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Same as in
application to NSF
dated Aug 1956
and appl to NIH,
dated June 23, 1959

Leo Szilard

Curriculum Vitae
(including list of Publications)

I was born in Budapest, Hungary in 1898. I went through officers' school there during the first World War and studied engineering there.

In 1920 I left Hungary to continue my engineering studies in Berlin. However, the attraction of physics proved to be too great. Einstein, Planck, Von Laue, Schroedinger, Nernst, Haber, and Franck were at that time all assembled in Berlin and attended a journal club in physics which was also open to students. I switched to physics and obtained a Doctor's degree in physics at the University of Berlin under Von Laue in 1922. My thesis (1 - see attached list of publications) showed lthat the Second Law of Thermodynamics covers not only the mean values, as was up to then believed, but also determines the general form of the law that governs the fluctuations of the values.

Subsequently, I was a research worker in one of the Kaiser Wilhelm Institutes in Berlin and later joined the teaching staff of the University of Berlin (as Privatdozent) where I remained until 1933. Of the papers (1 - 4) published during this period, some are experimental, and some are theoretical. The last one (4) established the connection between entropy and information which forms part of present day information theory.

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In the summer of 1934 I started work as a guest in St. Bartholomew's Hospital in London and this work resulted in the establishment of the Szilard-Chalmers Reaction (5) and the discovery that slow neutrons are emitted by beryllium if the beryllium is exposed to gamma rays of radium (6). In 1939, after the discovery of the fission of uranium, the use of these slow neutrons from beryllium made it possible to see that uranium emits neutrons when bombarded by neutrons; the fast neutrons emitted by uranium could be easily distinguished from the bombarding slow neutrons.

In 1935, after a visit to New York, where I spent a few months as research associate at New York University, I accepted a position at the Clarendon Laboratory, Oxford University. During this period I worked in the field of nuclear physics (8-11). In 1938 I came to America under arrangement with Oxford University, which permitted me to spend half my time in the United States. I was in the United States during the time the Munich Agreement was negotiated. After Munich I decided to stay in the United States on a full-time basis, and I resigned at Oxford.

In January 1939 I learned of the discovery of fission. It seemed important to find out at once if neutrons are emitted in that process, for in that case a chain reaction in uranium had to be regarded as a serious possibility. I therefore asked the permission of Columbia University to work there as a guest and perform an experiment in order to settle this question. This experiment (jointly performed with Walter Zinn) led to the discovery of the neutron emission of uranium, upon which the chain reaction is based (12,13). The same discovery was made independently at about the same time by Fermi and his co-workers and by Joliot and his group.

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Recently a patent was granted to the Atomic Energy Commission on the chain-reacting graphite-uranium system, jointly in the names of Enrico Fermi and myself.

In 1943 I became a naturalized citizen of the United States.

In October, 1946 I joined the staff of the University of Chicago as Professor of Biophysics in the Institute of Radiobiology and Biophysics. This institute never grew as originally intended, it had a succession of directors, and it was recently dissolved. I remained on the staff of the University of Chicago [but have so far not joined any department in the biology division.] as Professor of Biophysics and was transferred to the Enr. F. Inst. for Nucl. Studies

Term 1959 appt. {[I should perhaps mention here that I have been for a number of years also Visiting Professor in the Department of Biophysics of the Medical School at the University of Colorado.]

When in 1946 I was faced with the task of converting myself into a biologist, I teamed up with Dr. Aaron Novick, a physical chemist. I had known him from his work in the uranium project. We both got our training in biology through summer courses, such as Dr. Delbrück's course in Cold Spring Harbor in bacterial viruses, and Dr. VanNiel's course in bacterial bio-chemistry at Pacific Grove. Dr. Novick and I worked as a team until [recently when] the Institute of Radiobiology and Biophysics was dissolved.

A list of publications is attached, containing a short description of each paper. When we started out, we tried to understand a striking phenomenon just then discovered by A. Kelner, who showed that bacteria killed by ultraviolet light can be reactivated by shining visible light at them. (B1) A detailed analysis of the phenomenon enàbled us to interpret it in terms of a "poison" that is produced by ultraviolet light and is decomposed by visible light. This interpretation was at first controversial due to Dulbecco's work on light reactivation of ultraviolet killed bacterial viruses, but has in the meantime become widely accepted. My own interest in the subject waned when I could not convince myself that we were dealing with a phenomenon that serves a useful biological purpose in the life of the bacteria.

Next, we turned our attention to the study of bacterial viruses in the assumption that viruses may prove to be much simpler than bacteria. We obtained some very interesting results (2) but decided to shift after a while to the study of bacteria.

The two phenomena in which we were particularly interested were a) mutations and b) the formation of adaptive enzymes which promised to provide a tool for the study of protein synthesis.

We were dissatisfied, however, with the methods that were available for the study of these phenomena. It seemed to us necessary to study bacterial populations in the growing condition in a stationary state, i.e. we thought we ought to use a continuous flow device. We developed such a device, which we called a "Chemostat." In this particular device the rate of growth of the bacteria can be changed by changing the concentration of one of the growth factors of our choosing which we make the controlling growth factor.

We started out by using the "Chemostat" for the study of mutations and obtained quite unexpected results at the very outset. It turned out, for instance, that the rate at which certain mutations occur does not change when we change the rate at which the bacteria divide; we could vary the rate of growth within a wide range without changing the rate at which these mutations occurred. We found one family of compounds - purines - which may cause an about tenfold increase in the mutation rate of bacteria without any appreciable killing. And we also found antimutagens, which in very small contractions will fully counteract the effect of purine-type mutagens.

In a bacterial population maintained in the "Chemostat" there occur evolutionary changes (3) and one strain of bacteria is replaced by a mutant strain, which can grow faster in the conditions prevailing in the growth tube of the "Chemostat." We observed successive evolutionary steps of this sort in each experiment of sufficiently long duration and were able to analyze the phenomenon..

[Experiments on adaptive enzyme formation performed by means of the "Chemostat" are still in their infancy but it seems that the the "Chemostat" will prove to be a necessary tool in that field also.]

1959: After the dissolution of the Inst. of Radiobiol. + Biophys. I did not maintain a laboratory. In the last few years my interests centered mainly on quant. studies of general biological phenomena with strong emphasis on molecular biol. The paper I published most recently attempts to give a quant. theory of the process of aging which should be applicable to humans,

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Dr. Szilard's part in bringing about of the first nuclear chain reaction; in the design of the first nuclear reactor (atomic pile) are described, insofar as these matters lcan be made public, in the Official Report: Atomic Energy for Military Purposes, Henry D. Smythe, 1945, Princeton University Press, pages 34, 47, etc.

PUBLICATIONS OF LEO SZILARD FROM 1948 - 1955

17) A.Novick and Leo Szilard - EXPERIMENTS ON LIGHT-REACTIVATION OF ULTRA-VIOLET INACTIVATED BACTERIA. Proceedings of the NATIONAL ACADEMY OF SCIENCES. Vol.35,No.10, pp.591-600.

18) Aaron Novick and Leo Szilard - VIRUS STRAINS OF IDENTICAL PHENOTYPE BUT DIFFERENT GENOTYPE. Science, January 12,1951, Vol. 113, No.2924, pp.34-35.

19) Aaron Novick and Leo Szilard - EXPERIMENTS WITH THE CHEMOSTAT ON SPONTANEOUS MUTATIONS OF BACTERIA. Proceedings of the NATIONAL ACADEMY OF SCIENCES. Vol.36, No.12, pp. 706-719, December, 1950.

20) Aaron Novick and Leo Szilard - DESCRIPTION OF THE CHEMOSTAT. Science, December 15, 1950. Vol.112,No.2920, pp.715-716.

21) Aaron Novick and Leo Szilard - EXPERIMENTS ON SPONTANEOUS AND CHEMICALLY INDUCED MUTATIONS OF BACTERIA GROWING IN THE CHEMOSTAT. Cold Spring Harbor Symposia on Quantitative Biology. Vol.XVI,1951.

22) Aaron Novick and Leo Szilard - ANTI-MUTAGES. Nature, Vol.170, p.926, November 29, 1952.

23) Aaron Novick and Leo Szilard - EXPERIMENTS WITH THE CHEMOSTAT ON THE RATES OF AMINO ACID SYNTHESIS IN BACTERIA. Dynamics of Growth Processes. Princeton University Press, pp.21-32, 1954.

24) Maurice S.Fox and Leo Szilard- A DEVICE FOR GROWING BACTERIAL POPULATIONS UNDER STEADY STATE CONDITIONS. Journal of General Physiology 39, p.261-6, 1955.

The first of these papers (#17) investigates a phenomenon discovered by A. Kelner after the war, who showed that bacteria "killed" by ultra-violet light can be revived by shining visible light on them. Experiments designed to analyze the phenomenon are described in this paper; they lead to the conclusion that the ultra-violet light produces a "poison" which can be inactivated by light and that this "poison", if present when, subsequent to irradiation, the bacteria divide, will cause both death and mutations.

The second paper (#18) describes the discovery that, when a bacterium is infected simultaneously with two related viruses which differ from each other both in genotype and phenotype, the virus population emerging from the bacterium contains a class of viruses which have the genotype of one and the phenotype of the other.

The papers #19 to #23 describe a new way of studying bacteria by maintaining a bacterial population in a stationary (exponentially growing) state indefinitely and controlling the growth rate by controlling the rate of supply of an essential growth factor. An apparatus is described in these papers which will conveniently accomplish this and which is designated as the Chemostat.

In studying mutations in bacteria or the formation of adaptive enzymes in bacteria inaccurate, and therefore misleading, results are frequently obtained by studying bacterial cultures in flasks in which the number of bacteria increases exponentially and today the use of the Chemostat appears to be indispensable.

In the papers #19 to #22, the Chemostat is used in the study of mutations. It turns out that the rate at which mutations occur in a growing bacterial population under the conditions studied is not proportional to the rate at which cell division occurs, rather the mutation rate is constant per unit time independent of the rate at which the culture is growing. There is found one group of compounds, all purine derivatives, of which caffein is one, which greatly increases the mutation rate without having an appreciable killing effect on the bacteria.

There is another group of compounds described in these papers, all of them ribosides of purines which in small quantities will completely counteract the action of the above mentioned purine type mutagens and also reduce the rate of spontaneous mutations.

In paper #23, the Chemostat is used to study the bio-synthesis of amino acids in bacteria and the regulatory mechanisms which are involved in it. The bio-synthetic apparatus of the bacteria respond to amino acid concentrations in the medium, which are exceedingly low. For instance, a bacterium which can make arginine and will do so if there is no arginine in the medium, will stop making arginine if an arginine concentration of 10^{-9} ga/ce is maintained in the medium in the Chemostat. (Novick and Szilard - unpublished.)

One way of studying such regulatory mechanisms is based on the use of a mutant which is blocked in the synthesis of an amino acid -- in our case Tryptophane -- and which pours out into the medium a "precursor" of that amino acid. Paper #23 utilizes such a mutant. In the absence of Tryptophane in the medium, a precursor of Tryptophane is poured out by the mutant into the medium at a rate which is independent of the growth rate of the bacteria. In the presence of Tryptophane this "precursor" is <u>not</u> poured out by the bacteria. It is conceivable that this indicates a general phenomenon of regulation through a negative feed-back of the final product at one of the <u>early</u> steps of the metabolic pathway leading to Tryptophane.

In paper #24, there is described a device called a breeder. In this device bacteria may be grown in a continuous flow of nutrient. The flow of the nutrient is controlled by the turbidity of the bacterial culture and the growth is not limited by a growth factor, as is the case in the "Chemostat."

This device was developed in order to study mutations in bacteria under conditions of growth at the maximal rate, and such a study was carried out by Maurice S. Fox.

Paper # 25 develops a theory of the basic
process of aging. etc: see PHS appl. June 1959

Curriculum B – 3 pages original
+ 2 page list of Physics
Papers 1956 M 0

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Curriculum A$_2$ incl. Physics + Biol. Bibliography up to 1955 M (10 pages)

10 pages

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PARTIAL BIBLIOGRAPHY OF DR. LEO SZILARD*

A. Physics

(1) Zeitschrift fur Physik, 1925, p. 753, 32. This paper extends the application of thermodynamics to the derivation of the laws of thermodynamical fluctuations. It was accepted as dissertation by the University of Berlin.

(2) Zeitschrift fur Physik, 1925, p. 688,33. - jointly with H. Mark. This paper reports experiments which revealed anomalous scattering of X-rays.

(3) Zeitschrift fur Physik, 1926, p. 743,35. - jointly with H. Mark. This paper reports experiments on polarizing X-rays by reflection on crystals.

(4) Zeitschrift fur Physik, 1929, p. 840,35. This paper evaluates the increase of entropy which is connected with operations of an intelligent being on a thermodynamical system if these operations are controlled by measurements of variables which are subject to thermodynamical fluctuations. This paper was accepted as Habilitationschrift by the University of Berlin.

(5) "Chemical Separation of the Radioactive Element from its Bombarded Isotope in the Fermi Effect" - - - jointly with Chalmers. Nature, p. 462, 134, 1934. This paper demonstrates a generally applicable process (Szilard-Chalmers reaction) for the concentration of a radioactive element produced by neutrons if the element has to be separated from a mass of a stable element with which it is chemically isotopic.

(6) "Detecting Neutrons Liberated from Beryllium by Gamma Rays," p. 494, 134, 1934. Nature.
This paper describes the discovery of radium-beryllium photo neutrons which,being of low energy, represent a useful tool in nuclear research. They were universally used later in the discovery and investigation of neutron emission of uranium on which a chain reaction is based.

(7) "Liberation of Neutrons from Beryllium by X-Rays" - - - jointly with a group of six others, p. 880, 134, 1934. Nature. Using X-rays in place of gamma rays the threshold for the emission of photo neutrons from beryllium is determined by varying the voltage of an X-ray tube and is found to be somewhat above 1.5, and well below 2 m.e.v.

(8) "Radioactivity Induced by Neutrons" - - - jointly with Chalmers, p. 98, 135, 1935. Nature. In this paper a neutron induced radioactive period of about 3-1/2 hours is reported in Indium which does not fit in with the explanations found for other radioactive periods. In a later paper it is shown that it is due to an excited Indium nucleus which is isomeric with stable indium nucleus 115.

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*Some of Dr. Szilard's most important works still remain unpublishable, for reasons of national security.

(9) "Absorption of Residual Neutrons," p. , 136, 1935. <u>Nature</u>. This paper reports the discovery of neutron resonances at low energies, gives an estimate of their energies, and states that the energies can be measured by observing the absorption of the residual neutrons in boron or lithium.

(10) "Gamma Rays Excited by Capture of Neutrons," p. 323, 139, 1937 - - - jointly with Griffiths. <u>Nature</u>. This paper reports on the observation of gamma rays emitted by a number of odd elements which are strong neutron absorbers. The counts observed per absorbed neutron were found to be 15 per cent identical for all these elements.

(11) "Radioactivity Induced by Nuclear Excitation" - - - jointly with Goldhaber and Hill, p. 47, 55. 1939. <u>Phys. Rev.</u> In this paper the previously reported period in indium is investigated and the conclusion is reached that it is due to nuclear excitation of the stable indium isotope 115.

(12) "Instantaneous Emission of Fast Neutrons in the Interaction of Slow Neutrons with Uranium" - - - jointly with Zinn, p. 799, 55, 1939. <u>Phys. Rev.</u> In this paper the discovery of the neutron emission of uranium is reported. It is estimated that two neutrons are emitted per fission. The neutrons from uranium are made visible on an oscillograph screen. As primary neutrons, radium-beryllium photo neutrons were used which, because they are slow, can be easily distinguished from the fast neutrons emitted by uranium. This discovery which was made independently by Fermi in the same year indicated the feasibility of a sustaining nuclear chain reaction.

(13) "Emission of Neutrons by Uranium" - - - jointly with Zinn. p. 619, 56. 1939. <u>Phys. Rev.</u> Detailed report of above mentioned experiments, number of neutrons per fission measured as 2.3.

(14) "Neutron Production and Absorption in Uranium" - - - jointly with Anderson and Fermi. p. 284, 56, 1939. <u>Phys. Rev.</u> This paper reports an investigation on the chain reaction qualities of a uranium-water system. It is estimated that 1.5 neutrons are emitted for every thermal neutron which is absorbed by uranium.

Dr. Szilard's part in bringing about of the first nuclear chain reaction; in the design of the first nuclear reactor (atomic pile) are described, insofar as these matters can be made public, in the Official Report: Atomic Energy for Military Purposes, Henry D. Smythe, 1945, Princeton University Press, pages 34, 47, etc.

B. Biology

1) A. Novick and Leo Szilard - EXPERIMENTS ON LIGHT-REACTIVATION OF ULTRA-VIOLET INACTIVATED BACTERIA. Proceedings of the NATIONAL ACADEMY OF SCIENCES. Vol. 35, No. 10, pp. 591-600. ✓Bio 1

2) Aaron Novick and Leo Szilard - VIRUS STRAINS OF IDENTICAL PHENOTYPE BUT DIFFERENT GENOTYPE. Science, January 12, 1951, Vol. 113, No. 2924, pp. 34-35. ✓Bio 2

3) Aaron Novick and Leo Szilard - EXPERIMENTS WITH THE CHEMOSTAT ON SPONTANEOUS MUTATIONS OF BACTERIA. Proceedings of the NATIONAL ACADEMY OF SCIENCES. Vol. 36, No. 12, pp. 708-719, December, 1950. Bio 3

4) Aaron Novick and Leo Szilard - DESCRIPTION OF THE CHEMOSTAT. Science, December 15, 1950. Vol. 112, No. 2920, pp. 715-716. Bio4

5) Aaron Novick and Leo Szilard - EXPERIMENTS ON SPONTANEOUS AND CHEMICALLY INDUCED MUTATIONS OF BACTERIA GROWING IN THE CHEMOSTAT. Cold Spring Harbor Symposia on Quantitative Biology. Vol. XVI, 1951.

6) Aaron Novick and Leo Szilard - ANTI-MUTAGENS. Nature, Vol. 170, p. 926. November 29, 1952.

7) A. Novick and Leo Szilard - EXPERIMENTS WITH THE CHEMOSTAT ON THE RATES OF AMINO ACID SYNTHESIS IN BACTERIA. Dynamisc of Growth Processes. Princeton University Press, pp. 21-32, 1954.

8) Maurice S. Fox and Leo Szilard - A DEVICE FOR GROWING BACTERIAL POPULATIONS UNDER STEADY STATE CONDITIONS. Journal of General Physiology 39, p. 261-6, 1955.

The first of these papers (#1) investigates a phenomenon discovered by A. Kelner after the war, who showed that bacteria "killed" by ultra-violet light can be revived by shining visible light on them. Experiments designed to analyse the phenomenon are described in this paper; they lead to the conclusion that the ultra-violet light produces a "poison" which can be inactivated by light and that this "poison," if present when, subsequent to irradiation, the bacteria divide, will cause both death and mutations.

The second paper (#2) describes the discovery that, when a bacterium is infected simultaneously with two related viruses which differ from each other both in genotype and phenotype, the virus population emerging from the bacterium contains a class of viruses which have the genotype of one and the phenotype of the other.

The papers #3 to #7 describe a new way of studying bacteria by maintaining a bacterial population in a stationary (exponentially growing) state indefinitely and controlling the growth rate by controlling the rate of supply of an essential growth factor. An apparatus is described in these papers which will conveniently accomplish this and which is designated as the Chemostat.

In studying mutations in bacteria or the formation of adaptive enzymes in bacteria inaccurate, and therefore misleading, results are frequently obtained by studying bacterial cultures in flasks in which the number of bacteria increases exponentially and today the use of the Chemostat appears to be indispensable.

In the papers #3 to #6, the Chemostat is used in the study of mutations. It turns out that the rate at which mutations occur in a gorwing bacterial population under the conditions studied is not proportional to the rate at which cell division occurs, rather the mutation rate is constant per unit time independent of the rate at which the culture is growing. There is found one group of compounds, all purine derivatives, of which caffein is one, which greatly increases the mutation rate without having an appreciable killing effect on the bacteria.

There is another groupof compounds described in these papers, all of them ribosides of purines which in small quantities will completely counteract the action of the above mentioned purine type mutagens and also reduce the rate of spontaneous mutations.

In paper #7, the Chemostat is used to study the biosynthesis of amino acids in bacteria and the regulatory mechanisms which are involved in it. The bio-synthetic apparatus of the bacteria respond to amino acid concentrations in the medium, which are exceedingly low. For instance, a bacterium which can make arginine and will do so if there is no arginine in the medium, will stop making arginine if an arginine concentration of 10^{-9} gm/cc is maintained in the medium in the Chemostat. (Novick and Szilard - unpublished.)

One way of studying such regulatory mechanisms is based on the use of a mutant which is blocked in the synthesis of an amino acid -- in our case Tryptophane -- and which pours out into the medium a "precursor" of that amino acid. Paper #7 utilizes such a mutant. In the absence of Tryptophane in the medium, a precursor of Tryptophane is poured out by the mutant into the medium at a rate which is independent of the growth rate of the bacteria. In the presence of Tryptophane this "precursor" is <u>not</u> poured out by the bacteria. It is conceivable that this indicates a general phenomenon of regulation through a negative feed-back of thefinal product at one of the <u>early</u> steps of the metabolic pathway leading to Tryptophane.

In paper #8, there is described a device called a breeder. In this device bacteria may be grown in a continuous flow of nutrient. The flow of the nutrient is controlled by the turbidity of the bacterial culture and the growth is not limited by a growth factor, as is the case in the "Chemostat."

This device was developed in order to study mutations in bacteria under conditions of growth at the maximal rate, and such a study was carried out by Maurice S. Fox.

② Curriculum A, M O

First version (addl. § on page 3) without bibliography 6 pages

Leo Szilard 1955

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Subsequently, I was a research worker in one of the Kaiser Wilhelm institutes in Berlin and later joined the teaching staff of the University of Berlin (as Privatdozent) where I remained until 1933. Of the papers (1 - 4) published during this period, some are experimental, and some are theoretical. The last one (4) established the connection between entropy and information which forms part of present day information theory.

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of this possibility, it seemed that this was a matter in which the government ought to take an interest. I therefore went to see Professor Einstein to enlist his help in approaching the government. After several consultations, in which E. P. Wigner and Edward Teller participated, Einstein wrote a letter to President Roosevelt; and in response to this letter, the President appointed a committee under the chairmanship of the Director of the National Bureau of Standards.

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Reviewed c̄ Balazs Jan 26, 1964

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BIOGRAPHICAL DATA AND LIST OF PUBLICATIONS OF LEO SZILARD FROM 1922 to 1946

1948 – 1955 + References Bull. At. Sc.

I obtained my doctor's degree in Physics at the University of Berlin in 1922. My dissertation showed that the second law of thermodynamics permits to draw conclusions on the laws that control thermodynamic fluctuations. This dissertation was published in 1925.

have (1) Zeitschrift für Physik, 1925, p.753,-788 32.

"Über die Ausdehnung der phänomenologischen Thermodynamik auf die Schwankungserscheinungen"

Subsequently I worked for about two years with H. Mark at the Kaiser Wilhelm Institute für Faserstoffchemie in Berlin Dahlem. Our work on the anomalous scattering of X-rays in crystals and on the polarization of X-rays by reflection on crystals, resulted in two papers:

fehlt (2) Zeitschrift für Physik, 1925, p.688, 33.

(3) Zeitschrift für Physik, 1926, p.743,-47 35.

"Die Polarisierung von Röntgenstrahlen durch Reflexion an Kristallen"

Subsequently I was, for three years, Assistant at the Institute für Theoretische Physik at the University of Berlin (Director Prof. Max von Laue).

During this period I investigated the apparent decrease in entropy in a system in which variables that are subject to thermodynamic fluctuations are "observed", and used to control operations. This led me to the recognition of the connection between "entropy" and "information" and a theorem which now forms part of "modern information theory". The resulting papers were accepted as Habilitationschrift at the University of Berlin and I was appointed Privatdozent für Physik. This paper was published in 1929:

(4) Zeitschrift für Physik, 1929, p.840,-856 35.

"Über die Entropieverminderung in einem thermodynamischen System bei Eingriffen intelligenter Wesen." (Translated 1964)

When my three year term as Assistant at the Institute für Theoretische Physik ended I received a Forschungsstipendum for one year and worked on problems of quantum theory. This work did not result in any published paper.

In the meantime jointly with Professor Albert Einstein I thought of a method of pumping liquid metals through tubes through the action of a moving magnetic field on electric currents induced by this field in the liquid metal. The German General Electric Co. (A.E.G.) wanted to develop a pump based on this principle and for about three years -- until 1932 -- I acted as a consultant to them for this development. (This principle found at last its practical application in America after the introduction of atomic reactors in 1942.) U.K. Patent 303,065 (May 26, 1930 accepted / Dec 24, 1928 applied U.K. / Dec 27, 1927 Convention date (Germ

P "Electrodynamic movement of fluid metals particularly for refrigerating machine."

~~4a)~~ While acting as a consultant to the A.E.G., I collaborated with Dr. Rupp on experiments relating to the polarization of electrons. The results were published in "Die Naturwissenschaften", but they are probably wrong. All photographic films were developed by Rupp, even those which I exposed myself, and the pictures might well have been faked. At the time it did not occur to me to entertain a suspicion of this kind. (Paper withdrawn by Rupp, according to Balazs: from Franz v. Körösy, Negev Inst. for Arid Zones, Beersheba P.O.B. 79)

~~4.b)~~
fehlt

In 1932 my interest shifted to nuclear physics and I moved to the Harnack House in Berlin Dahlem with the thought of taking up some experimental work in one of the Kaiser Wilhelm Institutes there. I discussed the possibility of doing experiments in nuclear physics with Miss Lisa Meitner in the Kaiser Wilhelm Institute für Chemie, but before we reached a final conclusion one way or the other, the political situation in Germany became tense and it seemed advisable to delay a final decision.

I was still at the Harnack House at the time of the Reichstagsbrand in March 1933 but soon thereafter went to England. The laws promulgated by the National Socialist Government barred me from holding a University position in Germany by virtue of my "non-Aryan" descent, and I remained in England until 1938.

I began my work in nuclear physics in the summer of 1934 as guest of St. Bartholomew's Hospital in London. There, together with Chalmers, I developed a method (Szilard Chalmers separation) for the concentration of radioactive elements produced by neutrons. This method is used if a radioactive element has to be separated from the bulk of the stable element from which it is produced and with which it is chemically isotopic. This work was published in 1934:

(5) "Chemical Separation of the Radioactive Element from its Bombarded Isotope in the Fermi Effect" -- Szilard and Chalmers. Nature, p.462, 134, 1934.
463

Together with Chalmers I found that Gamma Rays from radium eject neutrons from beryllium. These photoneutrons of beryllium are of low energy. (In 1939 when I investigated with Zinn whether uranium emits neutrons in the fission process, the use of these slow photo neutrons as a primary neutron source made it possible for us to distinguish the fast neutrons emitted in the fission process from the primary neutrons.) The discovery of the photoneutrons from beryllium was published in 1934:

(6) "Detecting Neutrons Liberated from Beryllium by Gamma Rays," Szilard and Chalmers, Nature, p.494, 134, 1934.

In 1934 it was generally believed that the mass of the beryllium atom was sufficient to permit its spontaneous disintegration into two alpha particles and a neutron. Since such spontaneous disintegration did not occur it seemed important to investigate the energy threshold for a photo disintegration of beryllium X-rays. This was done jointly with six other authors. The threshold for photo-neutrons from beryllium was determined by varying the voltage of an X-ray tube and was found to be somewhere about 1.5 and well below 2 m.e.v. This information was partially responsible for inducing Bethe to revise the accepted mass of He and thereby to resolve the paradox of the stability of beryllium. Our paper was published in 1934:

(7) : Radioactivity Induced by Means of Electron Tubes

> "Liberation of Neutrons from Beryllium by X-rays" --jointly with a group of six others. Nature, p.880, 134, 1934.
> 135

Working with Chalmers I found that indium, which has only two isotopes, shows three radioactive periods when bombarded by neutrons. This was the first case of isomerism found among the artificial radioactive elements, and we recognized its importance. Subsequently, it was possible for me to show [see (11)] that one period is due to an excited indium nucleus which is isomeric with the stable indium nucleus 115. Our results obtained in 1934 were published in 1935:

(8)

> "Radioactivity Induced by Neutrons" -- Szilard and Chalmers. Nature, p.98, 135, 1935.

In June 1935 I accepted a research fellowship at the Clarendon Laboratory, Oxford.

Working at the Clarendon Laboratory, I discovered that if a slow neutron beam is filtered by cadmium, in order to remove the thermal neutrons, the residual neutrons show strong resonance absorptions at low energies in various elements. I was able to estimate the energy region at which these resonances occurred and to state that the resonance energy can be determined by observing the absorption of the neutrons in boron or lithium. This work was published in 1935:

~~fehlt~~

(9)
"Absorption of Residual Neutrons".
Nature, p. 136, 1935.

Working at the Clarendon Laboratory jointly with Griffiths, I investigated the Gamma Ray emission that occurs when slow neutrons are absorbed by odd elements. This work was published in 1937:

9a) Withdrawn "Radioactivity induced by neutrons" submitted Nov 1936 to Nature

(10)
"Gamma Rays Excited by Capture of Neutrons".
Griffiths and Szilard, Nature, p.323, 139, 1937.

~~fehlt neue~~ Nummer have

In January 1938 I went to the U. S. on a visiting basis under a new arrangement with the Clarendon Laboratory. While I was there, I received an offer of a lectureship in nuclear physics at Oxford University. In September 1938 I declined this offer, resigned from Clarendon Laboratory, and shifted my residence to New York.

In 1938, using the Rochester cyclotron, I found that one of the radioactive periods of indium which Chalmers and I had previously discovered was due to the nuclear excitation of the stable isotope 115. This conclusion, reached jointly with Goldhaber and Hill, we published in 1939:

(11)
"Radioactivity Induced by Nuclear Excitation" --
Szilard, Goldhaber and Hill, Physical Review,
p.47, 55, 1939
49

After the discovery of fission by Hahn and Strassman, I found, jointly with Walter Zinn, that fast neutrons are emitted in the fission process and that their number is about two per fission. The neutron emission in the fission of uranium was discovered independently, and about the same time, by Halban, Joliot and Kowarsky, and By Anderson and Fermi. This discovery revealed that the element uranium might sustain a chain reaction -- In our experiment, photoneutrons from beryllium were used as a primary neutron source and the fast neutrons emitted in the fission were made visible by using a hydrogen filled ionization chamber, and by recording the recoil protons. Our results were published in 1939:

(12) "Instantaneous Emission of Fast Neutrons in the Intersection of Slow Neutrons with Uranium" Szilard and Zinn, Physical Revue, p.799 800, 55,1939.

(13) "Emission of Neutrons by Uranium" -- Zinn and Szilard, Physical Revue, p.619 624, 56,1939.

The discovery of the neutron emission in the fission of uranium raised the question whether a chain reaction can in fact be sustained in a system containing uranium. A system composed of water and uranium-oxide was investigated by me jointly with Anderson and Fermi in the spring of 1939. We reached the conclusion that such a system came close to being chain-reacting but could not be used for a self-sustaining chain reaction. Our results were published in 1939:

(14) "Neutron Production and Absorption in Uranium" Physical Revue, p.284, 56, 1939.

In July 1939 I reached the conclusion that a graphite uranium system is likely to support a self-sustaining chain reaction, and I derived an approximate formula for a lattice of uranium spheres embedded in graphite. My manuscript, entitled "Divergent Chain Reactions in a System Composed of Uranium and Carbon", was submitted to the Physical Revue on February 16, 1940, and was accepted for publication. Publication was indefinitely deferred at the request of the U.S.Government.

(15) ? See manuscript

"Divergent Chain Reaction in a System Composed of Uranium and Carbon" received by the Physical Revue, February 16, 1940 - unpublished.

(The chain reaction based on this system was first demonstrated on December 2, 1942 at Stagg Field on the campus of the University of Chicago. See official U.S. report: "Atomic Energy for Military Purposes," Henry D. Smythe, 1945, Princeton University Press. A patent describing the system for which Fermi and I applied in 1944, was granted in 1955 to the U.S. Atomic Energy Commission, and named Fermi and me as inventors. See Fermi and Szilard, U.S. Patent No. 2,798,656.)

From February 1939 to November 1940 I worked as guest of Columbia University. In November 1940 I became a member of the staff of the Columbia University under a contract given by the U.S. Government to the University "for the purpose of developing the system proposed by Fermi and Szilard". Early in 1942 the group was transferred to the University of Chicago where I was a member of the staff of the Metallurgical Laboratory of the University of Chicago which was the code name for the uranium project. I held the position of "Chief Physicist" in that Laboratory until I resigned in 1946.

In October 1946, I was appointed to my present position as a full professor on the regular staff of the University of Chicago.

Beginning of Biology 1)

PUBLICATIONS OF LEO SZILARD FROM 1948 - 1955

~~15~~ 16 -1) A. Novick and Leo Szilard - Bio 1 EXPERIMENTS ON LIGHT-REACTIVATION OF ULTRA-VIOLET INACTIVATED BACTERIA. Proceedings of the NATIONAL ACADEMY OF SCIENCES. Vol. 35, No. 10, pp. 591-600, Oct 1949

~~18~~ 19 -2) Aaron Novick and Leo Szilard - Bio 2 VIRUS STRAINS OF IDENTICAL PHENOTYPE BUT DIFFERENT GENOTYPE. Science, January 12, 1951, Vol. 113, No. 2924, pp. 34-55.

~~17~~ 18 -3) Aaron Novick and Leo Szilard - Bio 3 EXPERIMENTS WITH THE CHEMOSTAT ON SPONTANEOUS MUTATIONS OF BACTERIA. Proceedings of the NATIONAL ACADEMY OF SCIENCES. Vol. 36, No. 12, pp. 706-719, December, 1950.

~~16~~ 17 -4) Aaron Novick and Leo Szilard - Bio 4 DESCRIPTION OF THE CHEMOSTAT. Science, December 15, 1950. Vol. 112, No. 2920, pp. 715-716.

~~19~~ 20 -5) Aaron Novick and Leo Szilard - Bio 5 EXPERIMENTS ON SPONTANEOUS AND CHEMICALLY INDUCED MUTATIONS OF BACTERIA GROWING IN THE CHEMOSTAT. Cold Spring Harbor Symposia on Quantitative Biology. Vol. XVI, 1951.

~~20~~ 21 -6) Aaron Novick and Leo Szilard - Bio 6 ANTI-MUTAGENS. Nature, Vol. 170, p. 926, November 29, 1952.

~~21~~ 22 -7) A. Novick and Leo Szilard - Bio 7 EXPERIMENTS WITH THE CHEMOSTAT ON THE RATES OF AMINO ACID SYNTHESIS IN BACTERIA. Dynamics of Growth Processes. Princeton University Press, pp. 21-32, 1954.

~~22~~ 23 - 8) Maurice S. Fox and Leo Szilard - Bio 8 A DEVICE FOR GROWING BACTERIAL POPULATIONS UNDER STEADY STATE CONDITIONS. Journal of General Physiology 39, p. 261-6, 1955.

The first of these papers ① investigates a phenomenon discovered by A. Kelner after the war, who showed that bacteria "killed" by ultra-violet light can be revived by shining visible light on them. Experiments designed to analyze the phenomenon are described in this paper; they lead to the conclusion that the ultra-violet light produces a "poison" which can be inactivated by light and that this "poison", if present when, subsequent to irradiation, the bacteria divide, will cause both death and mutations.

The second paper (2) describes the discovery that, when a bacterium is infected simultaneously with two related viruses which differ from each other both in genotype and phenotype, the virus population emerging from the bacterium contains a class of viruses which have the genotype of one and the phenotype of the other.

The papers Nos. 3 to 7 describe a new way of studying bacteria by maintaining a bacterial population in a stationary (exponentially growing) state indefinitely and controlling the growth rate by controlling the rate of supply of an essential growth factor. An apparatus is described in these papers which will conveniently accomplish this and which is designated as the Chemostat.

In studying mutations in bacteria or the formation of adaptive enzymes in bacteria inaccurate, and therefore misleading, results are frequently obtained by studying bacterial cultures in flasks in which the number of bacteria increases exponentially and today the use of the Chemostat appears to be indispensable.

In the papers Nos. 3 to 6, the Chemostat is used in the study of mutations. It turns out that the rate at which mutations occur in a growing bacterial population under the conditions studied is not proportional to the rate at which cell division occurs, rather the mutation rate is constant per unit time independent of the rate at which the culture is growing. There is found one group of compounds, all purine derivatives, of which caffein is one, which greatly increases the mutation rate without having an appreciable killing effect on the bacteria.

There is another group of compounds described in these papers, all of them ribosides of purines which in small quantities will completely counteract the action of the above mentioned purine type mutagens and also reduce the rate of spontaneous mutations.

In paper No. 7, the Chemostat is used to study the biosynthesis of amino acids in bacteria and the regulatory mechanisms which are involved in it. The biosynthetic apparatus of the bacteria respond to amino acid concentrations in the medium, which are exceedingly low. For instance, a bacterium which can make arginine and will do so if there is no arginine in the medium, will stop making arginine if an arginine concentration of 10^{-9} ga/ce is maintained in the medium in the Chemostat. (Novick and Szilard - unpublished.)

One way of studying such regulatory mechanisms is based on the use of a mutant which is blocked in the synthesis of an amino acid -- in our case Tryptophane -- and which pours out into the medium a "precursor" of that amino acid. Paper No. 7 utilizes such a mutant. In the absence of Tryptophane in the medium, a precursor of Tryptophane is poured out by the mutant into the medium at a rate which is independent of the growth rate of the bacteria. In the presence of Tryptophane this "precursor" is not poured out by the bacteria. It is conceivable that this indicates a general phenomenon of regulation through a negative feed-back of the final product at one of the early steps of the metabolic pathway leading to Tryptophane.

In paper No. 8, there is described a device called a breeder. In this device bacteria may be grown in a continuous flow of nutrient. The flow of the nutrient is controlled by the turbidity of the bacterial culture and the growth is not limited by a growth factor, as is the case in the "Chemostat."

This device was developed in order to study mutations in bacteria under conditions of growth at the maximal rate, and such study was carried out by Maurice S. Fox.

(2) Curriculum A Copy → Cherin

Leo Szilard First version - Engl. 1955

Curriculum Vitae

I was born in Budapest, Hungary in 1898. I went through officers' school there during the first World War and studied engineering there.

In 1920 I left Hungary to continue my engineering studies in Berlin. However, the attraction of physics proved to be too great. Einstein, Planck, Von Laue, Schroedinger, Nernst, Haber, and Frank were at that time all assembled in Berlin and attended a journal club in physics which was also open to students. I switched to physics and obtained a Doctor's degree in physics at the University of Berlin under Von Laue in 1922. My thesis (1 - see attached list of publications) showed that the Second Law of Thermodynamics covers not only the mean values, as was up to then believed, but also determines the general form of the law that governs the fluctuations of the values.

Subsequently, I was a research worker in one of the Kaiser Wilhelm institutes in Berlin and later joined the teaching staff of the University of Berlin (as Privatdozent) where I remained until 1933. Of the papers (1 - 4) published during this period, some are experimental, and some are theoretical. The last one (4) established the connection between entropy and information which forms part of present day information theory.

In 1933 I went to England. I considered at that time becoming a biologist, and A. V. Hill said that he would find a position for me as a demonstrator in physiology. It occurred to me, however, just then that a nuclear chain reaction might be possible if we could find an element that would emit neutrons when bombarded by neutrons. Artificial radioactivity was discovered a few months later by Joliot and seemed to provide an important new research tool in nuclear physics. This decided me to move into nuclear physics.

In the summer of 1934 I started work as a guest in St. Bartholomew's Hospital in London and this work resulted in the establishment of the Szilard-Chalmers Reaction (5) and the discovery that slow neutrons are emitted by beryllium if the beryllium is exposed to gamma rays of radium (6). In 1939, after the discovery of the fission of uranium, the use of these slow neutrons from beryllium made it possible to see that uranium emits neutrons when bombarded by neutrons; the fast neutrons emitted by uranium could be easily distinguished from the bombarding slow neutrons.

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I should perhaps mention here that I have been for a number of years also Visiting Professor in the Department of Biophysics of the Medical School at the University of Colorado.

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1898 – Feb 11, born in Budapest ①

1908 – 1916

Reáliskola, Budapest VI. (Budapester Staats oberrealschule des VI. Bezirkes)

Reifezeugnis June 27, 1916

1916 – 1919

kir. József – Műegyetem, Budapest
gépészmérnöki

(kön. Josef Technische Hochschule
Maschineningenieur Abteilung)

Registered Sept 9, 1916. Completed three years (six semesters). Passed exam
("I. Maschineningenieurrigorosum")
July 16, 1919

1917 – 1918 see p. ②

~~K. & K. Oesterreichisch – Ungarische Armee~~

~~Sept 28, 1917 entered as "Einjährig Freiwilliger" 4. k & k Gebirgsartillerie Regiment No. 18.~~

~~Reserve offizierschule, Budapest (to Gr. Kranzach (Spring 1918, ca. 3 months) Kufstein (Summer 1918, several months)~~

②

1917-1918 K. & K. Oesterreichisch-Ungarische Armee

Sept 27, 1917 entered as "Einjährig-Freiwilliger, 4. Gebirgsartillerie-regiment, No. 18.

Reserveoffiziersschule, Budapest
Kramsach, Tirol (May 1918 for ca. 3 months)
(Feuerwerker, Kadett aspirant)
Kufstein, Tirol (Saebelchargen-kurs, End August – End of September)
Reservespital No. 4, Budapest
(Attending lectures at Techn. Hochschule, Oct)
Nov 17, 1918 Discharged from "Vereinigte Ersatzbatterien der Gebirgsartillerie abteilungen 31. & 32." as Kadettaspirant" at the end of World War I.

1919 xmas Left Budapest for Berlin

1920 Technische Hochschule Berlin – Feb 9 – Nov 4 (2 semesters Maschinen Ingenieurwesen, Elektrotechnik)
During that time also took courses at K. Friedrich Wilhelms Universität (two during Winter semester 1919/20

1920 – and 4 during Sommersemester 1920, incl. v. Laue, Franck and Planck)

1920 – 1922 Friedrich Wilhelms Universität zu Berlin (Philosophische Fakultät)

Oct 30, 1920 registered. Studied ~~4~~ ⑤ KW Semesters: Winter 1920/21 to ~~Summer 1922~~) Winter 1922/23

Aug 14, 1922: Dr. phil (cum laude) (Eximia)
Dissertation:

1922 – 1924 under a Forschungsstipendium der Kaiser-Wilhelm-Gesellschaft zur Förderung der Wissenschaften

Kaiser Wilhelm Institut für Physik, Berlin-Dahlem
(Acting Dir: Max v. Laue)
→ until end of 1924

1924 – 1927 Assistent, Institut für Theoretische Physik, Friedrich Wilhelm Universität Berlin (Director: Max v. Laue)

1927 – 1933 Privatdozent
May 17, 1927 Habilitation
"Über die ~~Thermodynamischen~~...
No – This was Phil. Dr.
Nov 23, 1933 Position terminated for Political reasons

Rx Düsseldorf

Career

1916 graduated Oberrealschule, Budapest

1916-1919 Hungarian Institute of Technology
E Jösef Technische Hochschule
Electrical Engineering, Budapest

[1917-1918 Served in Hungarian Army]

1919-1920 Technische Hochschule, Berlin - Charlottenburg

1920-22 Friedrich Wilhelms Universität zu Berlin

1922 graduated Doctor Philosophiae
Dissertation: Über die th. dyn. Schwankungserscheinungen

1922-1933 Universität Berlin

1922-1924 K. W. Institut für Faserstoffchemie Berlin-Dahlem
? Assistent

1925 - 1933 Institut für Theoretische Physik (v. Laue)

1925 - ? ~~(1929)~~ Assistant

1927 ~~1929?~~ - 1933 Privatdozent

Also 1928 – 1932: Consulting Physicist
AEG

1933	March left Berlin for Vienna April " Vienna for London Academic Assistance Council
1934 – 1935	Physics Dept., St Bartholomew's Hospital, London (guest) also Feb – May 1935: Research Associate NYU
1935 – 1937	Clarendon Laboratory, Oxford Fellowship (I.C.I.)
Dec 24, 1937	Left England for N.Y. (Arr. Jan 2, 1938)
1938	Visited U.S. Laboratories officially resigned Oxford Sept 1938
1939	March 1 — June 1 Physics Dept Columbia University (guest) October 21 — became member of "Uranium Committee"
1940	June 7, — appointed member of 'Advisory Committee on Nuclear Research of the President's Committee on Uranium

1940-1942 National Defense Research Division

Nov 1, 1940 – Feb 1942 ~~appointed to~~ on Staff of Columbia University

Aug 1941 – July 1942 Appointed to Uranium Section of Ntl. Def. Res. Committee as member of consultants on power production and consultants on Theoretical Aspects

1942-1946 Metallurgical Laboratory Univ. of Chicago (Feb 1, 1942 – June 1, 1946)
Chief Physicist (Contract May 1, 1943)

1946-1964 University of Chicago

Professor of Biophysics
Oct 1946 – June 1954 Inst. for Radiobiology and Biophysics

Professor of Social Sciences
July 1954 – May 1956
also part time Oct 1949 – Sept 1950

Professor of Biophysics
July 1956 – 1963, Enrico Fermi Institute for Nuclear Studies

Professor Emeritus, Sept 30, 1963

Also:

1951 – 1953(?) Visiting Professor of
Biophysics, University of Colorado

1953 – 1954 Visiting Professor of
Sept 1 Aug 31 Physics, Brandeis University

1963 (July 1) – 1964 (April 1) Non resident
fellow, Salk Institute

1964 April 1 – Resident Fellow Salk
Institute

CURRICULUM VITAE

Name: Leo Szilard

Date and Place of Birth: February 11, 1898; Budapest, Hungary

Marital Status: Married; no children

Education:

1917-1919	Institute of Technology, Budapest
1919-1920	Institute of Technology, Berlin
1920-1922	University of Berlin, Ph.D. in physics

Positions Held:

1922-1925	Research in x-ray, Kaiser Wilhelm Institute, Berlin.
1925-1933	Privatdozent for physics, University of Berlin
1933-1934	Research in nuclear physics, St. Bartholomew Hospital, London, England
1935-1938	Research in nuclear physics, Clarendon Laboratory, London
1939-1942	Research in atomic energy, Columbia University, New York
1942-1946	Chief Physicist, Metalurgical Laboratory, University of Chicago
1946-19--	Professor of Biophysics, University of Chicago, Enrico Fermi Institute, Chicago
1963---	Non-Resident Fellow, The Salk Institute for Biological Studies, San Diego

Honors (Awards):

1959 Atoms for Peace Award

Re - Dr. Leo Szilard July 16, 1959

Leo Szilard was born in 1898, in Budapest, Hungary, and obtained his Degree of Dr. Philosophy in Physics at the University of Berlin in 1922. In his Doctor's dissertation, he demonstrated the connection between the Second Law of Thermodynamics on the one hand and the relation of entropy and probability on the other. He became a privatdozent for Physics at the University of Berlin in 1925. His Habilitations-schrift is often quoted these days because it first established the relationship between entropy and "information," subsequently rediscovered by Shannon.

In the years following 1922, he worked experimentally at the Kaiser-Wilhelm-Institutes in Berlin-Dahlem in the field of x-ray research.

While a refugee from Hitler Germany in London, in 1933, he became interested for the first time in nuclear physics. Working for a two-month period during vacation-time in 1934, at the St. Bartholomew Hospital in London, he discovered, jointly with a staff member of the Hospital, Dr. Chalmers, the disintegration of beryllium by the gamma rays of radium. They found that if beryllium is exposed to gamma rays of radium, it is disintegrated and that slow neutrons are emitted in this process. This radium-beryllium neutrons source played subsequently an important role in the history of the chain reaction, as will be described below.

During the same two-month period, they also discovered what is now called "Szilard-Chalmers Reaction" which permits the separation of a radio-isotope from the stable isotope from which it is produced through neutron capture.

While in England, Szilard became associated with the Clarendon Laboratory at Oxford where he worked in the field of nuclear physics. In 1938, Szilard was in the United States at the time of the Munich Crisis and, at that time, he resigned his position at Oxford and remained in the United States.

While still in England, he had recognized the possibility of a self-sustaining nuclear chain reaction that might be maintained if an unstable element could be found that would emit two neutrons for each neutron captured, and he had derived the general laws governing such a chain reacting system.

He learned in January 1939 of Otto Hahn's discovery of the fission of uranium. Hahn showed that uranium breaks into two heavy, charged, fragments when it captures a neutron. Szilard immediately thought of the possibility that neutrons might be emitted in this process and that a self-sustaining nuclear chain reaction might be set up in some system containing uranium. At once he borrowed $2,000 from personal friends, rented a gram of radium and made a radium-beryllium neutron source out of it. He thought that, if such a slow neutron source was used to bombard uranium with neutrons, then the neutrons emitted in the fission process could be distinguished from the primary neutrons because they could be expected to have a much higher energy than the neutrons from the primary source. He teamed up with Walter Zinn at Columbia University and they demonstrated, on March 3, 1939, that about two neutrons were emitted in the fission of uranium for each neutron captured in this process. The same discovery was made independently and about the same time by Anderson-Fermi at Columbia University as well as Halban and Joliot in Paris.

Subsequently Szilard then worked as a guest of Columbia University until the end of June. During that period, Fermi and Szilard teamed up and carried out jointly with Herbert Anderson an experiment which showed that uranium-water system came close, but not close enough, to being able to maintain a self-sustaining chain reaction.

In July, 1939, Szilard recognized that a uranium-graphite system was much more favorable in this respect than the uranium-water system and that it was likely that a chain reaction could be set up in such a system. He was aware of the military possibilities inherent in this development and realized also that a world war was impending. Szilard communicated his results and his apprehensions to Albert Einstein and these communications resulted in a letter written by Einstein to President Roosevelt, dated August 2, 1939.

In February, 1940, Szilard sent a paper to the Physical Review appraising the possibility of maintaining a self-sustaining chain reaction in the uranium-graphite system and concluding that self-sustaining chain reaction should be possible in this system. At the Government's request, the publication of this paper was withheld.

In November, 1940, a Government contract was given to Columbia University for developing the Fermi-Szilard System and at that time, Szilard became a member of the Columbia University National Defense Research Staff. In January, 1942, Fermi and Szilard moved to Chicago to continue their work under contract with the Government in the so-called Metalurgical Laboratory of the University of Chicago. The first self-sustained chain reaction was set up at Chicago on December 2, 1942. The Patent issued to the AEC is the first patent issued in the United States in this general field and names Fermi and Szilard as joint inventors.

Szilard stayed with the Metalurgical Laboratory of the University of Chicago with the rank of "Chief Physicist" until the end of the war and then resigned to accept a position as Professor of Biophysics on the regular Staff of the University of Chicago. This was a Research Professorship attached to the Institute of Radiobiology and Biophysics, which was one of the three research institutes created after the war by the University of Chicago. This Institute was lated dissolved, and Szilard was transferred to the Staff of the Enrico Fermi Institute for Nuclear Studies as Professor of Biophysics. He holds this position at present.

While at Chicago, Szilard developed jointly with Aaron Novick a method for studying mutations, induced enzyme formations and other phenomena in growing bacteria cultures, which is known as "The Method of the Chemostat." His work and interests centered on problems relating to mutations and induced enzyme formation in bacteria, antibody formation in mammals, and the general problem of protein synthesis.

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Dr. Leo Szilard

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