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The Hungarian Gymnasium Education Experience and Its Influence on the Global Power Shift

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Abstract

Starting from the turn of the 19^{th} - 20^{th} century, the Hungarian educational system brought up a number of scientists who became part of the international scientific elite. A number of them, such as Albert Szent-Györgyi, George de Hevesy, Eugene Wigner, George von Békésy, Dennis Gabor, George Olah received the Nobel prize, while others, like Theodore von Kármán, Michael Polanyi, Paul Erdős achieved at least the Nobel level but for some reasons never received the prize. In addition, some of these Hungarian scientists played particularly influential roles in politics of their time. In this paper we analyze the basis of this unprecedented and surprising success and call the attention to at least four major factors: the alma mater, student competitions, networking and immigration to science centers. However, we point out that whatever fruitful this system could be, it did not provide a recipe for schooling or pedagogical or methodological procedures that can surely produce outstanding scientists.

Keywords: talents, education, gymnasium, Nobel Prize, Budapest

Introduction

"The twentieth century was made in Budapest" declared an author, Vaclav Smil, a non-Hungarian unbiased Canadian professor, in Nature in the first year of the third millennium [1]. In this paper we analyze this phenomenon and try to draw some conclusions. The scientific and social role of the "century-making" scientists was partly due to the growing importance of science and technology in politics during their lifetime, partly to their mentality and their historic experiences going back to their youth in Hungary. Their complex scientific, technological and political role was born outside Hungary, mostly in the United States, the scientific center of their time. They left Hungary in their twenties equipped with a basic culture, a basis of their later knowledge, style of thinking, and a skill to solve problems.

The attention to the significance of the Budapest gymnasiums in the 20^{th} century history of science and politics was drawn by Eugene Wigner, a theoretical physicist, in his speech at the Nobel Banquet in Stockholm, December 10, 1963: "What I wish to draw attention to is how much of our interest in science, and how much of our attitude toward science, we owe to our teachers. My own history begins in the high-school in Hungary where my mathematics teacher, Ratz, gave me books to read and evoked in me a sense for the beauty of his subject." [2] Wigner's note was carried on by Norman Macrae, a former American editor of *The Economist*, biographer of John von Neumann, mathematician, a creator of computer: "The early 20th-century Hungarian education system was the most brilliant the world has seen until its close imitator in post-1945 Japan." [3]

The question how Hungary, with its schools, culture, way of living, intellectual attitudes, and politics contributed to the later success of the group of these gifted people is justified, provided that we do not suppose genetic factors in the background. The genetic aspect emerges from the assumption that scientific success is based on the 'genius' of researchers rather than cultural, economic and selection mechanisms. Because this assumption has no empirical basis whatsoever, the complex analysis of the fertile soil in of the 20^{th} century Hungary, and its capital, Budapest, seems to be sufficient to investigate the components of a particular pattern of scientific creativity [4].

Gymnasiums in the flow of history

The relevant historical context is full of paradoxes. One of them was that the school system, including the high schools, the Gymnasiums, was formed by the Habsburg rulers in the mid 19^{th} century, in a depressing period of Hungarian patriotism. Hungary had a history going back to the middle ages. Catholicism was introduced as an official religion in the year of 1000 by King István (Stephen) I. This was the starting point of the history of Hungarian statehood. Although, a large part of the country had been occupied by the Ottoman Empire for about 150 years (1541-1699), later from 1711, Hungary became part of the Habsburg Empire but with its own constitution. In 1918, after the First World War the Habsburg Empire collapsed and, as a consequence of the

Trianon (Paris) peace treaty, Hungary lost two thirds of its territory and population but became independent until the Second World War, when it was first occupied by the Nazi Germany, later by the Soviet Union. After the disintegration of the Soviet system in 1990, Hungary regained its independent status, and then joined the European Union in 2003.

Nationalism and modernization process

Under these political changes a slow but distinctive modernization proceeded, which was connected with building up the Hungarian nation, state and culture.

1. The nationalist movement starting in the late 18th century resulted, among others, in establishing fundamental cultural and scientific institutions, such as the National Museum (in 1802), the National Theatre (in 1837) and the Hungarian Academy of Sciences (in 1825). Modern elements were implanted into the traditional agrarian economy, like industry (first food industry, later others), finance, and trade. Agriculture, the most important branch of economy introduced new technologies and management. This process caused a continuously growing demand to expertise and schooling.

2. Nation building required the modernization of language. At the end of the 18th century a movement started among the educated people to create a Hungarian language usable in all territories of culture, including state administration. Before that Latin and in some areas German was used in high culture while Hungarian was considered a vernacular appropriate to discuss everyday subjects only. The renewal of language, in which the Hungarian Academy of Sciences played a crucial role, was a precondition of developing the school system.

3. The creation of modern nation was accompanied by a gradual sociological change. Industry, trade, building, transportation, finance, services, administration and other economic activities produced a largely but not exclusively urban middle class, different from the traditional rural, agrarian society based on the duality of landlords and peasants, in fact serfs, with very limited rights and education. Middle class was recruited mainly from non-Hungarian elements of the society.

4. Hungary has been a multiethnic society, having thirteen national minorities around the turn of the 19-20th century, including Germans, Slovaks, Greeks, Serbians, Jews, Romanians, Gypsies and others. Some members of ethnic minorities proved more susceptible to the modern economic possibilities than the Hungarians, because they were not pressed into the rigid dual social system. Modernization provided them a good chance to climb up in the social, political ladder. This is the social group to which most of the successful Hungarian scientists' families belonged. Indeed, modernization contributed to a significant social and sociological mobility.

This situation played an important role in the growing tension between the Hungarian and non-Hungarian ethnics. As a result Hungarian nationalism developed two faces: one against the Habsburg rules and another against the national minorities that demanded more civil rights, sometimes even political, cultural autonomies, as their social positions strengthened. As a consequence, Hungarian nationalism became double-faced. Political classes struggled both against the Austrian rule for more national independence and against the national minorities for limiting their aspirations for autonomy.

The struggle against the Habsburg rule combined the endeavor to gain more national independence with the endeavor to reform the law system to secure favorable legal circumstances for the modernization process. In 1848-49, this struggle led to a revolution and a war for national independence (Lajos Kossuth was its emblematic leader) against Austria that was defeated and followed by the absolutist rule of Franz Joseph I. The second face of Hungarian nationalism largely contributed to another defeat manifested in the disintegration of the country after the First World War.

The formation of gymnasiums

Paradoxically, the major school reform that served the success of the Hungarian scientists was implemented during the Habsburg neo-absolutism, which revenged the revolution by executions and long prison sentences of the participants, including Prime minister Count Lajos Batthyány. The suppressive political regime did not respect any Hungarian independence while made all the effort to unify the whole empire. German became the official language, administration was directed in Vienna, and all fields of social and political activity were controlled by the Habsburg government.

The reform of schooling aimed to unify the system of education in the whole empire. In 1849 the emperor signed the document submitted by the Minister of Religion and Education; Count *Leo Thun-Hohenstein* titled *Entwurf der Organisation der Gymnasien und Realschulen in Oesterreich* (Organization Plan for Gymnasiums and Real Schools in Austria). The document described the main intellectual character and organization framework of an education system that was meant to be introduced in all schools of the empire. The reform extended to the universities. In Hungary its elements were gradually introduced in the 1850s, fundamentally influencing the school system for a long period of time, in fact until the present.

The characteristic features of the reform were based on German ideas: the philosopher and pedagogue Johann Friedrich Herbart related to gymnasiums and Wilhelm von Humboldt, scholar, Prussian Minister of education. Unlike the traditional university aiming to educate servants of their states, churches or lords, the new German university (exemplified by the new Berlin university established in 1810), intended to produce free thinkers. They emphasized the importance of scientific research. Professors and students were meant to work together in production of new knowledge. Academic freedom was a basic principle. This was secured by the autonomy of the university, the exclusive right of professors to administer the university and by the students' rights to compose their curriculum. To realize these goals, high schools also had to be reorganized: they had to take over the task of teaching some skills previously taught at the universities. These high schools were called gymnasiums in Germany and its zone of influence; the meaning of the world is about the same as 'lycée' in France or 'grammar school' in Britain. The price of the freedom at the universities was the strict discipline in the gymnasiums, the place of learning basic knowledge. The most modern German educational system was introduced in Hungary by the repressive Austrian power. By this, scientifically, Hungary became part of a scientific network with a German center instead of an Austrian one.

The traditional gymnasiums had six grades, while the new ones had eight, taken over two years from the former universities that provided skills for two years. Gymnasiums were for 10-18 years old boys. Studies were closed by an examination, called maturity, and those who passed received a prestigious certificate. The teachers also had to pass exams certifying their special expertise in teaching the given the subject. To train teachers was a specialty of the system. As far as the curriculum is concerned, the gymnasiums focused on humanistic subjects: literature, history and languages, mainly Latin and Greek, but mathematics and some elements of natural sciences were also included. The gymnasium had to have cabinets for exhibiting experiments to demonstrate natural phenomena. This type of school with its humanistic cultural orientation was elitist. It was certainly not meant to train the general population, not even to mention lower classes.

The *Entwurf* also established a new type of high school, called "real school" consisting of six grades. The curriculum contained natural sciences and modern languages, less history and literature but no classic subjects. This type of school prepared the students for higher scientific and engineering studies.

Austro-Hungarian Monarchy

The new schools fostered modernization by educating modern middle class bourgeoisie, training professionals and civil service experts. This social group gained more space in the unprecedentedly fast growing period of Hungarian history. For complex political reasons, Austria decided to offer more independence to Hungary and more rights in governing the empire. This act was called Compromise and signed in 1867. Relying on the political peace with Austria and on the already active and growing bourgeois middle class, modernization process sped up enormously. As a result of the laissez faire economy, GDP tripled between 1867 and 1913; industry produced 11% of the GDP in 1867 and 25% in 1913; industry employed 10% percent of the population in 1867, while this number grew to 18% by 1913. Simultaneously, the number of employers in agriculture diminished from 76 % to 60% [5]. New capitalism favored competitive mentality rather than traditional rural collectivity. The population of Hungary amounted to 13.2 million in 1850 increasing to 20.7 million by 1910 [6].

This historic period provided favorable circumstances to the families of the famous Hungarian scientists. The family of Philipp Lenard lived on wine trade in Pozsony (now Bratislava). Von Neumann's family was successful in trade, later in banking. Hevesy's family was extremely successful both in the agrarian business and trade on both sides. Wigner's father was a shareholder and director in the Mauthner tannery. Teller's father worked as well-known lawyer. Szilard's father studied engineering and did very well as an entrepreneur in the railway and bridge development business. The Polanyi family and many others had similar history.

These families with many others belonged to the modern middle class started to form in the first part of the 19th century. After 1967, national liberalism provided good opportunities to the growth of this social class with a number of means, including a law, born in 1967, about the emancipation of Jewish religion, which opened the door to these families to all kinds of careers. Simultaneously, many Jewish families, including all the families of the famous scientists, fully assimilated to the Hungarian society. They considered themselves Hungarian with Jewish religion, rather than a separate ethnic group. They used Hungarian language, some of them changed their names to a Hungarian one, some of them left their religion and Christianized, learnt in Hungarian schools, participated in social life, and many of them became very successful in one or another segment of social life. National minorities had more difficulties to integrate into the Austro-Hungarian dual monarchy, and these difficulties constituted an insurmountable centrifugal power working in the country.

In the field of culture and education the progress was as impressive as in economy. Speaking about high schools, in 1883 Thun's system was codified by a law that was submitted by Ágoston Trefort, minister of education. A minor change was that real schools also had eight grades as those of gymnasiums. In 1867 143 gymnasiums and 21 real schools worked, while in 1914 these numbers grew to 195 and 34, respectively. The number of students increased from 36,000 to 78,000 in the same period [7].

Budapest

Most scientists, whose education is analyzed here, were brought up in Budapest, the capital city securing perfect circumstances to ambitious and gifted young people to gain a complex culture and to gain ambitions to contribute. The growth of this city epitomized the vigorous prosperity taking place in Hungary during dualism.

Budapest, in fact, was formed in 1873 from three parts: Buda, Pest and Óbuda. The population of the three parts amounted to 186,000 in 1850, 371,000 in 1880, 880,000 in 1910, 1 million in 1930, and 1,2 million in 1941 [8]. Budapest concentrated modern culture, science and the sectors of capitalist economy, mostly big industry, wholesale trade, and financial system. 20% of industrial workers lived here, while the characteristic urban middle class was recruited from former gentry that lost partly or fully its land, and assimilated or was assimilating (largely German and Jewish) ethnically non-Hungarian population.

This middle class fulfilled all the tasks emerging in a modern city: administration, organization, health, transportation, jurisdiction, press, small business, fashion, services and many other things. National politics and national institutions were also located or directed in Budapest. Ample job opportunities opened to competitive entrepreneurs and experts.

Architecture and the development of the city gave jobs to many people. The fast growth necessitated to build new houses, new streets, and new districts. The characteristic cityscape with wide boulevards, parks, bridges over the Danube, and transportation network was formed out in the few decades around the turn of the 19^{th}-20^{th} century. Emblematic buildings like the Parliament or the Opera house were built then. Museums, theaters, later movies, spas, hotels, café houses and restaurants made the city life vibrant and attractive.

Intellectual life in Budapest was exciting. The Academy of Music was established in 1875 and headed by the composer and pianist Franz Liszt. The new Opera House was opened in 1884, and from 1884 to 1891, it was directed by the composer, Gustav Mahler. In the early 20^{th} century, epoch making masters worked in the Budapest music life, like the composers Béla Bartók, Zoltán Kodály, or conductors George Széll, Antall Doráthy and others. Hungarian culture produced as many world famous musicians as scientists. Literature and theater impacted daily life of the city by new poems, novels and essays published in journals or books, these, however, remained unknown to the world, because they are closed in the Hungarian language. Philosophers, on the other hand, around George Lukács or Karl Mannheim, who organized informal meetings for Budapest intellectuals in private homes, have influenced their fields inside and outside Hungary until the present. The Budapest school of psychoanalysis was the second most active after Sigmund Freud's Viennese circle. Sándor Ferenczi and his colleagues, and students developed original ideas and methods that are used and discussed in the field even today.

In the excited atmosphere of the fast development and changing landscape, technological innovations arrived very fast in Budapest and they raised general interest. Trams started to work, in the streets in 1887; a telephone center (one of the earliest) was in operation already in 1881; some private homes have received electric light since 1893; the first underground metro on the continent started in 1896 (only London had an underground earlier); the beautiful Elisabeth bridge over the Danube was inaugurated in 1903; in 1905 160 private cars run in the streets of Budapest; electric street light has been used since 1909. All this explains that some technical inventions were born in Budapest, e.g. the transformer (Miksa Déri, Ottó Bláthy and Károly Zipernowsky), the electric locomotive (Kálmán Kandó), the telephone technology (Tivadar Puskás), and others. Another inventor, József Galamb, after finding a job in the US, participated in the design of Ford Model T.

Science was also blossoming. New scientific societies were established in that period (Mathematical and Physical Society, Hungarian Chemical Society, etc). Well illustrated, interesting popular scientific journals and books were published and the newspapers transmitted the latest scientific news, such as X-ray, radioactivity, wireless radio, airplane and many other sensations to the wider population. A scientific theater named

Urania worked in Budapest with great success. Popular science was incomparably more modern and more fruitful than academic science.

Budapest became a large European city, a competitor of Vienna or any other famous capitals of the time. Indeed, the culture in Vienna around the turn of the century was also extremely fruitful. Ernst Mach, Ludwig Wittgenstein and the Vienna Circle in philosophy, Freud in psychology, Robert Musil, Arthur Schnizler, Karl Kraus, Joseph Roth in literature, the famous medical school or the Viennese music and opera are more than well-known. All these and many other names and institutions prove that the last decades of the Habsburg empire was exceptionally creative in a wide spectrum of intellectual life, while its thinkers felt the approaching collapse.

Education in Budapest

As expected, Budapest was the seat of the German type school system in Hungary in the period of the Austro-Hungarian Monarchy, and this situation has never changed. However, boys were enrolled to gymnasium at the age of ten. Before that they were taught at home.

Teaching at home

Although an elementary school system worked in Hungary, higher social classes did not send their children to these low level schools. Typically, these children were taught at their homes until their age of ten. Their homes were comfortable, sometimes villa's (in Szilard's case) or big houses (in Neumann and Hevesy's case), or just larger apartments. In these homes pianos and large bookshelves were natural parts of furniture. Neumann's father bought a whole library and kept it a floor of their house. Beautifully bound volumes of Hungarian and German classic authors stood in lines on the shelves. Dennis Gabor accompanied his parents to opera performances, exhibits and other cultural events. The young boy was deeply impressed, as it can be seen from his sketchbook, which he filled with drawings at an age of 8 (see Fig. 1). Maids and cooks served the families and private tutors joined them. Native speaking German, French and English au pair girls helped their education, music teachers came to the houses regularly.

The big advantage of this kind of instruction was that it was accommodated to the developmental stage of the children. It was personal, friendly, and its pace could be tailored according to the inclinations of the children. They learned to read, write, count and also some elements of history, geography, some verses and songs. It was also fashionable to teach some sports to children, like fencing, skating or swimming.

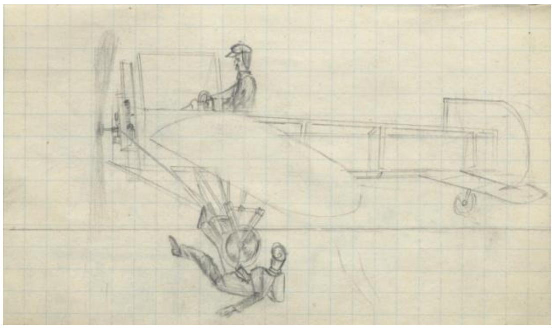


Fig. 1. Drawing of an airplane with the pilot and the technician falling back due to an accident. (From the sketchbook of Dennis Gabor, Library of the Hungarian Academy of Sciences).

Some families had lively social life in their homes. Von Neumann's father liked to give big dinner parties to the family and close friends who represented a strange selection of Budapest intellectuals, including among others psychologist Ferenczi, physicists Rudolf Ortvay, and even Lipót Fejér the legendary professor of many later famous mathematicians. In the house of the Polanyi family an informal intellectual circle worked with informal lectures and discussions with the most fashionable writers and poets, actors, philosophers, psychologists, sociologists but also the later world famous mathematician George Pólya, the founder of heuristics.

Family life itself was inspiring without formal instruction or tutors. In addition, some of these families were in contact in Budapest. For instance Hevesy's friend, Kornél Kőrösy, professor of physiology, father of Ferenc Kőrösy, later professor of chemistry in Israel, was a friend of Teller. They moved to Karlsruhe, Germany, to continue their studies. Kőrösy went to the same dancing school with John von Neumann, and later collaborated with his brother, Michael Neumann. Neumann's father asked for Kármán's advice about the future of his son. This kind of networking became more accented in the later period of life of the famous Hungarian scientists.

Gymnasiums in Budapest

At around the age of 10, the later scientists were enrolled in a Budapest high school, either a gymnasium or a real school. The number of Budapest high schools was 38 in 1914 with around 16,000 students [9]. This number provided a possibility for selection. Many schools were handled by churches, others, including real schools by the state. In harmony with the liberal atmosphere of the economy, politics and culture the gymnasiums enrolled students disregarding their religions. Consequently, the gymnasiums often belonged to one church but their students were mixed related to their religion.

By this time, gymnasiums had crystallized their practice in instruction and they had some individual characters. Some of them were more specialized to literature, others to sciences or languages. Some of them were strict, disciplined, others liberal. Three of them became more famous than the others partly because they are assumed to have produced more world famous people than the others, or because they had longer traditions. These three are the "Fasori" Lutheran Gymnasium, the Minta (Model) Gymnasium and the Piarist gymnasium. However, other schools were at the same level in producing graduates, perhaps not in science, or perhaps not at an international level. For instance, Leo Szilard, an initiator of the atomic bomb project in the USA was a graduate of the VI. District real school, Dennis Gabor, Nobel laureate inventor of holography of the V. district real school, Albert Szent-Györgyi, Nobel Laureate discoverer of vitamin C of Calvinist Gymnasium, and so on.

The elitist character and the effectiveness of the Budapest gymnasiums were related to an almost automatic selection of the students secured by a tuition fee. In a society with very large differences in the financial status of the social classes, the large population could not afford sending their children into expensive institutions. Those families which could afford the fee also could afford home instructors and governesses preparing the children for a high level gymnasium. This kind of selection caused a sort of social homogeneity of the students and later the educated middle class. The churches, the parents and the alumni contributed to funds for supporting needy students and the development of the schools in all ways.

The prominence of the Budapest gymnasiums relied largely on their teachers. The buildings, the cabinets, and the selection of students were significant factors, but as Wigner emphasized in his cited banquet speech in Stockholm, the teachers' influence on their students was the most important among them. Indeed, the Budapest gymnasiums required their teachers to be scientifically active in their fields. This could be afforded because of the sufficient supply of candidates to these jobs, which, on the other hand was related to the scant openings in the academic job market. In spite of the fast progress in many areas, Hungary had one university until 1872, when a new university was established in Kolozsvár, Transylvania (now Cluj, Romania) with a faculty of science while the Budapest University had no special science faculty. In addition, an engineering school worked in Budapest which received the rank of university also in 1872. These German type universities employed a little staff on the state's payroll as civil servants and offered almost no chance for young candidates to receive position. Therefore, the value of a teaching position in an elite high school was high. The schoolteacher of a gymnasium was a prestigious, reasonably paid safe position in which intellectual or scientific contribution was expected and appreciated.

Many of the teachers published articles in popular scientific journals explaining some new scientific ideas, including electricity, theory of relativity, and lot of practical advices based on science, such as the correct handling of wine, the effect of food on health, cleaning, and the like.

Fasori Lutheran Gymnasium

In his speech at the Nobel banquet Wigner referred to the Lutheran gymnasium, which was indeed one of the most successful schools. Its history goes back to the late 18th century, but it reached the level of gymnasium with four grades in 1823. In the 1860s, the gymnasium could meet all the criteria laid down by the *Entwurf*, and it had started to work entirely in the spirit of prescribed by the state from 1895. In 1904, Fasori received its beautiful building existing even today. Besides its 18 classrooms, it had cabinets, six rooms for libraries (with about 12,000 volumes and 20-30 subscribed journals for the teachers, disregarding the separate student library), medical office, photo room, a huge aula, modern heating, electric lighting, and a fitness center and school court for sports. The teachers had comfortable offices and an apartment for the family of the director.

The school was much more than a site to learn. It had a literary society, in which students read and debated their own works to an audience. Their works could, in principle, be poems, historic studies, philosophical assays or papers of new scientific theories about which they read in the popular scientific literature. A student theater, a singing and music society also worked in the gymnasium. In addition the school organized excursions, sport competitions and various outdoor programs.

While Fasori's instruction program was based on the national education program, the personality of teachers secured an individual character to it. Wigner mentioned László Rátz, his teacher of mathematics. Rátz was a graduate of the Pázmány Péter University in Budapest but also studied in Berlin, the scientific center, and in Strasbourg. He worked for Fasori throughout his life, between 1909 and 1914 as its director. Rátz had a significant educator activity outside the school. As a knowledgeable mathematician, he participated in the international reform movement of teaching science and mathematics, initiated among others by Felix Klein, professor of mathematics in Göttingen. His other, even more important activity was that Rátz worked as editor of the High School Journal of Mathematics between 1894 and 1914.

In his classes, Rátz applied the principles of reform mathematics: to consider the subject as part of human culture, to show its connections to daily life. According to various accounts, Rátz had the special ability to draw the attention of the students as a community and not just as individuals. He really liked educating his students. He participated in their excursions and other communal activities; he organized meetings in his favorite coffeehouses with some students and colleagues to discuss all aspects of life as a good Budapest intellectual.

Rátz was very popular among his students and colleagues. He was excellent teacher but not as excellent that he could produce such geniuses as Wigner and von Neumann by his method of training. He recognized the special gift in these young people and helped them develop instead of teaching them. Rátz recognized that they cannot be handled as other students. Wigner received mathematical books from Rátz read them during the classes and outside the school often in Rátz home they discussed the content. Von Neumann was impossible to teach. Rátz helped Neumann to get in contact with university mathematicians such as Gábor Szegő and Mihály Fekete (later they became famous mathematicians) to foster the child Neumann's advancement in science.

Sándor Mikola was the teacher of physics between 1897 and 1935, when he retired. For his excellent experiments made with electricity in the school's cabinet he was elected corresponding member of the Hungarian Academy of Sciences in 1921, member in 1942, but he kept his position in Fasori as a recognized scientist. He has published about the philosophical and historical issues of physics and worked as an editor of Matematikai és Fizikai Lapok (Journal of Mathematics and Physics). Like Rátz, Mikola wrote about the methods of teaching physics and tried to improve these methods throughout his career [10].

János Renner, successor of Rátz and Mikola, started to teach in Fasori in 1911, and became director between 1945 and 1948, a very difficult period after the Second World War. Besides being a popular and effective teacher of mathematics and physics in Fasori gymnasium, Renner, a disciple of Loránd Eötvös, the leading and the only internationally known Hungarian physicist before the First World War, continued his master's investigations in the field of measuring gravitation. As a result Renner, a leading authority of the field, became head of the Institute for Geophysics in Budapest in 1947. His student in the 1930s, Janos Harsanyi, an excellent mathematician, received the Nobel Prize in economy in 1994 for his contribution to the applications of game theory that was created by John von Neumann and Oscar Morgenstern in 1944.

Speaking about the intellectual roots of famous Hungarian scientists, to refer to their science teachers is justified but not necessarily leads to the key of their success. The route to later results is not direct, particularly in the case of very original thinkers. It may well be possible that classic languages, literature, history or the lively discussions among the students and between the students and teachers provided such a precious background to their scientific thinking that helped them even more indirectly than their training in science to which they had special affinities. Fasori had very influential teachers in humanistic fields. Philosopher Károly Böhm, later professor, member of the Hungarian Academy of Sciences taught there between 1873 and 1896, the music teacher of the 1930s, Zoltán Peskó was a well-known organist and musicologist, Dezső Kerecsényi, teacher of literature in the 1930s was invited to be professor at the University of Debrecen. All this shows that Fasori provided a wide range of knowledge to its students, and, in harmony with the mentality of the period, humanistic studies represented the main direction of instruction [11].

The Piarist gymnasium

The other famous school that produced two Nobel Prize winners and many other outstanding intellectuals did not differ fundamentally from Fasori. The Piarist gymnasium was the first high school in Pest. It was established in 1717 to become gradually a typical school of the dual Monarchy by 1883. Since then the school has applied the national standards prescribed by the state in accordance with the *Entwurf*. The Piarist Order was established in the 17th century. Its goal was to open schools for all children disregarding their religion or financial situation and age, meaning that Piarist schools had classes of both elementary and high school levels. The Piarists run schools all over the world. Although they lost their elementary schools in 1948, the Budapest Piarist gymnasium survived state socialism as the only Budapest gymnasium owned and run by a church. During state socialism it had the reputation of being independent of the official Marxist ideology, requiring very hard work and dignified, disciplined behavior of the students.

The Piarist school was located in the Piarist center, a huge beautiful building constructed between 1914 and 1917 in the center of Budapest.

Besides the facilities described in relation to Fasori (library, cabinets, theater, etc.) a neo baroque chapel worked in the house and some shops to rent in the first floor. In addition offices of the Piarist Order were placed in the large building. In 1953 the school was moved to another house in the city, while its own hose was nationalized and given to the faculty of philosophy of the university. The Piarists regained their building and moved back to it in 2011.

George von Hevesy, winner of the 1944 Nobel Prize in chemistry, graduated from the Piarist gymnasium in 1903. He was of Jewish decent whose family converted to the Catholic religion while he was a student, showing that the gymnasium had no discriminative policy in enrollment. Hevesy, unlike his brother Paul, a later ambassador of emperor, Franz Joseph, however, was a private student, meaning that he did not attend the classes but studied at home and had to exams regularly at school.

The other Nobel Laureate student of Piarist gymnasium George Olah, organic chemist, winner of the 1994 chemistry prize, graduated in 1945, an entirely different period from Hevesy's. Olah described his studies in this way: "Emphasis was on broad based education, heavily emphasizing classics, history, languages, liberal arts and even philosophy. The standards were generally high. … We also received a solid education in mathematics, as well as some physics and chemistry. … I particularly remember my physics teacher, Jozsef Öveges. … He was a very inspiring teacher who used simple but ingenious experiments to live up lessons. I must confess that I do not remember my chemistry teacher." [12]. For a while Olah was more interested in humanistic fields than sciences and decided to study chemistry after graduation from the gymnasium, showing that the intellectual sources of later scientific success might be found outside natural science.

The Minta (Model) Gymnasium

The third gymnasium to be described in detail was the youngest and the most important one which differed from the previous ones in two points: it was state owned and ruled and it served the training of teachers. Minta was established in 1872 in the framework of the reform of teacher's training [13]. The name Minta (nickname, means model, the official name changed many times) originates in the second goal: to gain qualification as a teacher, the student was expected to learn how to teach not only what to teach. In Minta students practiced teaching in classes and saw how an excellent school works. Accordingly, some teachers at school parallel taught practicing university students, and students of the gymnasium. After several movements, the school received its own building in 1887. This was far less complete than the houses of Fasori or Piarist Gymnasiums, but it met the basic requirements. Enlargements had to be made, new equipments had to be installed, and it went slowly as the government had budget problems.

Mór Kármán, a young philosopher and educator worked out the system of teacher's training, including Minta as part of the system, based on the German pattern that he studied in Leipzig. For this service, the Emperor ennobled him. His sons graduated from Minta, and one of them, Ferenc, became a teacher of mathematics and physics in Minta. Another son, one of the most successful Hungarian scientists, Theodore von Kármán, airplane engineer, father of supersonic flight, the leader of the first missile program in the USA, gave a vivid description about teaching in Minta. He writes that the special method consisted in "teaching everything by showing its connection with everyday living. In our beginning Latin class, for instance, I remember that we did not start with rules of grammar. Instead we were told to walk around the city and copy the inscriptions on statutes, churches, and museums. … When we had collected the phrases and brought them to class. The teacher asked us which words we already knew. We usually could recognize a few words among the phrases. If we didn't, we looked them up. Then he asked us if we recognized the same word in different forms. Why were the forms different? Because they showed different relationships to other words in the inscription. We continued in this way until we understood each phrase and why it was placed on the monument." [14]. As Kármán explained the same methods was used in teaching mathematics. "Mathematics, which I studied eagerly, was taught in terms of everyday statics. … For instance we looked up the figures of production of wheat in Hungary for several years. We set up tables and then drew graphs, so we could observe the changes and locate the maximum and minimum of wheat production. In the diagrams we searched for correlations and we learned about 'the rate of change,' which brought us to the edge of the calculus. We thus learned in a practical way that there was a relationship between quantities that varied, and, as with Latin, we learned at the same time something of the changing social and economic forces of the country." [15] Another factor was, as Kármán pointed out, the friendly, easy going relationship between pupils and teachers which let them discuss anything in the corridors during the breaks. This was an unusual behavior in the Monarchy then.

The Minta did not produce Nobel Prize winners but it produced a number of very successful intellectuals, politicians, and scientists. Thomas Balogh and Nicholas Kaldor, two economists of Oxford and Cambridge respectively, graduated in Minta in the 1920s, became the foremost economic advisors of the British Labor government in the 1960s. Alfred Rényi and Peter Lax mathematicians (Lax, a collaborator of von Neumann, lives in the USA), Michael Polanyi, physical chemist, philosopher, professor in Berlin and Manchester, Nicholas Kurti, low temperature physicist, FRS, Vice President of the Royal Society, professor in Oxford and, Edward Teller, theoretical physicist, the father of hydrogen bomb were also Minta graduates.

Unlike Kármán, Teller remembered that the "school was not academically stimulating. Students were required to participate but there was little enthusiasm for learning. The teachers were unenthusiastic; most classrooms were in semi-revolt. There was no real interest or exchange of ideas." [16]

Extracurricular activities

Teller's dissatisfaction points at a problem of the Budapest gymnasiums. Whatever excellent these schools might have been, they could not cope with impossible task of teaching extremely gifted pupils. Only Wigner and Kármán spoke with enthusiasm about their gymnasiums, but Kármán's case was not typical because he had a special family tie with the Minta. Wigner liked Rátz very much because Rátz gave him mathematical books to read while the other students were sweating to solve mathematical problems that were too easy and boring to him. Von Neumann received higher level mathematical teachers (Szego and Fekete) than those worked in Fasori. Hevesy, as a private student, did not attend the classes, and Olah was not enthusiastic about chemistry in Piarist gymnasium either. Thus, from the high level of teaching science in gymnasiums, the later scientific success cannot be derived. The schools provided general culture, outlines of contemporary science, urge to work hard, and commitment to intellectual values to these extremely gifted young people and by this the gymnasiums helped them to find their own ways in particular scientific fields.

There were three factors that directly contributed to the success of the famous Hungarian scientists: a mathematical tradition, the Mathematics Journal for High Schools, and the student competitions.

Mathematical tradition

Both the Journal and the competition were related to an increasing interest in mathematics, belonging to the many sided intellectual boom born in Budapest around the end of the 19th century. The boom started at the Technical University, with professors Gustav Rados, József Kürschák and Dénes König, the latter collaborated with Mór Kármán, the architect of modern Hungarian high schools. They established a long-lasting mathematical tradition continuing to the present. At the beginning of the 20th century, Lipót Fejér, professor of mathematics at the Pázmány Péter University in Budapest influenced a surprisingly wide circle of Hungarian intellectuals, inside and outside the circle of professional mathematicians, including John von Neumann, Manó Beke, George Polya, Gábor Szego, Alfréd Haar, Frigyes, Riesz, Béla Szőkefalvi, Paul Erdos, Pál Turán, Alfréd Rényi or László Lovász (winner of the 1999 Wolf prize, the greatest distinction in mathematics) to mention just a few as parts of this tradition. Mathematics in Hungary has been the most creative field of science. It produced the greatest number of internationally and nationally appreciated authorities [17].

Mathematics divided and divides the population into two parts: those who love it and those who do not. In Hungary, the first part, though a minority compared with the second group, has been large for a long time. The adherents of mathematics have liked to compete in solving problems in general. This has been the source of the popularity of the student competition and the journal.

The Eötvös competition

One of the leading persons of the field was Gyula König, at whose initiative the Mathematical and Physical Society announced a student competition for the graduating high school students in 1894. Theodore von Kármán offered a description of the competition: "Selected students were kept in a closed room and given difficult mathematics problems, which demanded creative and even daring thinking. The teacher of the pupil who won the prize would gain great distinction, so the competition was keen and teachers worked hard to prepare their best students. I tried out for this prize against students of great attainments, and to my delight I managed to win. Now, I note that more than half of all the famous expatriate Hungarian scientists, and almost all the well-known ones in the United States, have won this prize." [18] It was called Eötvös prize, and the competition was also named after Eötvös, the president of the Society. With similar procedure physics student competition was established in 1916, which also received the name of Eötvös in 1925.

Among the winners many later successful scientists can be seen, including Theodor von Kármán, Lipót Fejér, Edward Teller, Leo Szilard and others but some of them, such as von Neumann or Wigner are missing. The reason is that for three years after the First World War (1919, 1920, and 1921) the competitions were not held. The winners were proud of their results throughout their life, disregarding their later greater success. Teller accounted on the competition in his Memoirs, mentioning that he won two prizes: physics prize individually and shared the mathematics prize with Laszlo Tisza, later professor of physics at MIT [19].

Mathematics Journal for High Schools

In 1894, Dániel Arany, teacher of mathematics in the real school of Győr, a town in Western Hungary, founded the mathematical journal for students. In two years he passed the position of editor to László Rátz, teacher of Fasori who edited the journal until 1914. After the war, its publication restarted with a new editor and with the inclusion of the field of physics. The journal has been working to the present.

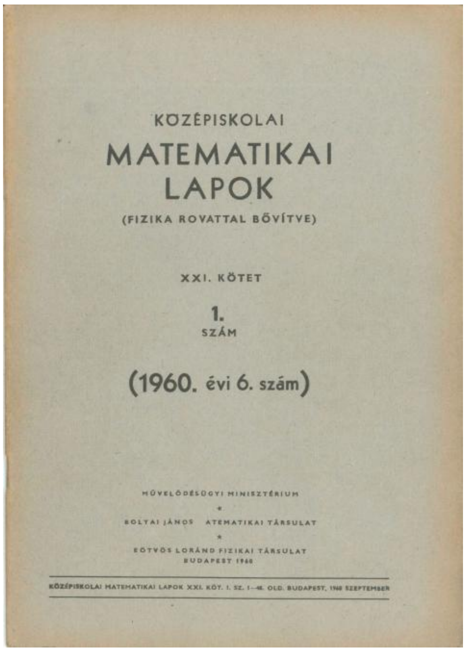


Fig. 2.Title page of the *Mathematics Journal for High Schools* from 1960.

The math journal published articles of interest, difficult mathematical (later also physical) problems to be solved by students of different age groups, and the most elegant solutions with the name of the sender. The solutions had to be sent to the editors who gave points to the senders according to the correctness and elegance of their solutions. The points were added up and the best problem solvers were honored [20].

Gradually the journal spread all over the country, as a great number of students felt to be challenged by the difficult problems, and they have been proud seeing their own names in the journal. To collect the problems, read the student's letters, and writing articles has been a huge amount of work. By 1914, 2,415 numbered problems were published to the 17-18 years old students. The problems constituted a valuable collection of mathematical problems which could be used for practicing mathematical problem solving by interested people. Rátz edited a two volumes of the problems published in the first ten years; Wigner returned to them when he felt tired and needed relaxation even in his old age.

Emigration waves and problematic continuity

Collapse after the First World War

The laissez faire culture, economy and social, cultural life ended with the collapse of the Austro-Hungarian dual Monarchy. The defeat in the First World War and the Paris peace treaty had devastating consequences to the country. Economic collapse, scarcity of basic commodities, the occupation of the Romanian army, and many other factors lead to revolutions, including a communist one that resulted in a short lived Soviet republic, then the right wing or extreme right retaliations, flaring anti-Semitism (including a *numerus clausus* law limiting the enrollment of Jewish students to universities), and other concomitant factors showed a hopeless chaos. This was the time of a mass emigration.

Many of the famous Hungarian scientists left Hungary, such as von Kármán, Hevesy, Polanyi, Szilard, Wigner, von Neumann, Teller, and others. They understood the unpromising future in Hungary (although two new universities were established in 1912) and also felt the attraction of the scientific life in Berlin. To learn from or work with Planck, Einstein, von Laue, Haber, Hilbert and many other German professors appeared an irresistible chance to success to them. In Germany they joined the most modern branches of mathematics, physics or physical chemistry.

Interwar period

Hungary needed a stabilization process of lasting at least five years to find its way under the new inter- and intra-national circumstances. The ten-year-long consolidation process ended and collapsed with the economic crisis starting at the end of the 1920s. At the end the period, Hungarian economy reached the prewar level but the vivid flamboyant life of the dual Monarchy never returned.

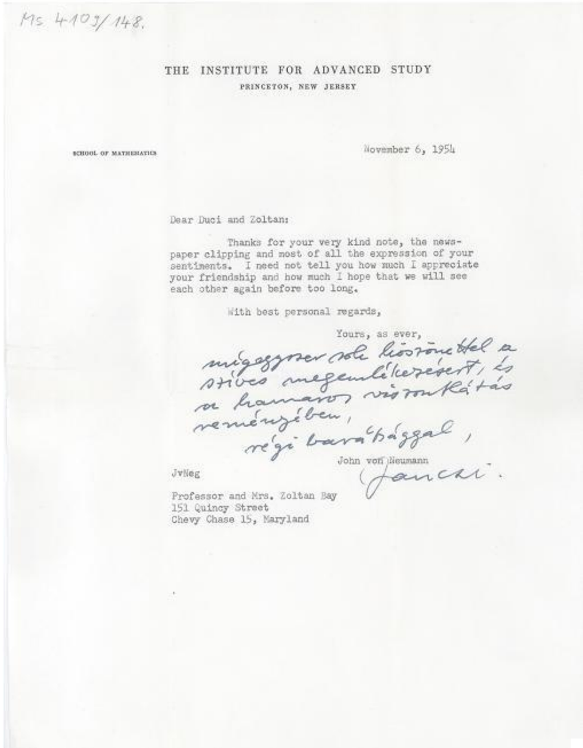
The gymnasiums continued to operate on the basis of the old principles, besides the limitation of anti-Semitic discrimination, including the *numerus clausus* law that penetrated the whole education system in the whole period. Yet, the schools could produce two later Nobel Laureates, George Olah, and Janos Harsanyi. Kuno Klebelsberg, minister of religion and education could secure an unprecedented state support for education and science. He introduced science policy in Hungary with the horizon of an organized scientific life, new laboratories, and new institutions. Albert Szent-Györgyi returned from Cambridge to the newly established University of Szeged and received his Nobel Prize while working there. In the Szeged University a remarkable local scientific center was formed in mathematics and medicine but also in physics based on Zoltán Bay, a young professor. Georg von Békésy, physicist, winner of the 1961 medical Nobel Prize for his results on the mechanism of hearing, unlike all the other famous Hungarian scientists, went to school outside Hungary, in Switzerland, and returned after the First World War

However, as a result of the world-economic crisis, Hungarian politics and culture gradually turned towards radical rightist politics, including an alliance with the Nazis Germany in the hope to regain the lost territories. In 1941 Hungary entered and remained in the war on the German side. As a result, the Soviet Army occupied the country in 1945. Hungary lost about one million people (around 450,000 victims of the Holocaust among them) and 40% of its national wealth.

By that time, however, many of the mentioned famous Hungarian scientists fled from Nazi Germany for the United States. On Szilard’s initiative, the USA started a nuclear bomb project. He, Wigner, Teller and von Neumann became part of the research and development. Kármán, as a general, contributed to the development of the US air force, later space technology. They constituted a visible group in the American science, and they became famous and influential.

State socialist period

After a short period between 1945 and 1948, a Soviet type communist administration operated in Hungary. Before its introduction, a new wave of emigration was formed. Among others Békésy, Szent-Györgyi, his friend in Szeged, Zoltán Bay and Harsanyi left Hungary for America, the new scientific center after Germany. They maintained and established lively contacts with each other and with the older generation of Hungarian scientists (see e.g. Fig. 3). Some, however, remained, like János Szentágothai, central figure of the world-class Hungarian brain research school.



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THE INSTITUTE FOR ADVANCED STUDY
PRINCETON, NEW JERSEY

SCHOOL OF MATHEMATICS

November 6, 1954

Dear Duci and Zoltan:

Thanks for your very kind note, the newspaper clipping and most of all the expression of your sentiments. I need not tell you how much I appreciate your friendship and how much I hope that we will see each other again before too long.

With best personal regards,

Yours, as ever,

még egyszer sok köszönettel a szíves megemlékezésért, és a hamaros viszontlátás reményében, régi barátsággal,

John von Neumann

Jancsi.

JvN:eg

Professor and Mrs. Zoltan Bay
151 Quincy Street
Chevy Chase 15, Maryland

Fig. 3. A letter from John von Neumann to Zoltán Bay. The Hungarian insert in English: once more many thanks for the kind remembering, and in the hope of seeing you soon, with the old friendship, Jancsi (Johnny). (From the collection of the Library of the Hungarian Academy of Sciences).

Because of the iron curtain, there was neither emigration from Hungary nor much contact between the Hungarian scientific society and the eminent Hungarian scientists living in America in the l950s. Hungarian science became part of a new world-science centered in Moscow, and its relations with the Western science became loose.

Paradoxically, during the Stalinist dictatorship in Hungary, an unprecedented statistical growth began in science. The communist state established a network of new scientific research institutes under the management of the Hungarian Academy of Sciences, many research positions were opened in all fields but mainly in natural sciences, the number of university students grew fast and the departments at the universities could secure new tenured faculties, mostly young people. However, after the defeat of the revolution against the Soviet political dictatorship lots of Hungarians emigrated from Hungary for fear of deterioration because of their participation in the revolution, or for the desire to live in Western democracy providing better opportunities in various activities, including science. George Olah, already a successful organic chemist in Budapest, left Hungary and completed his chemistry studies in America, for which he received the chemistry Nobel Prize in 1994. Similarly, Gábor Somorjai also left Hungary after the revolution and became a world class chemist in Berkely. He was decorated with the Wolf Prize in chemistry in 1998.

From the mid-1960s, Hungary's cultural and political isolation has relieved, some leaks emerged in the iron curtain through which a slowly growing number of scientists could travel to the West. They established new contacts, collaborated with Western colleagues, and helped Hungarian scientific community to join the non-Soviet scientific world. In this situation, the infrastructure built up in the Stalinist period proved to be useful. Science in Hungary started to produce internationally appreciated results in the fields of mathematics, physics, chemistry, and also in medical sciences.

This process was fostered by the famous Hungarians living in the West. From the early 1970s, some of the famous Hungarian scientists, such as Wigner, Dennis Gabor, Albert Szent-Györgyi regularly visited Hungary and gave long interviews to the media, met colleagues and delivered lectures to the scientific community. After the collapse of the Soviet-type state socialism, almost all of those who were still alive, including Teller, Harsanyi and Olah, regularly visited Hungary and reintegrated into the Hungarian scientific life. Simultaneously, they helped Hungarian science and Hungarian scientists reintegrate into global science [21].

Continuity

During all these politically, culturally and economically radically changing periods education could preserve its high level in Hungary. Except Fasori, the gymnasiums survived. Sometimes they changed their names and characters but they worked. Perhaps, their intellectual level was not as high as at the beginning of the 20th century, at the peak of their history. The slow decline was a consequence of many factors, mainly the changing political, economic, and intellectual context, and the fast growth of the number of the students. Some gymnasiums, however, could preserve their somewhat intellectually elitist character. Moreover, new gymnasiums joined the old ones, such as Mihály Fazekas Gymnasium (established in 1948) that has been producing outstanding scientists, mainly mathematicians, such as Laszlo Lovász.

The student competition grew to a large system of competitions at all levels of teaching and all geographic and many intellectual areas of the country. In the last decades the student competitions gained an international character with organizations such as the student Olympic Games in various fields. Hungarian students have achieved good results for a long time.

The High School Journal of Mathematics and Physics is still alive with its old popularity and attraction to young people interested in problem solving. New gifted people are continuously growing up in this system, perhaps not at the scale of Wigner or von Neumann, but certainly at an international level.

Concluding remarks

The long history of the Hungarian education system shows that gymnasiums can be effective means for producing very good scientists and intellectuals but not in a direct way. Whatever fruitful this system was at the beginning of the 20th century, it does not provide a recipe for a system of schools or pedagogical or methodological procedures that can surely produce outstanding scientists.

Three points can certainly be concluded from this history. Firstly, buildup of a system of gymnasiums depends on the requirements of the society. A fast growing society produces an ambitious class of people, eager to success in intellectual fields. If the education system meets the demand of this class, as it did in the Austro-Hungarian Monarchy, the interrelationship between the demand of this class and the school might lead to the excellent results. The precondition is the support of the surrounding culture and politics.

Secondly, the gymnasiums were important factors in the success of Hungarian scientists but the surroundings contributed greatly. The lively culture, the competitive and cooperative spirit of the society, the families, the student competitions, and the appreciation of excellence combined with a feeling of uncertainty about the future contributed a lot to the unique success of Hungary in nurturing many famous scientists.

Finally, these scientists could not reach such a high level on the scientific periphery. They immigrated to the scientific centers of their time, first to Germany, later to the United States, in which they could collaborate with the leading experts of their fields and in which all material and personal conditions served their ambitious work.

Appendix: Some World-Class Hungarian Scientists and Inventors of the 20th Century [22, 23]

Bay *Zoltán (Zoltán Bay)*
Physicist, born: Gyulavári, 1900; died: Washington, 1992. High school: Presbyterian gymnasium (Debrecen), higher education and Ph. D.: Pázmány

Péter University (Budapest). Studies abroad: 1926-30, Collegium Hungaricum (Berlin).
Positions: professor of theoretical physics 1930-6 (Ferencz József University, Szeged), director of laboratory 1936-48 (Tungsram light bulb company, Budapest), professor of physics 1938-48 (József Nádor Technical University, Budapest), professor of experimental physics 1948-55 (University of Washington), head of laboratory 1955-72 (U.S. National Bureau of Standards, Washington), professor of physics 1972-92 (American University, Washington).
Results: several patents in the field of high voltage gas discharge tubes, fluorescent and vacuum tubes; first observation of the reflection of radar beams from the moon in 1946, elaboration of the method of fast atom counting, operating on the principle of secondary electron multiplication; experimental justification of the validity of the universal system of measuring time and length based on the speed of light.
Awards: Boyden Prize, Lincoln Prize.

Békésy *György (Georg von Békésy)* [24]
Biophysicist, born: Budapest, 1899; died: Honolulu, 1972. High school: Werbőczi gymnasium (Budapest) schools in Constantinople, Munich and Zürich, higher education: University of Berne, Ph. D.: Pázmány Péter University (Budapest).
Positions: engineer, 1924-46 (Hungarian Telephone and Post Office Laboratory), professor of experimental physics 1939-1946 (Pázmány Péter University, Budapest), physicist 1926-27 (Siemens-Halske research laboratory, Berlin), professor of physics 1934-46 (Pázmány Péter University, Budapest), visiting scientist 1946-49 (Karolinska Institute, Stockholm), research fellow 1949-1966 (Harvard University, Cambridge, MA), professor of experimental physics 1966-1972 (University of Hawaii, Honolulu).
Results: development of anatomical techniques allowing rapid, nondestructive dissection of the cochlea; development of a new type of audiometer; development of a mechanical model of the inner ear with nerve supply, design of the acoustic setup of the Hungarian broadcasting system.
Awards: Nobel Prize, Gold Medal (American Acoustic Society).

Eötvös *Loránd (Lorand Eotvos)* [25]
Physicist, born: Pest, 1848; died: Budapest, 1919. Higher education: Budapest University, University of Heidelberg, University of Königsberg, PhD.: University of Heidelberg.
Positions: assistant professor 1871-2 (Budapest University), professor of physics 1872-94 and 1896-1919, rector 1891-2 (Budapest University), president of the High Court 1881-93 (Hungarian Parliament), minister of religion and education 1894-5, president 1889-1905 (Hungarian Academy of Sciences).
Results: derivation of the Eötvös law of capillarity, construction of the Eötvös pendulum, a torsion balance, which was used to prove the equivalence of the inertial mass and the gravitational mass accurately. Foundation of an elite college named after his father.
Awards: Benecke prize of the Göttingen learned society.

Erdős *Pál (Paul Erdős)* [26]
Mathematician, born: Budapest, 1913; died: Warsaw, 1996. High school: Tavaszmező street gymnasium, Szent István gymnasium (Budapest), higher education and Ph. D.: Pázmány Péter University (Budapest).
Positions: scholarship 1934-38 (Manchester University), scholarship 1939-1946 (Princeton University), from 1955 regularly in Hungary, research fellow 1962-93 (Mathematical Research Institute of the Hungarian Academy of Sciences, Budapest), continuous traveling from campus to campus.
Results: 1,525 mathematical articles, mostly with his 511 coauthors, numerous contributions to number theory, combinatorics, probability, set theory and mathematical analysis; development of the theory of random graphs (with A. Rényi) as well as the Ramsey theory, application of the probabilistic method, elementary proof for the prime number theorem, first example of a totally disconnected topological space that is not zero-dimensional.
Awards: Wolf Prize, Cole Prize.

Gábor *Dénes (Dennis Gabor)* [27]
Physicist, born: Budapest, 1900; died: London, 1979. High school: Vth District real school (Budapest), higher education: József Nádor Technical University (Budapest) and Technische Hochschule (Berlin), Ph. D.: Technische Hochschule (Berlin).
Positions: research engineer 1927-32 (Siemens and Halske, Siemensstadt), research engineer 1932-33 (Siemens-Reiniger-Velfa, Erlangen), research engineer 1933-34 (Tungsram light bulb company, Budapest), research engineer 1934-49 (British Thomson Houston, Rugby), associate professor 1949-58 (Imperial College, London), professor of applied physics 1958-67 (Imperial College, London), senior research fellow 1967-79 (Imperial College, London).
Results: invention of the principles of holography, production of the first hologram by laser light, theoretical foundation of re-holography, near hundred patents on information technology, optics,

nuclear physics and other fields. Member of the Club of Rome wrote the book *Inventing the Future*, dealing with the present and future problems of mankind.
Awards: Nobel Prize, Michelson Medal, Rumford Medal.

Galamb *József (Joseph A. Galamb)* [28]
Mechanical engineer, born: Makó, 1881; died: Detroit, 1955. Higher education: Industrial Technology Engineering Course (Budapest).
Positions: draftsman 1899 (Steel Engineering Factory, Diósgyőr), skilled worker 1903 (Adler Automobile Company, Frankfurt), toolmaker 1904 (Westinghouse Corporation, Pittsburgh), carburetor maker 1904 (Stearns Automobile Company, Cleveland), designer 1905, chief designer 1908, head of the engineering department 1919, chief constructor 1937 (Ford Motor Company, Detroit).
Results: redesigning of the cooling system for Ford Model N, design of Ford Model T (with H. Ford, C. H. Wills and J. Farkas), design of the Liberty aircraft engine, design of the Fordson tractor, organization and design of the conveyor belt system.

Harsányi *János (John C. Harsányi)*
Economist, born: Budapest, 1920; died: Berkeley, 2000. High school: Fasori Lutheran gymnasium (Budapest), higher education in pharmacology, Pázmány Péter University (Budapest), in sociology, philosophy and psychology, Pázmány Péter University (Budapest), in economics (Sydney University), Ph.D.: Stanford University (Palo Alto).
Positions: pharmacist 1944-6 (family drugstore, Budapest), assistant professor in sociology 1947-8 (Pázmány Péter University, Budapest), pharmacist 1948-50 (Budapest), factory worker 1950-4 (Sydney), lecturer 1954-6 (Brisbane University), guest professor 1958 (Stanford University, Palo Alto), professor of economics 1959-61 (Australian National University, Canberra), professor of economics 1961-3 (Wayne State University, Detroit), professor of economics 1964-90 (University of California, Berkeley), professor emeritus 1990-2000 (University of California, Berkeley).
Results: mathematical economy, ethics, science philosophy, game theory and its application to economics, analysis of games of incomplete information (Bayesian games), advisor of the United States Arms Control and Disarmament Agency.
Awards: Nobel Prize.

Hevesy *György (George C. von Hevesy)* [29]
Chemist, born: Budapest, 1885; died: Freiburg, 1966. High school: Piarista gymnasium (Budapest), higher education: University of Budapest, University of Freiburg, Ph. D.: University of Freiburg.
Positions: assistant professor 1908 (Eidgenössische Technische Hochscule, Zürich), visiting scientist 1909-11 (University of Karlsruhe), visiting scientist 1911-3 (University of Manchester), associate professor 1913-8, professor 1918-20 (Budapest University), research fellow 1920-6 (University of Copenhagen), professor of physical chemistry 1926-35 (University of Freiburg), research fellow 1935-43 (University of Copenhagen), professor of chemistry 1943-66 (University of Stockholm).
Results: discovery of hafnium (with Dirk Coster), development of the X-ray florescence analytical method, discovery of the samarium alpha-ray, development of the use of radioactive isotopes as indicators in molecular processes, foundation of nuclear medicine.
Awards: Nobel Prize, Copley Medal, Faraday Medal.

Kandó *Kálmán (Kálmán Kandó)* [30]
Mechanical engineer, born: Pest, 1869; died: Budapest, 1931. High school: Fasori Lutheran gymnasium (Budapest), higher education: József Nádor Technical University (Budapest).
Positions: engineer 1893-94 (Companie de Féres Lille, Paris), engineer 1894-95 (Ganz Works, Budapest), department head 1895-97 (Ganz Works, Budapest), deputy director 1897-1906 (Ganz Works, Budapest), vice president 1907-15 (Italian Westinghouse Company, Vado Ligure), director 1917-19, director general 1919-23, consultant 1923-31 (Ganz Danubius Works, Budapest).
Results: electric train system using electricity from public networks, development of a rotary phase converter suitable for locomotive usage, development of high-voltage three phase alternating current motors and generators for electric locomotives.
Award: Corvin medal.

Kármán *Tódor (Theodore von Kármán)* [31]
Mechanical engineer, born: Budapest, 1881; died: Aachen, 1963. High school: Trefort street Minta gymnasium (Budapest), higher education: József Nádor Technical University (Budapest), Ph.D.: University of Göttingen.
Positions: assistant professor 1904-6 József Nádor Technical University (Budapest), assistant professor 1908-12 (University of Göttingen), director 1912-30 (Aeronautical Institute, Rhein-Westphalische Technische Hochschule, Aachen), director 1930-44 (Guggenheim Aeronautical Laboratory, California Institute of Technology, Pasadena), founder 1936 (Aerojet company, Pasadena), founder 1944 (Jet Propulsion Laboratory, Pasadena), consultant 1944-

9 (US Air Force), retired 1949 (Paris).
Results: mathematical theory of fluid flow, contribution to the design of modern jet aircrafts, studies on non-elastic buckling, unsteady wakes in circum-cylinder flow, stability of laminar flow, turbulence, airfoils in steady and unsteady flow, boundary layers, and supersonic aerodynamics.
Awards: Freedom Medal, National Medal of Science, Gauss Medal

Lénárd *Fülöp (Phillip E.A. Lenard)* [32]
Physicist, born: Pozsony 1862; died: Messelhausen 1947. High school: Royal Hungarian Gymnasium (Pozsony), Higher education: Pázmány Péter University (Budapest), University of Heidelberg, Ph. D.: University of Heidelberg.
Positions: demonstrator 1887 (Pázmány Péter University, Budapest), assistant professor 1887-92 (University of Heidelberg), associate professor 1892-4 (University of Bonn), professor of physics 1894-5 (University of Breslau), associate professor 1895-6 (Rhein-Westphalische Technische Hochschule, Aachen), professor of physics 1896-8 (University of Heidelberg), director of the institute of physics 1898-1907 (University of Kiel), director of the institute of physics 1907-31 (University of Heidelberg), professor emeritus 1931-45 (University of Heidelberg).
Results: studies on cathode rays, design of the Lenard window (aluminum foil on the x-ray tube), discovery of the basic law of photoelectric effect. Proponent of "deutsche Physik", a Nazi movement in science.
Awards: Nobel Prize, Rumford Medal.

Lovász *László (László Lovász)*
Mathematician, born: Budapest, 1948. High school: Fazekas Gymnasium (Budapest), higher education: Eötvös Loránd University (Budapest), Ph.D.: Eötvös Loránd University (Budapest).
Positions: senior research fellow 1971-5 (Eötvös Loránd University, Budapest), professor of mathematics 1975-82 (József Attila University, Szeged), visiting professor 1972-3 (Vanderbilt University, Nashville), visiting professor 1978-9 (University of Waterloo), professor of mathematics 1982- (Eötvös Loránd University, Budapest), visiting professor 1984-5 (University of Bonn), visiting professor 1987- (Princeton University), visiting professor 1993-99 (Yale University, New Haven).
Results: several theorems in combinatorics and computer sciences. Proof of the weak, perfect graph conjecture and the Kneser graph conjecture, elaboration of the alpha-critical graph theory, solution of the Shannon pentagon, construction of the Lovász local lemma, Lovász basic reduction algorithm, the Lenstra-Lenstra-Lovász algorithm and the elaboration of the algorithmic theory of convex bodies and grids.
Awards: Wolf Prize, Kyoto Prize.

Mikola *Sándor (Sandor Mikola)* [33]
Physicist, born: Felsőpetrócz (Hungary), 1871, died: Nagykanizsa, 1945. High school: Lutheran High School (Sopron), higher education: Budapest University.
Positions: first substitute teacher 1897-8, tenured teacher 1898-1935, principal 1928-35 (Lutheran High School Budapest), secretary 1916-23 (Mathematikai és Fizikai Társulat, Mathematical and Physical Society), member 1921-36 (Országos Közoktatási Tanács, National Council for Education), member 1922-45 (Hungarian Academy of Sciences), member 1943-4 (upper house of the Hungarian Parliament).
Results: educated Eugene Wigner and John von Neumann, inventor of the Mikola tube for the demonstration of uniform linear motion, results on the polarization of dielectrics.

Neumann *János (John von Neumann)* [34]
Mathematician, born: Budapest, 1903; died: Washington, 1957. High school: Fasori Lutheran gymnasium (Budapest), higher education in chemical engineering: Eidgenössische Technische Hochschule, Zürich, Ph.D. in mathematics: Pázmány Péter University (Budapest).
Positions: associate professor 1926-30 (University of Berlin), professor of mathematics 1930-57 (Princeton University, one of the first four people selected for the faculty of the Institute for Advanced Study, member 1941-55 (Navy Bureau of Ordnance), consultant 1943-55 (Los Alamos Scientific Laboratory), member 1950-5 (Armed Forces Special Weapons Project), member 1954-7 (Atomic Energy Commission).
Results: contributions to the axiomatic system of the theory of sets, laying axioms of quantum theory, formulation of the theory of games and economic behavior, fundamental contributions to mathematical statistics, participation in the Manhattan Project, contribution to the development of the Monte Carlo method, basic results in computer science, laying the basis of computer design.
Awards: Freedom Prize, Fermi Prize, Einstein Medal.

Oláh *György (George A. Olah)* [12]
Chemist, born: Budapest, 1927. High school: Piarista gymnasium (Budapest), higher education: Budapest Technical University, Ph.D.: Hungarian Academy of Sciences (Budapest).
Positions: associate professor 1949-54 (Budapest

Technical University), deputy director 1954-6 (Central Research Institute of Chemistry, Hungarian Academy of Sciences, Budapest), chemist 1957-64 (Dow Chemical Canadian subsidiaries, Sarnia), chemist 1964-5 (Dow Eastern Research Laboratories, Framingham, MA), professor of chemistry 1965-77 (Case Western reserve University, Cleveland), professor of chemistry and director 1977- (Loker Institute, University of Southern California, Loas Angeles).
Results: observation of stable carbocations in chemical reactions, elaboration of the theory of superacids, new chemical reactions involving hydrocarbons, activation of carbon-hydrogen and carbon-carbon bonds, foundation of a new economy, in which methanol replaces fossil fuels in many aspects.
Awards: Nobel Prize, Humboldt Prize, Cope Medal.

Polányi *Mihály (Michael Polanyi)* [35]
Chemist and philosopher, born: Budapest, 1891; died: Oxford, 1976. High school: Trefort street Minta gymnasium (Budapest), higher education: Pázmány Péter University (Budapest), Technische Hochschule Karlsruhe, Ph.D.: Budapest University.
Positions: research fellow 1923-33 (Kaiser Wilhelm Institut for Fibre Research, Berlin), head of section 1923-33, (Institute for Physical Chemistry and Electrochemistry, Berlin), associate professor 1923 (Technische Hochschule, Berlin), professor of physical chemistry 1933-58 (University of Manchester), senior research fellow 1958-76 (Merton College, Oxford).
Results: formulation of the transition-state theory of chemical reactions, work on the adsorption of gases at solid surfaces, X-ray diffraction and plastic deformation, several books on the philosophy of science, the theory of knowledge and the critique of reductionism.

Rátz *László (Laszlo Ratz)* [36]
Mathematician, born: Sopron, 1863; died: Budapest, 1930. High school: Lutheran High School (Sopron), higher education: Budapest University, University of Berlin, University of Strasbourg.
Positions: first substitute teacher 1890-2, tenured teacher 1892-1925, principal 1909-14 (Lutheran High School, Budapest).
Results: educated Eugene Wigner and John von Neumann, editor-in-chief, *Középiskolai Mathematikai Lapok* (Mathematics Journal for High Schools), invention of the *Mikola tube* for the demonstration of uniform linear motion, studies on the polarization of dielectrics.

Somorjai *Gábor (Gabor A. Somorjai)*
Chemical engineer, born: Budapest, 1935. High school: Trefort street Minta gymnasium (Budapest), higher education: Budapest Technical University, Ph.D.: University of California (Berkeley).
Positions: research associate 1960-4 (IBM, Yorktown Heights), assistant professor 1964-7 associate professor 1967-72, professor of chemistry 1972- (University of California, Berkeley), head of research 1972- (Lawrence Berkeley National Laboratory, Berkeley).
Results: foundation of surface science, introduction of low-energy electron diffraction for the study of surfaces, location of surface defects and clarification their role in heterogeneous catalysis, development of sum frequency generation spectroscopy.
Awards: Priestley Medal, Wolf Prize.

Szentágothai *János (János Szentágothai)*
Physician, born: Budapest (under the name Schimert), 1912; died: Budapest, 1994. High school: German Gymnasium, higher education: Pázmány Péter University (Budapest), Ph.D.: Pázmány Péter University (Budapest), studies abroad: University of Basle.
Positions: assistant professor 1935-40, associate professor 1940-4 (Pázmány Péter University, Budapest), prisoner of war 1944-6, professor and head 1947-63 (Chair of Anatomy, University of Pécs), head 1963-77 (Chair of Anatomy, Semmelweis Medical University, Budapest), professor of anatomy 1977-86 (Semmelweis Medical University, Budapest), president 1977-85 (Hungarian Academy of Sciences, Budapest), member 1985-94 (Hungarian Parliament).
Results: foundation of the world-class Hungarian brain research school, recognition of the basis of lateral inhibition in the cerebellar cortex, studies on the organization of the cerebellar neuronal network, formulation of the concept of the modular organization of neural centers, design of the Atlas Anatomiae Corporis Humani, (with F. Kiss), with more than 82 editions, translation into at least 13 languages including Chinese.
Awards: Ferrier Lecture (Royal Society).

Szent-Györgyi *Albert (Albert von Szent-Györgyi)* [37]
Physician, born: Budapest, 1893; died: Woods Hole, 1986. High school: Lónyay reformed church gymnasium, higher education: Pázmány Péter University (Budapest), Ph.D.: Cambridge University. Studies abroad: Pozsony, Prague, Berlin, Leiden, Groningen.
Positions: research fellow 1919 (Kaiser Wilhelm Institut für Chemie, Berlin-Dahlem), 1919-20 (Institute of Tropical Diseases, Hamburg) 1920-1 (Leiden University), associate professor 1922-6 (University of Groningen), 1926-30 (Cambridge University), professor of chemistry 1928-45

(University of Szeged), special envoy of the Hungarian government, 1943 (Istanbul), professor of chemistry 1945-7 (Pázmány Péter University, Budapest), director 1947-62 (Institute of Muscle Research, Marine Biological Laboratory, Woods Hole), professor of biochemistry 1962-71 (University of Dartmouth).
Results: discoveries in connection with the biological combustion process with special reference to vitamin C and the catalysis of fumaric acid, contribution to the formulation of the Szent-Györgyi-Krebs cycle, isolation and characterization of proteins responsible for muscle contraction, the electronic theory of cancer.
Awards: Nobel Prize, Lasker Award, Cameron Prize.

Szilárd, *Leó (Leo Szilard)* [38]
Physicist and engineer, born: Budapest, 1998 (under the name: Spitz), died: La Jolla, 1964. High school: VIth District real school, higher education: József Nádor Technical University (Budapest) and Technische Hochschule (Berlin-Charlottenburg), Ph.D.: Humboldt University (Berlin).
Positions: assistant professor 1924-7, associate professor 1927-33 (Humboldt University, Berlin), research associate 1933-5 (St. Bartholomew Hospital, London), research fellow 1935-8 (Clarendon Laboratory, Oxford), 1938-42 (Columbia University, New York), senior physicist 1942-6 (Metallurgy Laboratory, University of Chicago), professor of biology 1946-63 (Department of Radiobiology, University of Chicago), member 1963-4 (Salk Biological Institute, La Jolla).
Results: developing the idea of the nuclear chain reaction (with Enrico Fermi), design of the Einstein-Szilard refrigerator, important discovery in the field of artificial radioactivity (Szilard-Chalmers effect), drafting the petition advocating demonstration of the atomic bomb, initiation and participation in the Manhattan Project.
Awards: Einstein Prize, Atom for Peace Prize.

Teller*, Ede (Edward Teller)* [39]
Physicist, born: Budapest, 1908; died: Stanford, 2003. High school: Trefort street Minta gymnasium (Budapest), higher education: József Nádor Technical University (Budapest), Technische Hochschule (Karlsruhe), University of Munich, Ph.D.: University of Leipzig.
Positions: research physicist 1930-1 (University of Leipzig), 1931-3 (University of Göttingen), 1934 (University of Copenhagen), 1934-5 (University of London), professor of physics 1934-41 (George Washington University, Washington), 1935-1941 (Columbia University), research fellow in the Manhattan Project 1942-3 (Chicago), 1943-6 (Los Alamos), professor of physics 1946-9 (University of Chicago), director 1949-52 (Los Alamos National Laboratory), science advisor 1952-3, professor of physics 1952-75 (University of California, Berkeley), deputy director 1952-8, 1960-75, director 1958-60, emeritus director 1975-2003 (Lawrence Livermore National Laboratory, Livermore), senior research fellow 1975-2003 (Hoover Institute).
Results: in spectroscopy (prediction of the Jahn-Teller effect and the Renner-Teller effect), in surface physics (derivation of the Brunauer-Emmett-Teller isotherm), in statistical physics (contribution to the formulation of the Metropolis algorithm), participation in the Manhattan Project, developing the hydrogen bomb, campaigning for the Strategic Defense Initiative.
Awards: Albert Einstein Award, Fermi Award, National Medal of Science, Presidential Medal of Freedom.

Wigner, *Jenő (Eugene P. Wigner)* [40]
Physicist, born: Budapest, 1902; died: Princeton, 1995. High school: Fasori Lutheran gymnasium, higher education: József Nádor Technical University (Budapest), Technische Hochschule (Berlin), Ph.D.: Technische Hochschule (Berlin).
Positions: research chemist in the leather factory of his father 1925-6 (Budapest), assistant professor 1926-7 Technische Hochschule (Berlin), assistant professor 1927-30 (University of Göttingen), lecturer of mathematical physics 1930-6 (Princeton University), professor of physics 1936-8 (University of Wisconsin, Madison), professor of mathematical physics 1938-71 (Princeton University), scholar 1942-5 (University of Chicago).
Results: application of group theory in quantum mechanics, discovery of symmetry principles in atomic physics and elementary particle physics, formulation of the shell theory of atomic nuclei, first design of nuclear reactors, participation in the Manhattan Project.
Awards: Nobel Prize, Franklin Medal, Atoms for Peace Award.

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