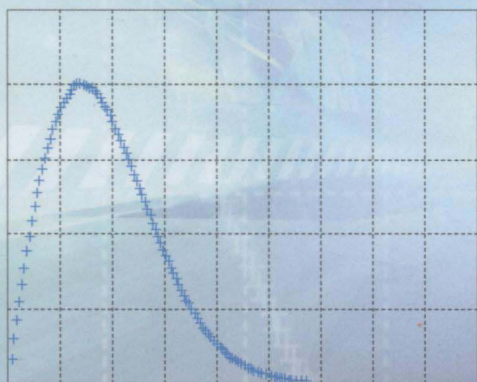


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Applied Reliability Engineering Risk Analysis

Probabilistic Models and
Statistical Inference



Editors

Ilia B. Frenkel

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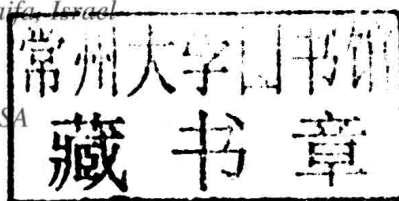
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Remembering Boris Gnedenko

Andre Kleyner¹ and Ekaterina Gnedenko²

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Boris Gnedenko was one of the most prominent mathematicians of the twentieth century. He contributed greatly to the area of probability theory, and his name is permanently linked to pioneering and developing mathematical methods in reliability engineering. Gnedenko is best known for his contributions to the study of probability theory, such as the extreme value theorem (the Fisher–Tippett–Gnedenko theorem). He first became famous for his work on the definitive treatment of limit theorems for sums of independent random variables. He was later known as a leader of Russian work in applied probability and as the author and coauthor of outstanding textbooks on probability, mathematical methods in reliability and queuing theory.

Boris Gnedenko was born on January 1, 1912, in Simbirsk (later Ulianovsk), a Russian city on the Volga River. He was admitted to the University of Saratov at the young age of 15 by special permission from the Minister of Culture and Education of the Soviet Union.

After graduation from the university, Gnedenko took a teaching job at the Textile Institute in Ivanovo, the city east of Moscow, which for many years was the center of the Soviet textile industry. While lecturing at the university, Gnedenko simultaneously was involved in the solution of some practical problems for the textile industry. This is when he wrote his first works, concerning queuing theory, and became fond of the theory of

probability. That triggered his later works on the applications of statistics to reliability and quality control in manufacturing.

In 1934, Gnedenko decided to resume his university studies at the graduate level. He was awarded a scholarship which allowed him to undertake research at the Institute of Mathematics at Moscow State University. He became a graduate student under the direction of Alexander Khinchin and Andrei Kolmogorov. The latter became one of the most famous mathematicians of the twentieth century (the Kolmogorov-Smirnov test in statistics, the Kolmogorov-Arnold-Moser theorem in Dynamics, the Kolmogorov Complexity, and other landmark achievements). As a graduate student, Gnedenko became interested in limiting theorems for the sums of independent random variables. In 1937, he defended his dissertation on "Some Results in the Theory of Infinitely Divisible Distributions," and, soon after the defense, he was appointed a researcher at the Institute of Mathematics at Moscow State University.

Years later, Kolmogorov would say:

Boris Gnedenko is recognized by an international mathematics community as one of the most prominent mathematicians who is currently working in the area of probability theory. He combines an exceptional skill and proficiency in classical mathematical methods with deep understanding of a wide range of modern probability problems and a perpetual interest to their practical applications.

In 1937, during the infamous Stalin's Purges, Gnedenko was falsely accused of "anti-Soviet" activity and thrown in jail. The NKVD (the Soviet secret police at that time) were trying to coerce him to testify against Kolmogorov, who was not yet arrested but was under investigation by the NKVD for running a conspiracy "against the Soviet people," a very common bogus charge at the time. However, Gnedenko survived brutal treatment at the hands of the NKVD and refused to support the false accusations against his mentor. He was released six months later, though his health suffered.

He returned to Moscow University as an assistant professor in the Department of the Theory of Probability in 1938 and as a research secretary (an academic title in Russia) at the Institute of Mathematics. During this period at Moscow State University, he solved two important problems. The first problem involved the construction of asymptotic distributions of the maximum term of the variation series and defining the nature of limit distributions and the conditions for convergence (Gnedenko 1941b). The second problem involved the construction of the theory of corrections to the Geiger-Muller counter readings used in many fields of physics and technology (Gnedenko 1941a). This paper is a landmark in what later became "the theory of reliability".

In 1939, Gnedenko married Natalia Konstantinovna and subsequently they had two sons.

During World War II, Gnedenko continued his research work at Moscow State University, although for two years, together with all the university colleagues, he had to temporarily relocate to Turkmenistan and later to the Ural mountains because of Moscow's proximity to the front lines. Some of his work during the war was of national defense nature, including quality and process control at military plants. During that time Gnedenko continued working on a variety of mathematical problems, including the limit theorem for the sums of independent variables, and discovering the classification of the possible types

of limit behavior for the maximum in an increasing sequence of independent random variables. The Weibull distribution, one of the most popular time-to-failure distributions in reliability engineering, is occasionally referred to as ‘Weibull-Gnedenko’ (see, e.g. Pecht 1995, or Chapter 19 in this book). Gnedenko developed this model at about the same time as Waloddi Weibull in Sweden, however, due to the relative isolation of the Soviet Union at that time, this was not common knowledge. Only in 1943, two years after Gnedenko had published his results in Russian, due to the warming relationship between the USA and the Soviet Union during World War II, did Gnedenko receive an invitation to publish his hallmark paper on extreme value limit theorem in the American journal, *Annals of Mathematics*. His research into limit theorems continued and in 1949 this resulted in a monograph with Kolmogorov, entitled “Limit Distributions for Sums of Independent Random Variables”. This monograph was awarded the Chebyshev Prize in 1951 and was translated into many languages. It was later published in English by Addison-Wesley publishing (Gnedenko and Kolmogorov 1954) and underwent a second edition in 1968.



Boris Gnedenko and his wife Natalia, 1978

During World War II, the western part of the Soviet Union was devastated by the German occupation, therefore after the war in 1945, Gnedenko was sent to Lviv, the largest city in Western Ukraine, to help rebuild Lviv University and undertake the restoration of the overall Ukrainian system of higher education. He accepted this challenging job with great energy and enthusiasm.

Building on the works of Kolmogorov and Smirnov establishing the limit distributions for the maximum deviation of an empirical distribution function from the theoretical,

Gnedenko developed effective methods to obtain the exact distributions in the case of finite samples in these and other related problems. This work received worldwide recognition, because it served as the basis for compiling tables which were very valuable in applied statistics at that time.

In 1948, Gnedenko was elected a full member of the Ukrainian Academy of Science and in 1950 he was transferred to Kiev, the capital of the Ukraine, to become Head of the recently created Department of the Theory of Probability at the Institute of Mathematics of the Ukrainian Academy of Sciences and also Head of the Physics, Mathematics and Chemistry Section of the Ukrainian Academy of Sciences. At the same time he served as the Chair of the Department of Probability Theory and Algebra at Kiev State University. Later he became Director of the Kiev Institute of Mathematics.

His work in Kiev followed several directions. Besides mathematics and statistics, his contribution was instrumental in developing computer programming and setting up a computing laboratory and encouraging his younger colleagues to study programming. His earlier efforts at the Ukrainian Academy of Science helped to create, in 1951, one of the first fully operational electronic computers in continental Europe.

In 1958, Gnedenko was a plenary speaker at the International Congress of Mathematicians in Edinburgh with a talk entitled, "Limit Theorems of Probability Theory". One of Gnedenko's most famous books is called *Theory of Probability*, which first appeared in 1950. Written in a clear and concise manner, the book was very successful in providing an introduction to probability and statistics. It has undergone six Russian editions and has been translated into English (Gnedenko 1998), German, Polish and Arabic. Earlier, in 1946, Gnedenko also co-authored, with Khinchin, the book, *Elementary Introduction to the Theory of Probability*, which also has been published many times in the USSR and abroad.

In 1960, Boris Gnedenko returned to Moscow State University and later, in 1966 became Head of the Department of Probability holding this post until his death in 1995. He took over from Andrei Kolmogorov, who became Head of the Interdepartmental Laboratory of Probability and Statistics in Moscow.

During the sixties, Gnedenko's interests turned to mathematical problems with industrial application, namely, the queuing theory and mathematical methods in reliability. In 1961, with several of his students and colleagues, he organized and chaired the Moscow Reliability Engineering Seminars. This was a very successful undertaking with around 800 participants: academics, engineers and mathematicians. Many attendees traveled from other cities, and besides academic activities, it resulted in a number of practical consultations helping engineers in various industries. This seminar was also a big promoter of reliability engineering, which at that time was in its infancy.

As Professor Vere-Jones, then a British graduate student at Moscow State University, remembers: "It was into this seminar that I strayed in 1961. I was much impressed, not so much by the academic level, which varied from excellent to indifferent, as by the strong impression I received that this was an environment in which everyone's contribution was valued" (Vere-Jones 1997). This "owed a great deal to Boris Vladimirovich Gnedenko's own personality and convictions, and the influence he had on his colleagues". Later, at the end of 1965, Vere-Jones managed to arrange for Gnedenko a two-month trip "down under". Gnedenko was invited by the Australian National University in Canberra, which had a special exchange agreement with Moscow State University. Unfortunately, Gnedenko was not able to take his family with him on this exciting trip – the Soviet

government, afraid of losing Gnedenko to the foreign capitalistic country, did not allow his wife and sons to accompany him. According to Vere-Jones, Gnedenko lectured on two themes: one was reliability theory (estimation and testing of the life-time distribution); and the second was mathematical education in the Soviet Union, which generated the greatest interest. Throughout his visit, Gnedenko displayed great interest in everything: the people, the birds and animals, the scenery, the universities and schools, shops, etc. He was particularly fascinated by the koala in Australia and by the kiwi and its huge egg in New Zealand. “His interest in matters ‘down under’ continued well past this visit. I believe he became a president or patron of the USSR side of the New Zealand-USSR friendship society”.

Most people who met Gnedenko remember their personal interactions very fondly and pay tribute to his disposition and personal qualities. Vere-Jones says:

I consider myself extraordinarily fortunate in having happened to drift into his seminar in October 1961. Not only was it a chance to step inside the legendary world of Russian probability theory, it was a chance to come to know a rare human being, to see him at home and with his family, and to work briefly alongside him.

(Vere-Jones 1997)

In 1991, Gnedenko visited the USA. Professor Igor Ushakov, his longtime colleague, who was his host during this trip, remembers:

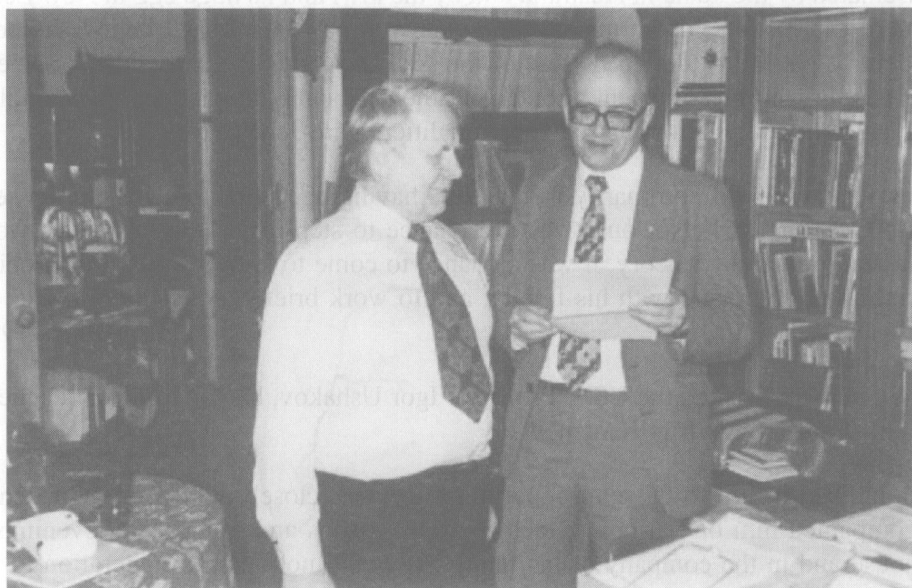
I was blessed in life to have an opportunity to work closely with Boris Gnedenko. I accompanied him on various academic business trips and spent many evenings at his house and in the company of his family. It would not be an exaggeration to say that I’ve never met another person with more zest for life and more willingness to share his kindness and help others in need.

(Ushakov 2011)

During that trip Gnedenko, accompanied by his son Dmitry, visited the University of North Carolina, where he lectured and had several research meetings. Then he went to Washington, DC, to give a lecture at the Department of Operations Research of George Washington University. Upon learning about Gnedenko’s arrival, the university photographers took a lot of photos and the university newspaper published an article about his visit. While in Washington, DC, Gnedenko met quite a few local mathematicians. Many invited him to their homes and he was always the center of attention. Since this was an international crowd, his knowledge of German and French (in addition to English) came in very handy.

During that visit he was also interviewed by Professor Nozer Singpurwalla at George Washington University. Answering questions, Gnedenko recalled many important events in his life, his work with Kolmogorov and other prominent Russian mathematicians, as well as other significant milestones (Singpurwalla and Smith 1992). During his professional life he held a number of high administrative positions, both at a university and the Academy of Science levels, however, his heart was clearly in academic work and research. Gnedenko said: “I prefer scientific work, lecturing and writing. I enjoy working with students. I have had over a hundred doctoral students, of whom 30 are professors in my country or in other countries”. Seven of his students became members of the Academy of Science, the highest academic distinction in Russia and the former Soviet Republics.

His teaching activities extended beyond academia, Boris Gnedenko had also contributed greatly to popularizing math and science. Besides the book on history of mathematics mentioned earlier, he also wrote for primary and secondary school. Gnedenko said: “This year I have also written a short book for school children on mathematics and life”, and later, “The second book I plan is for school children – a trip into a mathematical country”.



Boris Gnedenko and his colleague and friend, Igor Ushakov, at Gnedenko's home, 1970

Besides studying and doing research in mathematics, Gnedenko also took a keen interest in the history of this discipline, which he considered very important to a future development of mathematics. According to O'Connor and Robertson (2000), Gnedenko's interest in the history of mathematics extended well beyond his text aimed at secondary school pupils. He published much on this topic, including the important *Outline of the History of Mathematics in Russia* which was not published until 1946, although he wrote it before the start of World War II. It is a fascinating book which looks at the history of mathematics in Russia in its cultural background.

Later in 1993, Gnedenko visited the USA again, now by invitation from the MCI Corporation, at that time a telecommunication giant, where Professor Ushakov was a consultant at the time. Gnedenko was 81, but despite his health problems he put together a rigorous plan to visit all the technical and academic centers he was invited to. The first visit was to the MCI Headquarters in Dallas, where he lectured to a large audience about statistical problems in the telecommunications industry. Introducing him to the audience, Chris Hardy, the MCI Chief Scientist, said: “I did not have any difficulties inviting Prof. Gnedenko, I just said to our CEO that for us hosting Professor Gnedenko would be like for Los Alamos Labs hosting Norbert Wiener.”

Next stop was at Harvard University, hosted by Eugene Litvak, professor at the School of Public Health. For his lecture topic Gnedenko chose, “Probability and Statistics from

Middle Ages to Our Days”. Gnedenko always had a sixth sense and a feel for his audience; therefore, because this time he was not speaking to expert mathematicians, he chose one of his favorite subjects: the history of mathematics.

During his lifetime Gnedenko produced a remarkable number of published works. One of the most complete lists of his publications can be found in Gnedenko D.B. (2011). Interestingly enough, all his life, even after the introduction of word processors, Gnedenko still used a typewriter. When asked during one interview how many drafts it took for a paper or book, Gnedenko answered, “one draft only”. It was difficult to believe one draft would have no errors or need for improvement. Gnedenko replied, “it is necessary to think first and only then to write. At this stage I am almost finished” (Singpurwalla and Smith 1992).

Many of the facts and events of Gnedenko’s life that are presented here are also recounted in greater detail by the great man himself in his memoirs (Gnedenko 2012). More information about Boris Gnedenko can be found on a dedicated website, Gnedenko Forum, an informal association of specialists in reliability (Gnedenko Forum 2013). The Forum, created by Gnedenko’s followers, I. Ushakov and A. Bochkov, is designed to commemorate his legacy and also to promote contacts between members of the global reliability community. It contains the latest professional news in the areas of probability theory, statistics, reliability engineering, risk analysis, mathematical methods in reliability, safety, security and other related fields. Many contributors of this book are members of the Gnedenko Forum and were inspired or influenced in some way by the lifelong work of this great mathematician. This book commemorates the centennial of his birth and pays tribute to his immense contribution to the probability theory and reliability mathematics and also celebrates his legacy.

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