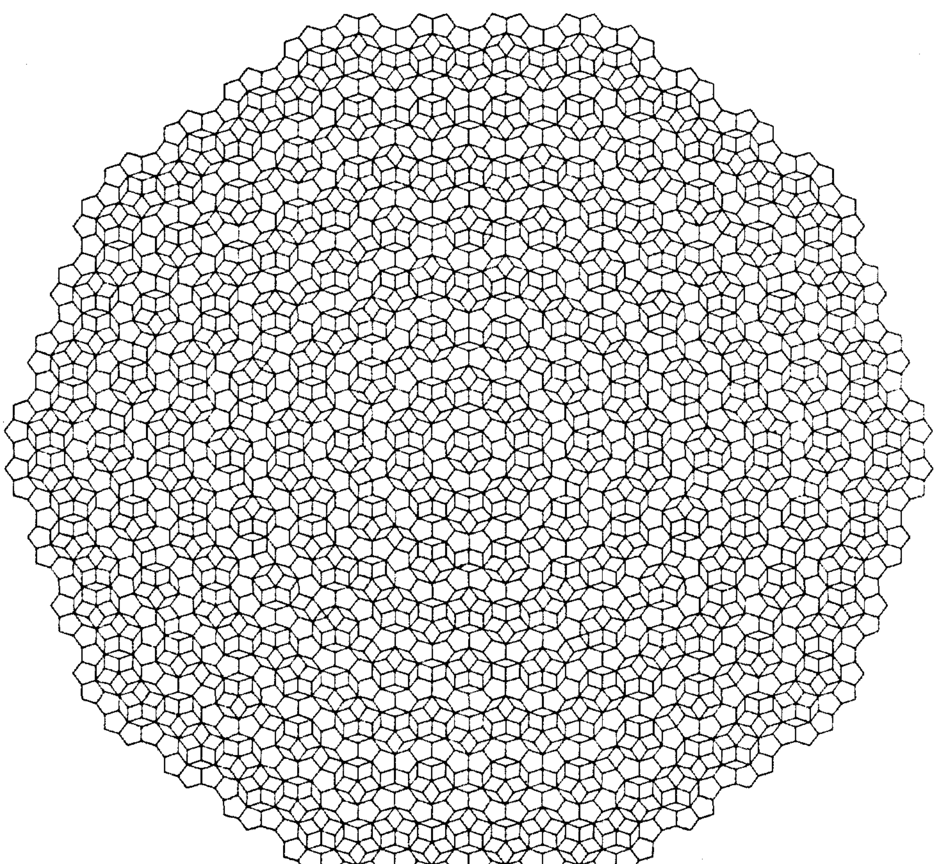
Symmetry: Culture and Science

The Quarterly of the
International Society for the
Interdisciplinary Study of Symmetry
(ISIS-Symmetry)

Editors:
György Darvas and Dénes Nagy
Volume 7, Number 1, 1996



EUGENE PAUL WIGNER
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February 1,1994

Dear Dr.Darvas,

My membership in the ISIS Symmetry Society is a great honor.

Symmetry, was for me, an important subject, and I still think so.

I send you all good wishes, and my appreciation for the honor you have given me.

Most Sincerely

Eugene P. Wigner

Eugene P. Wigner

E. P. Wigner's last letter to György Darvas

Symmetry: Culture and Science
Vol. 7, No. 1, 9-26, 1996.

OBITUARY

WARS AND SYMMETRIES
Wigner Jenő - Eugene P. Wigner, 1902-1995

György Marx

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Old friend, as I approach my 90th birthday I would much prefer to feel your handshake, and talk with you in person, but my years intervene. A few thoughts from the past may bring cheer:

I have been called modest, but I bear in mind the German proverb, which I feel justified, "modesty is an ornament, but one gets farther without it."

The exact theoretical consequences of my work in symmetry and group theory took years to develop, but eventually it had quite fundamental applications. It spread the basic truth that "laws of nature" have simple invariance properties. It even influenced the design of nuclear reactors.

The years after 1928 were good ones for me, I learned a lot, worked very hard, and was very happy. It is a wonderful thing to know that you are truly a physicist. What else besides love can compare to it?

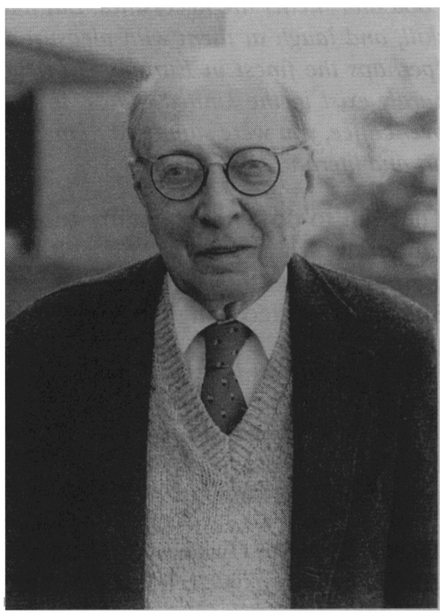
I hoped to make Quantum mechanics predict and explain consciousness and life, but we will need new concepts, which no longer rely chiefly on physics and chemistry. People say "well Eugene, consciousness is hardly physics." Perhaps so.

Poetry, humor and folk songs (which I sing very poorly) are still a pleasure to me. I wish we could share them!

The future is uncertain, says the optimist; so goes my favorite proverb.

With all good wishes!

Eugene P. Wigner



Eugene Paul Wigner,
Honorary Member of ISIS-Symmetry

"Like all children, I was born without my permission. What a pity it is that we cannot recall the day of our birth. What a memory that would be! But as soon as I realized that I was alive, I was curious about the world and happy with it. At least internally, I thanked my parents for having given me life." Wigner told *Andrew Szanton* who wrote the most comprehensive biography of E. P. Wigner (Szanton, 1992).

Wiegner means cradle-maker in German, this was shortened to *Wigner* in Hungary. Well, Wigner was born in Budapest, Hungary, early 20th century, and he waved good-bye to it on New Year's day of 1995 in Princeton, USA. He not only witnessed our bitter-sweet century but consciously shaped it. He has become a historic personality both in cultural and political sense. How people of the 21st century will live, how it will look at Nature, will be connected to the name of Eugene Wigner.

Eugene said about Budapest (Blumberg and Owens, 1976) that *"you heard a great deal more erudite conversation than you hear in the United States – people talked more about culture."* Andrew Szanton reports Wigner saying with his wonderfully rich, heavily accented voice (Szanton, 1992): *"Simple Hungarian poems and songs that I learned before 1910 still come to me unbidden. After 60 years in the United States, I am still more Hungarian than American, much of the American culture escapes me. Jokes are apparently universal, but no country could possibly love them more than Hungarians did. I have never known such a taste for jokes in all the years since I left Hungary; certainly not in Germany and not in the United States either. Food and shelter are necessities. But laughter is not. So why we invent jokes with such skill, and laugh at them with pleasure?"* Wigner especially liked Hungarian poetry, *"perhaps the finest in Europe. – In Budapest there were many cafés, of a kind that hardly exist in the United States. In such places, you were not only allowed to linger over coffee, you were supposed to linger, making intelligent conversation about science, art and literature."*

The well-to-do Wigner family took special care of sending also Eugene to the Lutheran Gymnasium, to *"the best school in Hungary, at that time it could have been the finest school of the world"* (Marx, 1992), as Wigner said in his late years. In Stockholm, at receiving the Nobel Prize (1963) he emphasized:

"I wish to say on this occasion a few words on a subject about which we think little when we are young but which we appreciate increasingly when we reflect on our intellectual development. I mean the indebtness to our teachers." Wigner made his mathematics teacher, László Rátz a legendary figure. When he was 85, he told Hungarian high school students (Wigner, *Fizikai Szemle*, 1987):

"In the Lutheran Gymnasium the teachers enjoyed teaching. Rátz taught calculus and its applications as well. It is not easy to create such schools as the Lutheran Gymnasium was. I feel this strongly in America. There the high schools are far less good than the Lutheran Gymnasium was." Furthermore (Wigner, *Fizikai Szemle*, 1983): *"I enjoyed mathematics, but I was really interested in physics. Physics developed a lot when it began applying mathematics. It impressed me how many relations connect physics and chemistry. My physics teacher, Sándor Mikola wrote a book, saying: 'Atoms and molecules perhaps exist, but this is irrelevant from the point of view of physics.' Later when I had learned that the solution was found to describe microphysics, it made a tremendous impression on me."*

In 1919, after the collapse of the Austrian-Hungarian Empire the communists took over in Budapest. Their leader, Béla Kun who was a Jew indoctrinated in Russia as a prisoner of war. Most of his top commissars were Jews as well: they wished to get rid of the feudalistic supremacy of landlords. After the fall of communism this created a further excuse for antisemitism. This was the reason why not only *Theodore von Kármán, Arthur Koestler, Michael Polanyi* and *Leo Szilard* (leaning towards the left politically), but later also *George de Hevesy, Edward Teller, Eugene P. Wigner* and *John von Neumann* (coming from well-to-do capitalist families) emigrated from Hungary. "*Béla Kun can unwittingly take credit for the American preeminence in the development of nuclear energy*" – as Stanley A. Blumberg and Gwinn Owens wrote (1976). But this was not the reason why Béla Kun was executed by Stalin's purges in Russia in 1937.

When Eugene became 17, he had to decide on his future profession (1987, Marx, 1992).

"*My father came and asked me: 'My son, when you grow up, what do you want to become?' – After a short silence I answered: 'Father, if I am to be frank with you I have to say that I would like to become a physicist.' – My father seemed to have expected this answer, and asked me: 'Tell me, my son, how many jobs are available in our country for a physicist?' – With some exaggeration I told: 'I think, four.'* [In reality there were only 3 at the three universities.] *'And do you think, my son, that you will obtain any of these four jobs?' This is how and why I started studying chemical engineering. After the high school classes of Sándor Mikola, the lectures at the Budapest and Berlin Institutes of Technology were just repetitions. Essentially the physics lessons in the Lutheran Gymnasium were the last physics courses which I regularly attended.*"

He was enroled to the Budapest Institute of Technology for chemical engineering, but the new right-wing military regime reduced the rights of Jews to attend university, thus Wigner left for the Technical University in Berlin-Dahlem. In the nearby Kaiser Wilhelm Institute Wigner's consultant was *Michael Polanyi*, who studied medicine and made Ph.D. in chemistry in Budapest, then became the director of the Department for Physical Chemistry in Berlin, and was the father of the Nobel laureate chemist *John Polanyi.*

"*After László Rátz of the Lutheran Gymnasium, Michael Polanyi was my dearest teacher*" – remembered Wigner (Szanton, 1992). "*His finest gift was to encourage young men with his very great heart. In all my life, I have never known anyone who used encouragement as skilfully as Polanyi. He was truly an artist of praise.*" – Later, when Polanyi was already working in America, he advocated that not centrally planned research, not a sort of Big Science is what promotes progress, but the Republic of Science, a mutual cooperation and criticism of scientists.

"*Once I made a remark to Polanyi about the impossibility of an association reaction. He heard my idea without grasping it. Months later Polanyi told me, 'I am quite sorry.*

This point which you have made on association reactions: I have heard that the same problem had been discussed in a very recent paper of Max Born and James Franck'. [Both obtained Nobel Prizes later.] *'I told them that you had the same idea. I am quite sorry, I failed to understand you.'"*

Wigner completed his Ph.D. thesis under the supervision of Michael Polanyi in Berlin. His thesis (published later in 1925 jointly with Polanyi) treated the formation and decay of molecules. *"As two hydrogen atoms collide, they stick to a single molecule. After a bit of thinking I found it to be a miracle: the molecules have discrete energy levels. How do they know that they have to collide just with such an energy? How do they manage that their angular momentum is an integer multiple of Planck's constant* h*? I suggested that the energy of molecular levels is not sharply determined, because the excited molecular state may decay after a while to atoms. Even the conservation of angular momentum is not a completely strict law! At collision the value of the angular momentum jumps to the nearest integer multiple of Planck's constant* h*. These were written down much before quantum mechanics was invented. This is why several people accused me of having invented Heisenberg's uncertainty relation which is not true. But my conclusions turned out to be right."* (Marx, 1992).

Anthony Wigner was the director the leaders of a leather tannery factory, this is why he worked hard to convince his son, Eugene to study chemical engineering. Dr. Eugene Wigner worked in the tannery in Budapest in 1925-1926, there he ordered the *Zeitschrift für Physik*, the avant-garde journal of modern physics. From this journal Wigner learned that quantum mechanics had been invented! After having read the paper of *Max Born* and *Pascual Jordan*, he was in heaven. He could not refuse the invitation to become an assistant at the Kaiser Wilhelm Institute for a salary of 136 Marks per month. (It turned out that Polanyi's helping hand was behind this invitation.) This is when Wigner's interest started in *s y m m e t r y*. Let us listen to his recollection (Marx, 1992):

"When I returned to Berlin, the excellent crystallographer, Weissenberg asked me to study: how come that in a crystal the atoms like to sit in a symmetry plane or symmetry axis. After a short time of thinking I understood: being on the symmetry axis secures that the derivatives of the potential energy vanish in two directions perpendicular to the symmetry axis. (In case of a symmetry plane the derivative of the potential energy vanishes in one direction.) This is how I became interested in the role of s y m m e t r i e s i n q u a n t u m m e c h a n i c s. *I spent the holidays – Christmas-time and summertime – in Hungary, in Budapest and in Alsógöd, at the shore of the Danube. There I wrote the book on* Group Theory and its Application to the Quantum Mechanics of Atomic Spectra." (Marx, 1992).

The intrusion of group theory into quantum mechanics was not received with applause. *Wolfgang Pauli* called the idea *Gruppenpest*, *Albert Einstein, Max von Laue, Erwin Schrödinger* also expressed their uneasiness. *John von Neumann* and *Leo Szilard*, however, encouraged *Eugene Wigner's* efforts.

If an experiment is repeated in another laboratory, under similar conditions identical result will come out. The experiment today brings the same result as brought yesterday. If the Earth rotates by 30°, it does not influence the result. *The outcome does depend neither on the location and timing of the experiment, nor spatial orientation of the equipment. Even the speed (e.g., that of the Earth) does not influence the way how the laws of Nature work.* To express this basic experience in a more direct way: the world does not have a centre, there is no absolute rest, preferred direction, privileged origin of calendar time, even left and right seem to be rather symmetric. From these symmetries of Nature the conservation of *momentum, speed of center of mass, angular momentum, energy* and *parity* follow.

In the 1920s Wigner has shown the utmost power of these experienced symmetry properties of space and time in quantum mechanics. His book has become one of the most important classics of the new science.

The observed interference of electrons, photons, neutrons indicated that the *state* of a particle can be described by *vectors*, possessing a certain number of components. As the *observer* is replaced by an other one (working elsewhere, looking at a different direction, using an other clock, perhaps being even left-handed), the state vector of the very same particle is transformed, meaning a multiplication by a matrix.

If a body is rotated by 90° around the x-axis, and after that around the y-axis, the outcome differs from the outcome of a 'y *first*, x *second*' rotation. Rotations *don't commute*, their generators, the components of angular momenta *don't commute*. This simple everyday experience of non-commutability of transformations in the 3 dimensional space and time implies that the corresponding quantities cannot be measured exactly at the same time: the corresponding matrices cannot be diagonalized simultaneously. The *uncertainty relation* of angular momenta, furthermore uncertainty relation between time and energy was noticed by Wigner already in 1925 while working on his Ph.D. thesis, studying the formation process of a molecule, well before Heisenberg's quantum mechanics and Heisenberg's uncertainty relation. The extra power of reflection symmetry – resulting in the parity conservation law for atomic spectra – was recognized by Wigner.

The matrices describing momentum and center-of-mass coordinate don't commute either. This specific $x{\cdot}p - p{\cdot}x = i\hbar$ cannot be represented by finite matrices. This implies that the state vector has infinitely many components, that is the ensemble of all the possible states of a single electron is a space with infinite dimensions, it's a *Hilbert space*. (Eugene Wigner was David Hilbert's assistant for a while.)

The generators of the symmetry transformation in Euclidean space and time play so important roles in the infinite dimensional state vector space, that they have deserved their specific names: momentum, angular momentum, center of mass coordinate, energy, parity. Actually, the *energy* generates the change of the time coordinate: it transforms *present to the future.* Thus the symmetry generators express the dynamics (how future evolves from the present), the structure (how objects interact by exchanging momenta), and the outcome of our measurements (how human brain observes the state of objects described by the state vector).

The author of this paper is convinced that the long-lasting essence of quantum mechanics has been understood by Eugene Wigner: the basic experiences of superposition and symmetries will serve as foundation how this intellectual achievement of the 20th century with upmost importance will be taught in the 21st century.

Wigner received the Nobel Prize *for his contribution to the theory of atomic nucleus and the elementary particles, particularly through the discovery and application of fundamental* symmetry *principles.*

He recognized a new symmetry in Nature which manifests itself in the conservation of the number of protons and neutrons. (Antiprotons and antineutrons are counted with minus sign.) Proton and antiproton can annihilate, but our world – made of common matter, protons, neutrons (and electrons) – survived billions of years due to Wigner's *conservation theorem of baryonic charge.*

*

History reached again Wigner in Berlin: Nazism was at the corner. Thus he accepted the invitation from Princeton University. *Cornelius Lánczos, John von Neumann, Edward Teller* and *Eugene Wigner* were called to America to teach the New Physics to the New World. For their advanced understanding of these revolutionary scientific ideas and their special political instinct they were called *the Martians,* who landed on Earth, but were unable to learn speaking English without an alien (Hungarian) accent. Neumann, Szilard and Teller enjoyed being called Martians, only Wigner did not like it. He considered himself to be the slowest among the four, but he was the one not only sparking with ideas but completing works. This is why he was who received the Nobel Prize. Eugene Wigner enjoyed *Teller*'s wide interest and fast logics, liked him from the start. He was puzzled by the selfish, pushy character of *Szilard,* opposite to Wigner's polite modesty. As Wigner expressed, *"Szilard was the most original mind I ever had met".* But he respected the mathematical ingenuity of *Neumann* the most: *"I have known only one genius in my life, Johnny von Neumann."* With a modest smile he added: *"You may value my statements more if you recall that I had known Einstein as well."*

The late 1920s and the 1930s were heroic times for quantum mechanics: it was successfully applied to explain the empirical facts collected in spectroscopy, chemistry, atomic physics, molecular physics, solid state physics, nuclear physics. Eugene Wigner took a leading role, published over 60 fundamental papers in these years, alone and with such celebrities as *Michael Polanyi, Pascual Jordan, John von*

Neumann, Victor Weisskopf, Frederick Seitz, John Bardeen, George Breit, R. Smoluchowski and *Edward Teller.*

From time to time Wigner visited Hungary to spend holidays with his family, and to lecture at the Colloquium organized by *Rudolf Ortvay* about quantum mechanics in Budapest. Professor Ortvay once invited *Paul Adrien Maurice Dirac*, the Nobel laureate creator of the relativistic quantum mechanics, to lecture at his Colloquium. Dirac is known to be withdrawn, not interested in social activities. Therefore it was a great surprise when in the next year Dirac himself offered his new visit and lecture to Ortvay. Dirac arrived, "by chance" his visit happened in coincidence with that of Wigner, and they both spent a relaxing holiday at the Lake Balaton, together with Wigner's sisters. After one of his prominent visits, the deeper reasons for Dirac's interest in Hungary became understood: he married Manci Wigner.

*

Neutron, a new nuclear particle with zero charge, was discovered in 1932. Wigner Jenő published his first paper on nuclear physics in Hungarian, in the periodical of the Hungarian Academy in 1932, about *the theory of neutrons*. He has shown how quantum mechanics can be used to understand nuclear properties as well. *Hideki Yukawa* started his Nobel lecture by saying: "*Wigner pointed out that nuclear forces between two nuclear particles must have a very short range, in order to account for the rapid increase of the binding energy from the heavy hydrogen to the helium.*" Later on, Wigner contributed to the understanding of nuclear spectra, based upon symmetry principles. He discovered the conservation theorem for the number of nuclear particles.

In the meantime history took sharp turns, and Wigner played a decisive role in them. Let us listen to Szilard's 'version of facts':

"*I found myself in London, and in the 12 September 1933 issue of The Times I read a speech by Lord Rutherford given at the British Association under the headline" BREAKING DOWN THE ATOMS. "He was quoted as saying that anybody who talks about the liberation of atomic energy on an industrial scale is talking moonshine. This sort of talk set me pondering as I was walking the streets of London. I remember that I stopped for a red light at the intersection of Southampton Row, and I was waiting for the light to change. As the light changed to green, it suddenly occurred to me that if we could find an element which is split by neutrons and which would emit t w o neutrons when it absorbed o n e neutron, such an element, if assembled in sufficiently large mass, could sustain a nuclear chain reaction.*" Leo Szilard visited Lord Rutherford, asking for support. Enter *Edward Teller* (1993, Marx, 1994):

"*In the fall of 1934 I went to England. There was a meeting of physicists, and Lord Rutherford was the speaker. Rutherford was speaking for ten to fifteen minutes about some crazy people believing in the utilization of nuclear energy. But this was* *impossible, he claimed. The energy of the nucleus is interesting only for physics itself, it cannot be utilized for anything. I cannot repeat Rutherford's words, as he was explaining it for a quarter of an hour, but this was essentially what he said. I could not understand what happened to him. But after this, the very same week, an old friend of mine met me in London, Leo Szilard. He told me that he had visited Rutherford and told him that nuclear energy could be utilized. Enormous explosions could be generated. In response, Rutherford threw him out of his office. Rutherford got so excited, that even some time later the only thing he could talk about was proving what nonsense this idea was.*"

Szilard found greater interest among *chemists*, who knew chemical chain reactions like fire. *Michael Polanyi* was especially interested, and asked Szilard on 11 November 1934: "*Will you let me report to Aschner that you are in the process of making great inventions and I would see a favourable opportunity for interest?*" Lipot Aschner was the open-minded, research-supporting director of the Tungsram Company in Budapest. In another letter, dated 28 June 1935 Polanyi wrote: "*My dear Szilard, I gather from my talk with Weizmann that he is favourably inclined towards the foundation a research corporation. Yours M.P.*" *Chaim Weizmann*, an other chemist (later the first president of Israel) tried to collect the 2000 pounds asked by Szilard for the experiments, but in vain. Finally, on 12 March 1934 Szilard decided to apply for a patent of "*a chain reaction which goes with neutrons. This chain can be realized only with metastable elements. Such an element captures a single neutron, and the liberated binding energy should be enough to make the element decay, liberate energy and emit two neutrons. (The metastability of Uranium and thorium is shown by their radioactive decays.) There is a small but nonvanishing chance that explosives constructed according to this principle may become many thousands of times more efficient than customary bombs.*" The patent was issued under No 440 023 – and classified as secret by the British Admiralty at the request of Leo Szilard.

Eugene P. Wigner, the chemical engineer was already an expert in the structure of nuclei, said: "*I watched Szilard's idea with great interest, it did not contradict any known physical principle. Controlled nuclear energy seemed to be only a question of time. I told this to a man from the General Electric in late 1935 who consulted me on other business. And I said as much to friends. In the spring of 1935, I gave a lecture in Madison*" [Wisconsin, USA] "*and predicted we would have nuclear energy production in five years. But I had very little basis for that predicted number. And I did not expect myself to play a vital role in producing it.*" – Well, Wigner was wrong: igniting the s e c o n d f i r e took two years longer than he foresaw.

The neutron was discovered in Rutherford's laboratory, but it was an Italian, *Enrico Fermi* who recognized the importance of the discovery: neutrons are neutral, therefore their entrance into the positive nucleus is not prevented by any electric barrier. Neutrons are advantageous tools for producing nuclear reactions. *Edward Teller* visited Fermi, and, as he recalled (1993, Marx, 1994):

"Fermi irradiated the elements one by one with neutrons. The excess neutrons made the nuclei radioactive. As he reached Uranium, observed not only a single sort of radioactivity, but a lot of them. Fermi concluded that this Uranium – being over-rich in neutrons – transformed to a sequence of transuranic elements. (For that Fermi received the 1938 Nobel Prize in physics.) Ida Noddack – who herself discovered a new element: Rhenium – published a paper proposing that the complex radioactivity pattern may indicate the fission of the Uranium nucleus into two fragments. This caused Fermi to calculate that possibility, but he concluded that splitting could not occur because of energy considerations. And his calculations were correct. The only problem was that his calculations were based on an incorrect measurement of atomic masses by Aston. – It is worth meditating about it for a moment. In 1932 Hitler wasn't in power yet. If in 1932 we had known about Uranium splitting, it is impossible to tell who would have continued to work on it and what it would have been used for. The fission of the Uranium nucleus – as we all know – was actually discovered only at the end of 1938." – The discovery – made in the Kaiser Wilhelm Institute in Berlin, December 1938 – was published in the German journal *Naturwissenschaften* on 6 January 1939. That January Niels Bohr brought the news of Uranium fission to America. *Eugene P. Wigner* remembered (Szanton, 1992):

"I was laid up in the hospital for about six weeks with jaundice. Leo Szilard was staying in my apartment. He came by the infirmary nearly every day to see me and raised my spirits with gentle Hungarian conversation. I appreciated that tremendously. One morning" [after the Princeton talk of Bohr] "Szilard came to my bed and said: 'Wigner, now I think there will be a neutron chain reaction.' He meant that a nuclear fission would make it possible. I disagreed at first, but soon I saw that of course he was right. I had miscalculated how neutron-rich the fission fragments were. Their richness in neutrons enabled the ejection of several neutrons in each fission. In the course of these talks in the Princeton infirmary, Szilard and I developed all of the essential points of fission theory." Szilard and Wigner were what *Alvin Weinberg* called *predisposed minds*. The equilibrium percentage of neutrons in Uranium is much higher than in its fragments, chemical elements located in the middle of the Periodic Table, so there is a good chance for the $n \rightarrow 2n$ reactions to occur. And that was which Szilard was desperately seeking to accomplish. Bohr and Fermi doubted but Szilard immediately declared that Uranium fission would result in the liberation of nuclear energy. Szilard borrowed 2000 dollars from a friend to make a neutron source. The neutrons were slowed down, as in Szilard's previous experiments. During the evening of 3 March 1939, on the 7th floor of the Pupin Lab at Columbia University, *Leo Szilard* and *Walter Zinn* watched the neutron counter to see whether neutrons would be produced in Uranium fission. During the same evening, Teller was relaxing while playing Mozart on his piano, when his phone rang: *"Megtaláltam a neutronokat."* (For security reasons Szilard spoke Hungarian, meaning: 'I have found the neutrons.') As Szilard recalled in his response at obtaining the Atoms for Peace award in 1960, he told himself this night: *"H. G. Wells! Here we come!"*

Enrico Fermi decided to make a similar experiment in the basement of Pupin Hall at Columbia, but he was less successful because he used fast neutrons. Then he borrowed Szilard's slow neutron source, and observed the neutrons after fission in a completely different experimental arrangement.

Szilard, Teller and Wigner were Central European refugees, who had first hand experiences with Nazism and antisemitism. The atomic bomb must not get into Hitler's hand. Fission was discovered in Berlin! The Hungarians agreed that full secrecy must be imposed immediately.

As summer – and World War II – approached, *Anderson, Fermi* and *Szilard* began discussing the possibility of realizing a neutron chain reaction experimentally. In June they published a design for Uranium reactor. In July 1939, the idea of a nuclear reactor seemed promising. Fermi tried to approach the Navy to explain the reactor and get support, but in vain. The Navy distrusted a stranger from an enemy country. So Fermi left for a holiday.

Eugene Wigner visited Szilard. Szilard explained his calculations about the Uranium-graphite reactor. Wigner understood and became concerned. They agreed that Belgium should be warned not to let the Germans get hold of Uranium imported from the mines in the Congo. Both Wigner and Szilard were at good terms with *Albert Einstein*. Wigner remembered that Einstein knew the Queen of Belgium. On a summer Sunday, 16 July 1939, Wigner drove Szilard to Einstein who was spending on the seaside in Long Island.

Einstein did not feel home with nuclear physics, perhaps because he disliked quantum mechanics. This was the first occasion Einstein had heard about the possibility of a chain reaction, but he understood it quickly – in about 14 minutes (Marx, 1992, Wigner, *Fizikai Szemle*, 1983). Einstein then dictated a letter to Belgium in German, and Wigner scribbled down his words. They left. Wigner translated the German text to English, gave it to Szilard, then travelled to California for the summer.

Szilard started thinking that it was not such a good idea to spread the news abroad about the possibility of a fission chain reaction. He found a contact to Alexander Sachs who previously worked on the New Deal of President Roosevelt. Sachs said that if Einstein were to write a letter, he would be ready to personally deliver it to the President. Szilard composed a new letter, addressed to the President, and visited *Edward Teller* who owned a 1935 Plymouth car. Enter Teller (*Fizikai Szemle*, 1993):

"After the discovery of nuclear fission, people said that a lot of things would be affected by this discovery and it was worthwhile to work on it. The Americans' opinion was negative. But by accident, there was a Hungarian there, Leo Szilard. He was a versatile person. He was even capable of explaining to the Americans the concept of a nuclear chain reaction. There was one thing that even Szilard could not do: drive a car. On the

summer of 1939 I was working at Columbia University in New York just like Szilard. One day Szilard came up to me and said: 'Mr. Teller, I am asking you to drive out with me to Einstein.' Well, so we drove out on 2nd August. We entered, Einstein was cordial, offered a tea to Szilard, and being democratic, he invited in the chauffeur as well. Szilard pulled a letter from his pocket addressed to President Roosevelt: SIR, SOME RECENT WORK BY ENRICO FERMI AND LEO SZILARD, WHICH HAS BEEN COMMUNICATED TO ME IN THE FORM OF A MANUSCRIPT, LEADS ME TO EXPECT THAT THE ELEMENT URANIUM MAY BE TURNED INTO A NEW AND IMPORTANT SOURCE OF ENERGY IN THE IMMEDIATE FUTURE... *Einstein read it slowly and said: 'Well, this will be the first case when we use nuclear energy directly, not indirectly. (The Sun produces it, and we are gaining light from the Sun.)' And with these words he signed the letter: 'Albert Einstein'. Roosevelt received the letter from Dr. Sachs on 3 October. He could not have received it at a better time, it happened just after Nazi Germany and the Soviet Union had occupied and divided Poland. By that time an intelligent man like Roosevelt could clearly see: great danger has arrived, it is imminent, the danger is on the doorstep. Right away he wrote to the head of the National Bureau of Standards: 'Convene a meeting to discuss the content of the letter in detail.'*"

On Saturday, 6 December 1941, the Japanese made a surprise attack on Pearl Harbour, and annihilated a part of the American fleet. The USA found itself at war. On the very same day Washington decided in favor of "*an all-out effort to build a nuclear bomb*". The next day *Arthur Compton*, the director of the top-secret project, ruled that the reactor project should move to Chicago under the code-name: 'Manhattan Project'. In the spring of 1942, Compton invited Fermi, Teller and Wigner to move to Chicago. That happened. Fermi's code-name was Farmer, Wigner's code-name was Wagner. Wigner recalled (Szanton, 1992): "*One day we were driving together along a high-security road. At the checkpoint, the military guard asked my name. I said: 'Wigner – oh, please excuse me: Wagner!' The guard could not help but notice my Hungarian accent. He regarded me with suspicion and asked sternly: 'Is your name really Wagner?' What could I say? Enrico saved me. Quite firmly and confidently, he said: 'If his name's not Wagner, then my name's not Farmer.' And the guard let us pass.*"

In Chicago an artificial neutron source was placed on the floor, then Uranium rods and graphite blocks were placed upon it. According to Fermi's instructions, after placing newer and newer layers onto the pile, the distribution of neutrons was observed at different distances from the source. As the neutron multiplication was higher, the neutrons reached a larger distance in the graphite before being absorbed. It was Wigner's duty to calculate the neutron multiplication from the measured distribution of the neutrons at increasing distances, and to foresee the critical size of the pile needed for a self-sustaining chain reaction. As Alvin Weinberg said (Marx, 1992): "*There were two dominant scientific brains in Chicago. Fermi* *conducted the experimental work. Wigner headed the theoretical research. Szilard, Teller and Wigner were called the Hungarian Mafia in Chicago.*

Fermi performed 25 experiments with different arrangements of Uranium and graphite. The first self-sustaining neutron chain reaction was realized on 2 December 1942. Let us quote the description of the eye-witness Wigner (Szanton, 1992):

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The 1942 DuPont Chemical Company, charged with building the Plutonium producing reactors, accepted Wigner's proposal for using normal water as coolant. By December 1942 (before Fermi's reactor started operating) the plan for the water cooled reactor was ready: four months were enough for the Wigner group of five to design the 500 million watt reactor. Once – looking through the technical plans proposed by DuPont – Wigner noticed that there was an error in the design. He recalculated the reactor control system, and realized that DuPont's plan did not include enough control rods. He corrected the error in time. Szilard said that *Wigner was the conscience of the whole project.* In 1943, the Plutonium producing reactors (with natural Uranium fuel, graphite moderator and normal water coolant, as proposed by Wigner) were built in Hanford, at the far north-east corner of the USA. From there the first shipments of Plutonium arrived in May 1944. A year later there was enough Plutonium produced to make atomic bombs.

One of them was tried in New Mexico on 16th July 1945. The second one was dropped on Nagasaki on 9th August 1945.

The design and fabrication of the atomic bomb was directed by *Robert Oppenheimer* in Los Alamos. *Leo Szilard* was not permitted to enter: he did not have a security clearance, he stayed in Chicago. Reactor construction went on in Oak Ridge, where *Eugene Wigner* worked, later on became director of the Oak Ridge National Laboratory. Hitler committed suicide and Germany surrendered already in May 1945. The Europeans – Bohr, Szilard, Teller, Wigner – had more direct information about Hitler and intended to prevent Nazi Germany to possess the bomb as first. After the collapse of Hitler's might, they did their best to prevent the use of the terrible weapon against Japanese. Japan was almost defeated anyhow. But for the Americans, shocked by the attack on Pearl Harbor, Japan was the *enemy*. Including *Robert Oppenheimer* they supported the sharp use of the bomb. 200 000 people died in Hiroshima and Nagasaki. This hounded the mind of the nuclear pioneers since then. Wigner – a mild personality – advocated *civil defense* instead of the mad *Mutually Assured Destruction*. Now we have got a hope that *oak* will survive poplars (*alamos*).

Still in 1943, simultaneously with the construction of the Plutonium producing reactors, other alternatives were also searched for. *Eugene Wigner* asked his theoretical group to look for other possible materials to slow down the neutrons. He told: "*Don't forget common water!*" So *Alvin Weinberg* started to investigate H_2O. He found that natural Uranium fuel and common water moderator could achieve a 98 % neutron multiplication factor. Almost enough for a chain reaction. Weinberg said [Budapest 1989]: *"Wigner was the first reactor engineer. As the scientific director of the Oak Ridge Laboratory, proposed a research reactor based on natural Uranium fuel, a heavy water moderator, and light water cooling. In 1945 Colonel Abelson from the Navy came to me with the question how reactors could be used to operate submarines. I answered: 'These reactors must be compact. The simplest solution is to use water as the moderator, and as coolant as well.' For simplicity, we left heavy water off. The first reactor with enriched Uranium as fuel, a light water moderator, and light water cooling was built in Idaho. But due to the low boiling point of the water, only 17 % thermal efficiency could be reached. This is why in submarines the reactors are moderated and cooled by pressurized water, boiling at higher temperature. This type of power reactor is now in use worldwide. Although Wigner did not design a nuclear power plant, we can nevertheless say: he was the grandfather of water-moderated and water-cooled power reactors."*

After World War II the time came for peaceful use of nuclear power. President Eisenhower created the ATOMS FOR PEACE medal. The first recipient was *Niels Bohr*, the Danish creator of models for atoms and nuclei (1957). In the second year *George de Hevesy*, the Hungarian inventor of radioactive tracing obtained the medal. In 1959, two Hungarians received the medal from the President: *Leo Szilard* and *Eugene Wigner* for the design of the nuclear reactor. After them in 1960 the American *Alvin Weinberg* (student of Wigner) and the Canadian *Walter Zinn* (a former co-worker of Szilard) were honoured for building reactors...

*

"Eugene and Heckmann were lying on the lawn near the municipal swimming pool in Göttingen. Heckmann (a German astronomer) observed that a trail of ants was crawling across Eugene's right leg, and he asked Eugene 'Don't they bite?' The answer was 'They do.' Question: 'Then why don't you kill them?' Answer by Eugene Wigner: 'I don't know which one it was.' This story was told by Edward Teller (Wagner, 1981). According to his other story, while Wigner was driving in Princeton, an other car crossed the street unexpectedly. As the blood pressure went up, Wigner shouted at the other driver: *"Go to hell – please!"*

According to John von Neumann, when Leo Szilard entered a revolving door *following* somebody, he somehow managed to come out *first*. Not so with Wigner. If you are accompanied by Wigner, and let him enter the revolving door as first, he manages to leave it last. *"In America every physicist knows Wigner's modesty – Valentine Telegdi* said (Wagner, 1981). *This is, however, an 'apparent' modesty. Wigner knows his own value very well, the modesty serves only as defense against provocations."* – *Edward Teller* characterizes Wigner: – *"When he says to a seminar speaker: 'What you say is interesting', that is a much harder criticism than my saying him 'That's damned nonsense'."* (The author of the present paper experienced himself this behaviour of Eugene Wigner.)

As a small child, he was taken on an excursion in a carriage. Eugene was supposed to chat with grown-ups politely, but he would have preferred talking with the horse. Unfortunately, the horse did not speak Hungarian. But he kept this kind of interest through his whole life.

Albert Einstein – and a lot of other giants of physics – had reservations with respect to quantum mechanics because it is not deterministic in the strict Newtonian sense. One can compute the time evolution of the wave function, but at the instant of *measurement* the wave function suddenly shrinks to one of the eigenfunctions of the measured quantity, and we cannot predict exactly, to which of them. Quantum mechanics offers only probabilistic prediction about the outcome of a measurement, and about its impact upon the state of the microobject. "*But what is a m e a s u r e m e n t ?*" asked Wigner. He tried to give himself an answer. It is the interaction of the real outside world with the mind of the physicist. This has raised the further question of consciousness. What happens if a human looks at the measuring device but he misses appreciating the position of the dial? And do animals possess consciousness? In the last 20 years, Eugene P. Wigner thinks more and more about *consciousness* and its relation to quantum mechanics. In his acceptance lecture of the honorary Ph.D. degree at the Eötvös University Wigner expressed his personal opinion (1987, Marx, 1994):

"*There are phenomena which physics cannot yet describe. For example, it cannot describe life, emotion or consciousness. This situation is like n o t t a k i n g gravitation into account would be. But gravitation exists and life exists. I am here, I feel joy and desire. It used to be said that man is subdued to the laws of physics, and his emotions are irrelevant. I cannot accept that! I am convinced that the sequence of events is influenced by my consciousness in a similar way as it is influenced by the force of gravity. If this were true, there would be something which physics is not interested in as it was not interested in the existence of atoms 100 years ago.*

I can imagine that human intellect has its own limitations just like animal brain is limited. Once I tried to teach the multiplication table to a nice and skilful dog. Not to make a difficult calculation like 6·8. I showed him 2 squares and 3 squares, and I wanted the dog to indicate that the product makes 6 squares. I failed. The dog can learn very different skills, but it seems not to be interested in multiplication. Up to a certain degree we are like animals. It is quite possible that our interest and our knowledge is limited as well. I would like to hope that understanding life does not lie beyond the limits of our intellect. We have learned to describe the behaviour of gases and the behaviour of atoms. Once perhaps we shall understand life as well. This is why one cannot exclude that the deterministic description of the human mind will not be possible. It may be that present physics will be enough to describe a bacterium. When it succeeds, the bacterium will not be considered to be a l i v e any longer. But in order to describe the whole complexity of life, including human c o n s c i o u s n e s s, we shall be unable to restrict ourselves to pure wave functions, because the impact of the *macroscopic environment disturbs it immediately, e.g., by the cosmic background radiowaves, which are present everywhere with a temperature of 2.7 K.*

It is possible that understanding consciousness remains as far from human intellect, as multiplication from my dog."

According to Wigner, Newton was the greatest physicist because he was able to condense all the knowledge about the physical Universe in the single volume of the *Principia*. Early 20th century he welcomed the arrival of relativity and quantum theory because they promised again a compact world picture at the price of a certain abstraction. As a matter of fact, Wigner's monograph on the *Group Theory and its Application to the Quantum Mechanics of Atomic Spectra* is a rather successful attempt to offer this synthesis for the 20th century. Seeing the expansion of physics, the recent flood of scientific information filled him with anxiety. At his age of 85 he was asked by Hungarian secondary school students about his view of the future (1987, Marx, 1994]:

"*Well, please, it is a hard question. The realm of physics has been extended tremendously. In the first book I ever read about physics when I was 17,* [written by Sándor Mikola] *it said: 'Atoms and molecules may exist but this is irrelevant from the viewpoint of physics.' Only chemists were interested in atoms. It is marvelous that physics succeeded to explain the atoms. It is not clear whether such a success will be also reached in the future. How far humans can progress in science is not clear.*

Physics have offered me a lot of joy. I loved physics. I still love it. But I cannot grasp a considerable part of recent physics: it is getting too complex and too sophisticated for me. But if a single person is able to catch only smaller and smaller fractions of science, if one cannot understand the essence of science, young people may lose their interest in it. Today it is almost impossible to know the whole of physics. I consider this complexity to be a danger for the future of science. If people don't get an overview, they may become less interested. If they are not interested, they will not learn science. If young people will not study science, that will terminate the development of science.

I am deeply worried that we have not yet received any message from alien civilizations. It is probable that there are other habitable planets; people or other similar creatures may live on them. It is likely that some of these civilizations have developed more knowledge than we did. Therefore it is surprising that they have not established contact with us. I don't think on a direct visit because of the huge distances, but they might use telecommunication. I am surprised that there is only one Earth and only one race which is interested. There are two possible explanations for this puzzle. One possibility is that they developed science and technology in the past, they started an armament race, and then they annihilated themselves and their whole planet. If this is a rule of the development of intelligence, it could explain the silence. Another possibility is that they developed science, which increased their standard of living. The luxury made them lazy, they gave up reading books and learning science. It is also possible that physics turned

"Fermi irradiated the elements one by one with neutrons. The excess neutrons made the nuclei radioactive. As he reached Uranium, observed not only a single sort of radioactivity, but a lot of them. Fermi concluded that this Uranium – being over-rich in neutrons – transformed to a sequence of transuranic elements. (For that Fermi received the 1938 Nobel Prize in physics.) Ida Noddack – who herself discovered a new element: Rhenium – published a paper proposing that the complex radioactivity pattern may indicate the fission of the Uranium nucleus into two fragments. This caused Fermi to calculate that possibility, but he concluded that splitting could not occur because of energy considerations. And his calculations were correct. The only problem was that his calculations were based on an incorrect measurement of atomic masses by Aston. – It is worth meditating about it for a moment. In 1932 Hitler wasn't in power yet. If in 1932 we had known about Uranium splitting, it is impossible to tell who would have continued to work on it and what it would have been used for. The fission of the Uranium nucleus – as we all know – was actually discovered only at the end of 1938." – The discovery – made in the Kaiser Wilhelm Institute in Berlin, December 1938 – was published in the German journal *Naturwissenschaften* on 6 January 1939. That January Niels Bohr brought the news of Uranium fission to America. *Eugene P. Wigner* remembered (Szanton, 1992):

"I was laid up in the hospital for about six weeks with jaundice. Leo Szilard was staying in my apartment. He came by the infirmary nearly every day to see me and raised my spirits with gentle Hungarian conversation. I appreciated that tremendously. One morning" [after the Princeton talk of Bohr] "Szilard came to my bed and said: 'Wigner, now I think there will be a neutron chain reaction.' He meant that a nuclear fission would make it possible. I disagreed at first, but soon I saw that of course he was right. I had miscalculated how neutron-rich the fission fragments were. Their richness in neutrons enabled the ejection of several neutrons in each fission. In the course of these talks in the Princeton infirmary, Szilard and I developed all of the essential points of fission theory." Szilard and Wigner were what *Alvin Weinberg* called *predisposed minds*. The equilibrium percentage of neutrons in Uranium is much higher than in its fragments, chemical elements located in the middle of the Periodic Table, so there is a good chance for the $n \rightarrow 2n$ reactions to occur. And that was which Szilard was desperately seeking to accomplish. Bohr and Fermi doubted but Szilard immediately declared that Uranium fission would result in the liberation of nuclear energy. Szilard borrowed 2000 dollars from a friend to make a neutron source. The neutrons were slowed down, as in Szilard's previous experiments. During the evening of 3 March 1939, on the 7th floor of the Pupin Lab at Columbia University, *Leo Szilard* and *Walter Zinn* watched the neutron counter to see whether neutrons would be produced in Uranium fission. During the same evening, Teller was relaxing while playing Mozart on his piano, when his phone rang: *"Megtaláltam a neutronokat."* (For security reasons Szilard spoke Hungarian, meaning: 'I have found the neutrons.') As Szilard recalled in his response at obtaining the Atoms for Peace award in 1960, he told himself this night: *"H. G. Wells! Here we come!"*

Enrico Fermi decided to make a similar experiment in the basement of Pupin Hall at Columbia, but he was less successful because he used fast neutrons. Then he borrowed Szilard's slow neutron source, and observed the neutrons after fission in a completely different experimental arrangement.

Szilard, Teller and Wigner were Central European refugees, who had first hand experiences with Nazism and antisemitism. The atomic bomb must not get into Hitler's hand. Fission was discovered in Berlin! The Hungarians agreed that full secrecy must be imposed immediately.

As summer – and World War II – approached, *Anderson, Fermi* and *Szilard* began discussing the possibility of realizing a neutron chain reaction experimentally. In June they published a design for Uranium reactor. In July 1939, the idea of a nuclear reactor seemed promising. Fermi tried to approach the Navy to explain the reactor and get support, but in vain. The Navy distrusted a stranger from an enemy country. So Fermi left for a holiday.

Eugene Wigner visited Szilard. Szilard explained his calculations about the Uranium-graphite reactor. Wigner understood and became concerned. They agreed that Belgium should be warned not to let the Germans get hold of Uranium imported from the mines in the Congo. Both Wigner and Szilard were at good terms with *Albert Einstein*. Wigner remembered that Einstein knew the Queen of Belgium. On a summer Sunday, 16 July 1939, Wigner drove Szilard to Einstein who was spending on the seaside in Long Island.

Einstein did not feel home with nuclear physics, perhaps because he disliked quantum mechanics. This was the first occasion Einstein had heard about the possibility of a chain reaction, but he understood it quickly – in about 14 minutes (Marx, 1992, Wigner, *Fizikai Szemle*, 1983). Einstein then dictated a letter to Belgium in German, and Wigner scribbled down his words. They left. Wigner translated the German text to English, gave it to Szilard, then travelled to California for the summer.

Szilard started thinking that it was not such a good idea to spread the news abroad about the possibility of a fission chain reaction. He found a contact to Alexander Sachs who previously worked on the New Deal of President Roosevelt. Sachs said that if Einstein were to write a letter, he would be ready to personally deliver it to the President. Szilard composed a new letter, addressed to the President, and visited *Edward Teller* who owned a 1935 Plymouth car. Enter Teller (*Fizikai Szemle*, 1993):

"After the discovery of nuclear fission, people said that a lot of things would be affected by this discovery and it was worthwhile to work on it. The Americans' opinion was negative. But by accident, there was a Hungarian there, Leo Szilard. He was a versatile person. He was even capable of explaining to the Americans the concept of a nuclear chain reaction. There was one thing that even Szilard could not do: drive a car. On the

summer of 1939 I was working at Columbia University in New York just like Szilard. One day Szilard came up to me and said: 'Mr. Teller, I am asking you to drive out with me to Einstein.' Well, so we drove out on 2nd August. We entered, Einstein was cordial, offered a tea to Szilard, and being democratic, he invited in the chauffeur as well. Szilard pulled a letter from his pocket addressed to President Roosevelt: SIR, SOME RECENT WORK BY ENRICO FERMI AND LEO SZILARD, WHICH HAS BEEN COMMUNICATED TO ME IN THE FORM OF A MANUSCRIPT, LEADS ME TO EXPECT THAT THE ELEMENT URANIUM MAY BE TURNED INTO A NEW AND IMPORTANT SOURCE OF ENERGY IN THE IMMEDIATE FUTURE... *Einstein read it slowly and said: 'Well, this will be the first case when we use nuclear energy directly, not indirectly. (The Sun produces it, and we are gaining light from the Sun.)' And with these words he signed the letter: 'Albert Einstein'. Roosevelt received the letter from Dr. Sachs on 3 October. He could not have received it at a better time, it happened just after Nazi Germany and the Soviet Union had occupied and divided Poland. By that time an intelligent man like Roosevelt could clearly see: great danger has arrived, it is imminent, the danger is on the doorstep. Right away he wrote to the head of the National Bureau of Standards: 'Convene a meeting to discuss the content of the letter in detail.'* "

On Saturday, 6 December 1941, the Japanese made a surprise attack on Pearl Harbour, and annihilated a part of the American fleet. The USA found itself at war. On the very same day Washington decided in favor of "*an all-out effort to build a nuclear bomb*". The next day *Arthur Compton*, the director of the top-secret project, ruled that the reactor project should move to Chicago under the code-name: 'Manhattan Project'. In the spring of 1942, Compton invited Fermi, Teller and Wigner to move to Chicago. That happened. Fermi's code-name was Farmer, Wigner's code-name was Wagner. Wigner recalled (Szanton, 1992): "*One day we were driving together along a high-security road. At the checkpoint, the military guard asked my name. I said: 'Wigner – oh, please excuse me: Wagner!' The guard could not help but notice my Hungarian accent. He regarded me with suspicion and asked sternly: 'Is your name really Wagner?' What could I say? Enrico saved me. Quite firmly and confidently, he said: 'If his name's not Wagner, then my name's not Farmer.' And the guard let us pass.*"

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In September 1941 *Eugene P. Wigner* explained *Compton* the difference between fast neutrons (producing atomic bomb) and slow neutrons (utilized in reactors). A large nuclear reactor could make all the Plutonium needed for a bomb. In his book *The Atomic Quest* Compton recalled how Wigner had urged him "*almost in tears*" to do so. Finally Compton charged Wigner to design large reactors with high neutron fluxes. (Wigner was the perfect candidate for the job: he was educated as a chemical engineer, was at home with nuclear physics, and disliked Hitler.) Planning of large reactors was started in the first half of 1942, much before Fermi's reactor became operational. The Chicago reactor was of low power. The intended large reactors were 17 000 times more powerful, they needed efficient cooling. Compton proposed helium gas as coolant because it does not absorb neutrons at all. But gaseous helium has a small heat capacity. In April 1942 *Wigner*, a practical man proposed normal water as coolant, because the electrical industry had accumulated much experience with water boilers. This was a daring idea from the nuclear point of view, because light hydrogen absorbed some neutrons, and this fact takes 1.5 %

off the neutron multiplication factor. In the summer of 1942, while Fermi's experiments were still running, a trial arrangement was assembled with water tubes. From the measured neutron distribution *Alvin Weinberg* calculated that a water cooled graphite reactor with natural Uranium as fuel may realize a neutron multiplication of 104 %. Wigner seemed to be right!

The 1942 DuPont Chemical Company, charged with building the Plutonium producing reactors, accepted Wigner's proposal for using normal water as coolant. By December 1942 (before Fermi's reactor started operating) the plan for the water cooled reactor was ready: four months were enough for the Wigner group of five to design the 500 million watt reactor. Once – looking through the technical plans proposed by DuPont – Wigner noticed that there was an error in the design. He recalculated the reactor control system, and realized that DuPont's plan did not include enough control rods. He corrected the error in time. Szilard said that *Wigner was the conscience of the whole project.* In 1943, the Plutonium producing reactors (with natural Uranium fuel, graphite moderator and normal water coolant, as proposed by Wigner) were built in Hanford, at the far north-east corner of the USA. From there the first shipments of Plutonium arrived in May 1944. A year later there was enough Plutonium produced to make atomic bombs.

One of them was tried in New Mexico on 16th July 1945. The second one was dropped on Nagasaki on 9th August 1945.

The design and fabrication of the atomic bomb was directed by *Robert Oppenheimer* in Los Alamos. *Leo Szilard* was not permitted to enter: he did not have a security clearance, he stayed in Chicago. Reactor construction went on in Oak Ridge, where *Eugene Wigner* worked, later on became director of the Oak Ridge National Laboratory. Hitler committed suicide and Germany surrendered already in May 1945. The Europeans – Bohr, Szilard, Teller, Wigner – had more direct information about Hitler and intended to prevent Nazi Germany to possess the bomb as first. After the collapse of Hitler's might, they did their best to prevent the use of the terrible weapon against Japanese. Japan was almost defeated anyhow. But for the Americans, shocked by the attack on Pearl Harbor, Japan was the *enemy*. Including *Robert Oppenheimer* they supported the sharp use of the bomb. 200 000 people died in Hiroshima and Nagasaki. This hounded the mind of the nuclear pioneers since then. Wigner – a mild personality – advocated *civil defense* instead of the mad *Mutually Assured Destruction*. Now we have got a hope that *oak* will survive poplars (*alamos*).

Still in 1943, simultaneously with the construction of the Plutonium producing reactors, other alternatives were also searched for. *Eugene Wigner* asked his theoretical group to look for other possible materials to slow down the neutrons. He told: "*Don't forget common water!*" So *Alvin Weinberg* started to investigate H_2O. He found that natural Uranium fuel and common water moderator could achieve a 98 % neutron multiplication factor. Almost enough for a chain reaction. Weinberg said [Budapest 1989]: *"Wigner was the first reactor engineer. As the scientific director of the Oak Ridge Laboratory, proposed a research reactor based on natural Uranium fuel, a heavy water moderator, and light water cooling. In 1945 Colonel Abelson from the Navy came to me with the question how reactors could be used to operate submarines. I answered: 'These reactors must be compact. The simplest solution is to use water as the moderator, and as coolant as well.' For simplicity, we left heavy water off. The first reactor with enriched Uranium as fuel, a light water moderator, and light water cooling was built in Idaho. But due to the low boiling point of the water, only 17 % thermal efficiency could be reached. This is why in submarines the reactors are moderated and cooled by pressurized water, boiling at higher temperature. This type of power reactor is now in use worldwide. Although Wigner did not design a nuclear power plant, we can nevertheless say: he was the grandfather of water-moderated and water-cooled power reactors."*

After World War II the time came for peaceful use of nuclear power. President Eisenhower created the ATOMS FOR PEACE medal. The first recipient was *Niels Bohr*, the Danish creator of models for atoms and nuclei (1957). In the second year *George de Hevesy*, the Hungarian inventor of radioactive tracing obtained the medal. In 1959, two Hungarians received the medal from the President: *Leo Szilard* and *Eugene Wigner* for the design of the nuclear reactor. After them in 1960 the American *Alvin Weinberg* (student of Wigner) and the Canadian *Walter Zinn* (a former co-worker of Szilard) were honoured for building reactors...

*

"Eugene and Heckmann were lying on the lawn near the municipal swimming pool in Göttingen. Heckmann (a German astronomer) observed that a trail of ants was crawling across Eugene's right leg, and he asked Eugene 'Don't they bite?' The answer was 'They do.' Question: 'Then why don't you kill them?' Answer by Eugene Wigner: 'I don't know which one it was.' This story was told by Edward Teller (Wagner, 1981). According to his other story, while Wigner was driving in Princeton, an other car crossed the street unexpectedly. As the blood pressure went up, Wigner shouted at the other driver: *"Go to hell – please!"*

According to John von Neumann, when Leo Szilard entered a revolving door *following* somebody, he somehow managed to come out *first*. Not so with Wigner. If you are accompanied by Wigner, and let him enter the revolving door as first, he manages to leave it last. *"In America every physicist knows Wigner's modesty – Valentine Telegdi* said (Wagner, 1981). *This is, however, an 'apparent' modesty. Wigner knows his own value very well, the modesty serves only as defense against provocations."* – *Edward Teller* characterizes Wigner: – *"When he says to a seminar speaker: 'What you say is interesting', that is a much harder criticism than my saying him 'That's damned nonsense'."* (The author of the present paper experienced himself this behaviour of Eugene Wigner.)

As a small child, he was taken on an excursion in a carriage. Eugene was supposed to chat with grown-ups politely, but he would have preferred talking with the horse. Unfortunately, the horse did not speak Hungarian. But he kept this kind of interest through his whole life.

Albert Einstein – and a lot of other giants of physics – had reservations with respect to quantum mechanics because it is not deterministic in the strict Newtonian sense. One can compute the time evolution of the wave function, but at the instant of *measurement* the wave function suddenly shrinks to one of the eigenfunctions of the measured quantity, and we cannot predict exactly, to which of them. Quantum mechanics offers only probabilistic prediction about the outcome of a measurement, and about its impact upon the state of the microobject. "*But what is a m e a s u r e m e n t ?*" asked Wigner. He tried to give himself an answer. It is the interaction of the real outside world with the mind of the physicist. This has raised the further question of consciousness. What happens if a human looks at the measuring device but he misses appreciating the position of the dial? And do animals possess consciousness? In the last 20 years, Eugene P. Wigner thinks more and more about *consciousness* and its relation to quantum mechanics. In his acceptance lecture of the honorary Ph.D. degree at the Eötvös University Wigner expressed his personal opinion (1987, Marx, 1994):

"*There are phenomena which physics cannot yet describe. For example, it cannot describe life, emotion or consciousness. This situation is like n o t t a k i n g gravitation into account would be. But gravitation exists and life exists. I am here, I feel joy and desire. It used to be said that man is subdued to the laws of physics, and his emotions are irrelevant. I cannot accept that! I am convinced that the sequence of events is influenced by my consciousness in a similar way as it is influenced by the force of gravity. If this were true, there would be something which physics is not interested in as it was not interested in the existence of atoms 100 years ago.*

I can imagine that human intellect has its own limitations just like animal brain is limited. Once I tried to teach the multiplication table to a nice and skilful dog. Not to make a difficult calculation like 6·8. I showed him 2 squares and 3 squares, and I wanted the dog to indicate that the product makes 6 squares. I failed. The dog can learn very different skills, but it seems not to be interested in multiplication. Up to a certain degree we are like animals. It is quite possible that our interest and our knowledge is limited as well. I would like to hope that understanding life does not lie beyond the limits of our intellect. We have learned to describe the behaviour of gases and the behaviour of atoms. Once perhaps we shall understand life as well. This is why one cannot exclude that the deterministic description of the human mind will not be possible. It may be that present physics will be enough to describe a bacterium. When it succeeds, the bacterium will not be considered to be a l i v e any longer. But in order to describe the whole complexity of life, including human c o n s c i o u s n e s s, we shall be unable to restrict ourselves to pure wave functions, because the impact of the *macroscopic environment disturbs it immediately, e.g., by the cosmic background radiowaves, which are present everywhere with a temperature of 2.7 K.*

It is possible that understanding consciousness remains as far from human intellect, as multiplication from my dog."

According to Wigner, Newton was the greatest physicist because he was able to condense all the knowledge about the physical Universe in the single volume of the *Principia*. Early 20th century he welcomed the arrival of relativity and quantum theory because they promised again a compact world picture at the price of a certain abstraction. As a matter of fact, Wigner's monograph on the *Group Theory and its Application to the Quantum Mechanics of Atomic Spectra* is a rather successful attempt to offer this synthesis for the 20th century. Seeing the expansion of physics, the recent flood of scientific information filled him with anxiety. At his age of 85 he was asked by Hungarian secondary school students about his view of the future (1987, Marx, 1994]:

"*Well, please, it is a hard question. The realm of physics has been extended tremendously. In the first book I ever read about physics when I was 17,* [written by Sándor Mikola] *it said: 'Atoms and molecules may exist but this is irrelevant from the viewpoint of physics.' Only chemists were interested in atoms. It is marvelous that physics succeeded to explain the atoms. It is not clear whether such a success will be also reached in the future. How far humans can progress in science is not clear.*

Physics have offered me a lot of joy. I loved physics. I still love it. But I cannot grasp a considerable part of recent physics: it is getting too complex and too sophisticated for me. But if a single person is able to catch only smaller and smaller fractions of science, if one cannot understand the essence of science, young people may lose their interest in it. Today it is almost impossible to know the whole of physics. I consider this complexity to be a danger for the future of science. If people don't get an overview, they may become less interested. If they are not interested, they will not learn science. If young people will not study science, that will terminate the development of science.

I am deeply worried that we have not yet received any message from alien civilizations. It is probable that there are other habitable planets; people or other similar creatures may live on them. It is likely that some of these civilizations have developed more knowledge than we did. Therefore it is surprising that they have not established contact with us. I don't think on a direct visit because of the huge distances, but they might use telecommunication. I am surprised that there is only one Earth and only one race which is interested. There are two possible explanations for this puzzle. One possibility is that they developed science and technology in the past, they started an armament race, and then they annihilated themselves and their whole planet. If this is a rule of the development of intelligence, it could explain the silence. Another possibility is that they developed science, which increased their standard of living. The luxury made them lazy, they gave up reading books and learning science. It is also possible that physics turned *out to be too complicated for them, thus they found it boring, and stopped being interested in science. This is why those beings ahead of us by 50 years or more are not interested in contacting us. I hope I am wrong. I hope my fear of an end of the story is mistaken. I don't know."*

In the last two decades *Wigner Jenő* visited his home country several times, lectured to students and professors, published in the Hungarian physics monthly *Fizikai Szemle*. He had become honorary member of the Hungarian Physical Society (as Neumann and Teller had) and also member of the Hungarian Academy of Sciences. Now Professor Wigner has left us. He was buried in the Princeton Cemetery on the side of his former wife Mary. In Hungary, several hundreds of people attended the Memorial Session on the 23rd January 1995. Newspapers brought obituaries, physics teachers spoke about his scientific and historic importance to their students. The New York Times printed a six-columns-obituary about *the bold physicist who changed science's perception of subatomic particles* and *who helped usher in the Atomic Age.* The New York Times wrote:

"Dr. Wigner was part of a circle of remarkably visionary scientists born and educated in Budapest who eventually came to the West and transformed the modern world."

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