this part is not larger in a population than in the other. The important social issue is whether a given society provides suitable circumstances for people with high gifts to become successful or they do not represent either an important asset for the society or the society is unable to make use of the gift.

In this way, the existence of the Hungarian phenomenon suggests that Hungary provided favorable circumstances for gifted people. Although the number of very good brains, processing modules, was not higher than in other countries, the Zeitgeist, the social, cultural milieu was more stimulative. When analyzing the impact of this milieu, I speak about Hungarian creativity, referring to the collective, social, cultural characters of the phenomenon in contrast with the individual character of the creative Hungarians approach.

Hungarian Zeitgeist as a Source for Scientific Creativity

Hungarian creativity, defined as Zeitgeist, was communal, social, as it related to a national culture, not primarily to individual abilities.[16] In this approach, the "good brains", the individual gifts, and other personal features (endurance, ambition, etc.) are considered as necessary but not sufficient conditions for becoming a successful scientist. These features are put into brackets while focusing on the scientific input and output of Hungarians.

From the input point of view, the social, cultural circumstances were favorable at the beginning of the twentieth century. Before the First World War, during a peaceful era, Hungary lived as a part of the liberal, laissez faire Austro-Hungarian Monarchy and enjoyed an unprecedented modernization process. The economy grew vigorously. Agriculture was robust. New factories, new industrial branches, banks were born, urbanization progressed, including the modern capital, Budapest, with its wide boulevards, elegant buildings, electric lights, urban transportation, newspapers, and all this happened within a few decades. Modernity partly formed by and partly resulted from the birth of a new middle class recruited to a large extent from people, who originated from outside the traditional Hungarian classes, and included Jews, Germans, Croatians, Greeks, Slovaks, and others. In Budapest, a vivid, frivolous, open, multicultural atmosphere became prevalent. It was similar to that of contemporary Vienna, which had educated the philosopher, Ludwig Wittgenstein, the psychoanalyst, Siegmund Freud, the writer Robert Musil, the physicist Ludwig Boltzmann, and so many others.

The scientists of the Hungarian phenomenon were educated in this world. They all were born in middle class families, many in assimilated Jewish families. They lived in pleasant large apartment houses in Budapest, with successful working fathers. Von Neumann's father, a banker, Békésy's father, a diplomat, Teller's father, a lawyer could serve as typical examples. The mother took care of the household, directed the domestic help. The families had lots of books, often a piano, and paintings. The families spoke several languages, above all German because they often went to Vienna to do their shopping or just see the latest theater shows. Their young children were taught at home by private teachers, learning to read and write, simple calculations, music, sport, and foreign languages. This kind of instruction could conform to the child's personal requirements, interests, and the pace depended on their interests and abilities. By the time they started school, around the age of 10, they had the most important skills, including a kind of style and manners.

The schools in Budapest, mainly on the Pest side, were sometimes good enough to contribute to the development of the gifted children. Usually, however, as everywhere, the schools were fashioned to serve the instruction of average children. Some of them tolerated the genius students, as in the case of Wigner and Kármán, sometimes not, as with Teller and others. These high schools provided better instruction in the humanistic fields than in science. Thus, these schools might have served the students extremely gifted in science better than if they had provided a somewhat higher level science program, because they could progress in science by following their own interests and speed.

Many members of the group of Hungarians gifted in science proved extremely able in mathematics even before they started school, and mathematics was precisely the field that gave wonderful extramural opportunities for progress.[17] A journal, called *Középiskolai Mathematikai Lapok* (Journal of High-School Mathematics) published interesting and very difficult problems that could only be solved by creative students. They sent their solutions to the editors, who published the wittiest solutions with the names of the students. Many Hungarian students who later became outstanding scientists could be found among the best problem solvers. The journal awakened in the students a competitive ambition that would later be served more openly by the student competitions.[18] The Eötvös competition (named after the physicist Roland Eötvös, who served as an exemplar in science) was organized yearly for high school students. This was also a mathematical and physical problem solving competition, in which to achieve a good result was a great honor. Among the winners, we can find Kármán, Szilárd, Teller, Harsanyi.[19]

The Hungarian phenomenon scientists started the university in Budapest. Some of them, such as Kármán, Michael Polanyi, Szent-Györgyi and Harsanyi graduated there, others, such as Hevesy, Szilárd, Wigner, Gábor continued their studies abroad, mostly in Germany, after some semesters in Budapest, while Békésy and Teller studied exclusively in foreign universities. The Hungarian universities did not inspire them very much. In addition to mathematics, in which some very influential professors lectured at the university, including Lipót Fejér, Gyula König, Frigyes Riesz, and others, and besides some insulated persons, e.g., the physiologist Ferenc Tangl, the Hungarian universities could not contribute much to the progress of these students.[20]

They could, however, meet brilliant people outside the universities. The Budapest middle class intellectuals had a non-institutionalized network that included family life, sports, coffee houses, and other circles (the Galileo circle was the most prominent). Michael Polanyi's mother lead a saloon in her living room, where scientists, artists, writers, younger and older people met and discussed regularly. Over the dinner table of the Neumann family, all kinds of poets, psychoanalysts, mathematicians, economists discussed the latest events of many areas of life. In these informal circles, gifts, knowledge, wit and sensibility were more appreciated than in the institutionalized part of society. These circles constituted the scenes of a large part of their intellectual education giving an impetus to the open-minded young generation.

After the two World Wars, however, life changed a great deal. Following the first war an authoritarian right wing, after the second war a communist regime took over. The wide multicultural horizon with the liberal political atmosphere seemed to have largely gone after the first war; even the remnants disappeared after the second. Even before the first war, the dark shadow of anti-Semitism appeared as more than a menace. The families of the young students understood or just felt that their sons' future was insecure. One conclusion of this feeling was to choose a field that provided a good opportunity to earn a living in all civilized countries. Therefore, the mathematically or theoretically gifted sons studied in practical fields such as industrial chemistry (even von Neumann and Wigner), engineering (Szilárd, Gábor), or medicine and pharmacy (Szent-Györgyi, Polanyi, Harsanyi), rather than in mathematics, theoretical physics or philosophy. The other conclusion was that the future in Hungary was not safe. After the first war, most of the bright sons moved to Germany, while after the second war those who had stayed in Hungary (Békésy, Szent-Györgyi, Harsanyi, and Oláh) left for the USA. Here, they could meet their fellow Hungarians who fled from Hungary after the first war and from the Nazi Germany in the 1930s. Emigration gave them shelter but the competition they met abroad gave them the feeling that they should be brilliant for their mere survival as scientists. The recognition of the importance of emigration was the last and most important source of success that they gained as input in Hungary.

The Characteristic Features on the Output Side

These Hungarian phenomenon scientists had received the basic training in their scientific fields outside Hungary. For the most part their scientific output was realized on the international intellectual market. The Hungarian context was manifested rather in their research strategy, their choice of subject, and style than in the scientific content of their results.

In many of their most important results, they could combine the theoretical, mathematical impulses gathered in Budapest with practical mindedness originating from their university studies. The abstract theoretical physicist, Wigner was considered the first nuclear engineer, von Neumann, the mathematician was a pioneer in building computers, Szent-Györgyi, the researcher of biological combustion discovered vitamin C, Oláh, the pioneer of super acid chemistry works on energy cells and, vice versa, the mechanic engineer, Kármán significantly contributed to solid-state physics. The most spectacular activity was the Hungarians' participation in the Manhattan Project aimed at building the first atomic bomb.

In emigration, in particular in Germany around 1920, finding an academic job was virtually impossible because of the competition. Nevertheless, new disciplines and new approaches were born then. Biochemistry, quantum physics, nuclear physics began to emerge. They were more open to anybody, including emigrants, than the classical fields occupied by the highly esteemed local authorities. In addition to their intellectual gifts, their knowledge and love of mathematics helped the Hungarians to work in these new abstract theoretical fields.

Many of them did research in the intersection of different disciplines, such as physical chemistry (Polanyi), quantum chemistry (Wigner, Teller), biophysics (Békésy), biochemistry (Szent-Györgyi), mathematical economy (von Neumann, Harsanyi), nuclear medicine (Hevesy), technical physics (Gábor). They were versatile. They easily changed their successful fields: Polanyi changed from chemistry to philosophy, Wigner from quantum chemistry to nuclear physics, then to solid-state physics, Szilárd from physics to biology, Hevesy from electrochemistry to nuclear biology. They crossed the borders of countries and disciplines with similar ease. When moving from Germany to America or Britain or Denmark, the adaptation to the new circumstances required change in the research work. Flexibility was connected to versatility, with working on several fields.

The advantage of many interests originated from Hungary, from the circles of the intelligentsia constituted by specialists of very different fields and discussing diverse subjects. This kind of discussion requires and educates the ability of problem solving disregarding the field to which the given problem belongs. In this way, their results depended on the problems raised in their actual institutional positions, local scientific communities or, as some of them supposed, the entire contemporary human civilization.

The commitment to the most important matters of humanity, the feeling that they can and they had to save the world is expressed in Szilárd's essay on the "Bund"[21] or in Polanyi's philosophy. Implicitly and sometimes explicitly, this mentality is present in the vivid and visible political activity of the Hungarian phenomenon scientists. Szilárd initiated both the work on nuclear arms and the prohibition of its usage; Wigner designed nuclear reactors that produced the fissionable substance for the bombs and later became active in civil defense. Von Neumann worked as an adviser in Los Alamos, then as a member of US Atom Energy Commission; Teller became the chief designer of the hydrogen bomb. Szent-Györgyi, who left Hungary after the communist takeover in 1947, fought against Nazism in Hungary, while in the USA he became part of the struggle for the peace movement. On the other side, Philip Lenard, a great supporter of Nazism, a founder of the "deutsche Physik" movement, openly expressed his strong anti-Semitic sentiments, although he never joined Hitler's party. In a different time period Dennis Gabor was active in the Roman Club, an early environmentalist movement, Harsanyi gave advice in the diplomatic negotiations between the two superpowers on the limitation of nuclear arms.

The political significance of these Hungarian phenomenon scientists' activity strongly contributed to their fame. They were good communicators of their views as can be verified by watching their performances on television, as well as in long interviews in popular magazines and daily newspapers. The audience could enjoy fervent, witty but very serious political debates between Szilárd and Teller on TV, or discussions of political problems by Szent-Györgyi and Teller in a Chicago radio station. Scientific and political success supported each other. Scientific success could be converted into important political status; thus indicating a shift in the scientists' role in society. The most relevant scientific problems became the most relevant political and moral issues.

Inspiring Screening and Evaluation

From the output point of view, the success of the Hungarian phenomenon scientists was related to the effective screening and evaluating activity conducted by the actual local community. In an evolutionary approach, ideas and results survive only if they are communicated and undergo long screening procedures before they are published. Some scientific communities play central roles in scientific research through their lavish projects, active universities, research institutes, well-equipped laboratories, and libraries, eminent experts, competing research stuff, occupy the position of evaluation. They select what and whom they need or what and whom they refuse. They have their vested interests in being well served by those who want to join. This ideal meritocratic work of the scientific center, in principle, provides a field of competition for scientific production.

The meritocratic character gave the migrating Hungarians better chances for finding their good fortune than in those fields of life in which being embedded in a local culture was more important than in science. Nevertheless, even science cannot work on an ideal universalistic meritocratic basis as its universal character is manifested through local activities and influenced by the interests of the participants. For success, the Hungarians had to establish contacts with the local scientific communities of the country in which they worked. In this, their practice in networking proved to be of great help. Networking means the establishment of non-institutionalized relationships, an activity that intrinsically belonged to the Budapest urban, middle class, intellectual culture, to the main source of their thinking. In emigration they built up two kinds of networks, an insider network for themselves and an outsider network with the larger local scientific community. Both had two central figures: Michael Polanyi and Leo Szilard (however, Kármán, Hevesy and Teller were also outstanding in establishing networks). Through these central networkers, the Hungarians established close personal relationships with the emblematic personalities of twentieth-century science, such as Albert Einstein, Max Planck, Niels Bohr, David Hilbert, Ernst Rutherford, Fritz Haber and many others. Networking helped them in adaptation to the new circumstances, in learning the latest ideas from the authors themselves, in selecting the most promising subjects for their research, in understanding the requirements for success, and it was very useful in finding new jobs, when they had to change homes.

All the Hungarian scientists became successful outside Hungary, not in their own country. Szent-Györgyi was the only one who received the Nobel Prize while working in Hungary. However, he returned to Szeged from a long stay in Cambridge, England a decisive center of biochemistry during that time. He identified himself with G. N. Hopkins' research school and style of thinking; and his research was supported by American foundations, including the Rockefeller Foundation and the Josiah Macy Jr. even during his Szeged years. After the Second World War, Szent-Györgyi emigrated from Hungary. It was Békésy, who had developed his theory of hearing in Hungary, for which he received the Nobel Prize, and who wrote about the advantage of doing research in Hungary, which was after all a quiet and isolated place. He was the exception. Yet, he was also decorated with the Noble Prize as a Harvard professor after leaving Hungary in 1945.[22]

The success achieved in a Western center of science was not due to the personal presence of some Hungarians working there, though this could also play some role. For success, for being selected by the scientific community as an eminent member, one has to work on subjects that the central community considers as the most relevant ones, and the contribution should be extremely significant.

The Manhattan Project was a particularly suitable opportunity to become successful and famous. Its relevance was behind any doubt because it was set up to defeat Nazism and successfully end the war. In this goal politics met science and technological development as they had never met before and exactly as they had met in the minds of the Hungarians. To defeat Nazism, and later Communism, the totalitarian political systems gave opportunities to the Hungarians for saving the world, for being active in the most relevant issues of the whole humankind at their time. They had to use both their theoretical and practical abilities and knowledge, since the problems to be solved raised all kinds of organizational, political, technological, mathematical, physical and chemical problems. Many members of the Hungarian group could cope with such complex tasks. Szilárd and Wigner participated in the design of the first nuclear plant, and then Wigner directed the technological side of the Oak Ridge laboratory, while Szilárd was active in political issues. Teller did research on fusion reactions; von Neumann helped in working out the implosion techniques and recognized the importance of electronic computing. Kármán contributed to the development of aircraft, started missile research in the US, and then became a chief scientific advisor in NATO.

The screening and evaluating processes are easier, if the tasks of the research are clear and the personal contributions to the work of the members of the group, even in an extremely large group, are distinguishable, visible, and well-known. The product speaks for itself. This was the case with Dennis Gabor's holography, a theoretical idea that came to reality with the development of lasers. The same was true with George Hevesy whose radioactive tracer method became part of the standard medical practice following the creation of artificial radioactive isotopes twenty years after Hevesy's purely scientific investigations. George Oláh built up a new chemistry applicable in carbohydrate, including petrol, technology.

For an appreciation these results an effective intellectual market is necessary in the restricted academic and in the wider, business or intellectual, senses of the expression. This was what the Hungarians found in their ever changing locations for research and could not find in Hungary.

Conclusions

A simple model of scientific creativity provided a framework for discussing the assumed special abilities of Hungarian scientists. The statistical argument for the existence of a particular Hungarian form of creativity, which refers to the relatively large number of very successful scientists as compared with the size of the Hungarian population, can be interpreted in two ways. First, we may employ an individualistic, biological, psychological approach, which is related to the genius theory of creativity, implies that the high number should be related to some kind of genetic advantage of the Hungarian population. However, no additional evidence was presented to prove this hypothesis, only the high number of gifted people from around the turn of the nineteenth and twentieth centuries was cited.

Second, in a collective, sociological, cultural approach, called Zeitgeist theory, the statistical argument receives another interpretation. Refusing to assume the presence of any biological event that could enhance the number of gifted people in the Hungarian population above the number given by probabilistic estimation, the Zeitgeist theory focuses on the social conditions that can be favorable, or not favorable, for extremely gifted people to realize their intellectual potential. Success is a more adequate term for analysis then gift, which is individualistic and biological. Zeitgeist approach presumes the presence of a certain number of gifted people in all societies as a fact of probability, and emphasizes the role of social circumstances in the success of these people.

Accordingly, in the twentieth century, Hungary could provide an excellent intellectual input to young people for starting an intellectual career. This input can only be shown in some implicit features of their scientific results because they were trained as scientists outside Hungary, mostly in Germany and Switzerland, or in some cases in Britain. Their thinking style, their selection of fields and subjects, some features of their research strategy, however, were closely related to their Hungarian culture.

The success of the Hungarian phenomenon scientists is measured by their output. For the appreciation of the output, they needed a suitable audience, a meritocratic scientific community, interested and thirsty for the results they could produce. To put their abilities, their problem solving passion, their theoretical and practical inclinations, their political mindedness in motion, a community was necessary. In the lack of this, their abilities would never come to the light. Therefore, a key factor of their success was that they left Hungary to work in a scientific center that could make use of their potential. Even without an anti-Semitic, anti-democratic Horthy regime, or an isolationist communist Rákosi regime, they could not meet the challenge of the Manhattan Project, the project of electronic computers, and many other things, because Hungary never initiated such large projects. Consequently, the Hungarian phenomenon scientists could really use their abilities in scientific centers that could provide the necessary meritocratic scientific life.

Notes

1 Vaclav Smil, "Genius loci: The twentieth century was made in Budapest". *Nature* 409(4) (January 2001): 21.

2 Arthur Koestler, *The Act of Creation*. London: Hutchinson and Co., 1964; George Polya, *How to Solve it: A New Aspect of Mathematical Method*. Princeton, NJ: Princeton University Press, 1945; Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy*. London: Routledge and Kegan, 1958; Imre Lakatos, *Proofs and Refutations: The Logic of Mathematical Discovery*. Cambridge: Cambridge University Press, 1976; Mihály Csikszentmihályi, *Creativity: Flow and the Psychology of Discovery and Invention*. New York: Harper and Collins, 1996.

3 The series: *Reception and Creativity* (series editor Gábor Palló) consists of seven works: *Közelítések a magyar filozófia történetéhez: Magyarország és a modernitás* [Aproximations to the History of Hungarian Philosophy], ed. Béla Mester, László Perecz, *A kreativitás mintázatai: Magyar tudósok, magyar intézmények a modernitás kihívásában* [The Patterns of Creativity: Hungarian Scientists and Institutions in Modernity], ed. Vera Békés, *Átvilágítás: a magyar színház európai kontextusban* [The Hungarian Theater in European Context], ed. Zoltán Imre, *Alkotás és befogadás a magyar nyelv 18. század utáni történetében* [Reception and Creativity in the Post Eighteenth-Century History of the Hungarian Language], written by Gábor Tolcsvai Nagy, *A honi Kopernikusz-recepciótól a magyar Nobel-díjakig*, [From Copernicus' Reception to Nobel Prizes], ed. Gábor Palló, *Teremtő befogadás: Összefüggések, tanulságok* [Creative Reception: Conclusions], ed. Gábor Palló. The full text of all the books can be de downloaded from the Internet: http://zeus.phil-inst.hu/recepcio/.

4 See, e.g., George Marx, *The Voice of the Martians*, Budapest: Akadémiai Kiadó, 1997, and Endre Czeizel, *Tudósok, gének, dilemmák: A magyar származású Nobel-díjasok családfaelemzése*. [Scientists, genes, dilemmas: an analysis of the family trees of the Hungarian Nobel Prize winners]. Budapest: Galenus Kiadó, 2002.

5 Harriet Zuckerman, *Scientific Elite: Nobel Laureates in the United States*. New York–London: The Free Press 1977.

6 Although the list of the uncrowned kings is far from complete, to list scientists who remained in Hungary and became nearly as successful as the listed ones, would be difficult, except some mathematicians.

7 Francis Galton, *Hereditary Genius*, London: Macmillan, 1869; Cesare Lombroso, *The Man of Genius*, Walter Scott, 1891.

8 E. Paul Torrance, *Guiding Creative Talent*. Englewood Cliffs, NJ: Prentice-Hall, 1962, E. Paul Torrance, *Rewarding Creative Behavior; Experiments in Classroom Creativity*, Englewood Cliffs, NJ: Prentice-Hall, 1965.

9 R. J. Sternberg, *The Nature of Creativity*. New York: Cambridge University Press, 1988.

10 See Eysenck's works, e.g., Hans J. Eysenck, *Genius: The Natural History of Creativity*. New York: Cambridge University Press, 1995. Edward De Bono, *Lateral Thinking: Creativity Step by Step*. Harper & Row, 1973.

11 Robert K. Merton, "Singletons and Multiples in Scientific Discovery: A Chapter in the Sociology of Science", In. R. K. Merton, *The Sociology of Science: Theoretical and Empirical Inves-*

tigation. Chicago–London: The University of Chicago Press, 1973. The article was first published in 1961.

12 Dean K. Simonton, "Multiple Discovery and Invention: Zeitgeist, Genius, or Chance?" *Journal of Personality and Social Psychology* 37 (1979): 1603–1616.

13 Dean Keith Simonton, "Creativity as a Secondary Darwinian Process", D. K. Simonton, *Origins of Genius: Darwinian Perspectives on Creativity*. New York: Oxford University Press, 1999.

14 Mihály Csikszentmihályi, *Creativity: Flow and the Psychology of Discovery and Invention*. New York: Harper and Collins, 1996. Csikszentmihályi, *Creativity*... footnote 2.

15 About the problematic implications of the bell curve's application to the human intelligence, see Gould's criticism on Herrnstein and Murray's book (The Bell Curve) in Stephen Jay Gould, *The Mismeasure of Man*.

16 I have written about the Hungarian phenomenon in a Zeitgeist approach in Palló Gábor, *Zsenialitás és korszellem* [Genius and Zeitgeist]. Budapest: Áron Kiadó, 2004.

17 See Reuben Hersh, Vera John-Steiner, "A Visit to Hungarian Mathematics", *The Mathematical Intelligencer* 15 (1993): 13–26.

18 Viktor Starnitzky, "100 éves a Középiskolai Matematikai Lapok", [The Journal of High school Mathematics is 100 years old] *Természet Világa* [The world of nature], 124 (1993/12): 562–569.

19 See Gyula Radnai, "Az Eötvös-verseny centenáriuma" [The Centenary of the Eötvös competition]. *Fizikai Szemle*, 44 (1994): 421–424.

20 Concerning the biographical details, I do not make references in all points. These details are based on a long study. Many details can be read in the published biographies of the Hungarian scientists, the most important among them are as follows: T. E. Allibone, "Dennis Gabor", *Biographical Memoirs of Fellow of the Royal Society,* 1980, 107–147, Stanley A. Blumberg, Gwinn Owens, *Energy and Conflict: The Life and Times of Edward Teller* New York: G. P. Putnam's Sons, 1976, Edward Teller, with Judith Shoolery, *Memoirs: A Twentieth-Century Journey in Science and Politics*. Cambridge, MA: Perseus Publishing, 2001, Th. Kármán, L. Edson, *The Wind and Beyond: Theodore von Kármán Pioneer in Aviation and Pathfinder in Space*. Boston–Toronto: Little, Brown and Co. 1967, W. Lanouette, B. Szilard, *Genius in the Shadows: A Biography of Leo Szilard*. New York–Toronto: Charles Scribner's Sons, Maxwell Macmillan 1992, H. Levi, *George de Hevesy: Life and Work*. Copenhagen: Rhodos, 1985, Siegfried Niesse, *Georg von Hevesy: Wissenschaftler ohne Grenzen*. Dresden: Forschungszentrum Rossendorf, 2005, N. Macrae, *John von Neumann*. New York: Pantheon Books, 1992, R. W. Moss, *Free Radical: Albert Szent-Gyorgyi and the Battle over Vitamin C*. New York: Paragon House Publishers, 1988, George A. Olah, *A Life of Magic Chemistry: Autobiographical Reflections of a Nobel Prize Winner*. New York, etc: John Wiley & Sons, Inc., Publication, 2001, Richard Rhodes, *The Making of the Atomic Bomb*. New York: Simon and Schuster, 1986, Richard Rhodes, *Dark Sun: The Making of the Hydrogen Bomb*. New York, London etc: Simon and Schuster, 1995. A. Szanton, *The Recollections of Eugene P. Wigner*. New York–London: Plenum Press, 1992, E. P. Wigner, "Michael Polanyi", *Biographical Memoirs of the Fellows of the Royal Society*, 23 (1977): 413–448. William T. Scott, Martin X. Moleski, S.J., *Michael Polanyi: Scientist and Philosopher*. Oxford: Oxford University Press, 2005.

21 Leo Szilard, "Der Bund", reprinted in S. R. Weart, G. Weiss Szilard, *Leo Szilard: His Version of the Facts*. London, UK – Cambridge, MA: MIT Press 1978, 23.

22 In his later years in America, Békésy explained his Hungarian experience in a remarkable way. Georg von Békésy, "Some biophysical experiments from fifty years ago", *Annual Review of Physiology* 36 (1974): 1–16. Georg von Békésy, "Success and failure of teamwork in biology and medicine", *Perspectives in Biology and Medicine* 14 (1970): 69–81.