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The Man Who Tamed Uncertainty: Andrei Kolmogorov and the Mathematics of Chance

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Abstract

This essay explores the life and contributions of Andrei Nikolaevich Kolmogorov (1903–1987), one of the twentieth century's most influential mathematicians. Beginning with the Borel–Kolmogorov paradox, we examine how Kolmogorov transformed probability theory from a collection of informal methods into a rigorous mathematical framework. We trace his remarkable journey through the tumultuous Soviet era, his historic visit to the Indian Statistical Institute, Kolkata, and his profound contributions spanning probability theory, turbulence, complexity theory, topology, and mathematical education. Kolmogorov's ideas continue to shape modern science, from stochastic modeling and statistical inference to turbulence theory and algorithmic information theory. This essay explores both the mathematical contributions that reshaped probability theory and the historical context in which those ideas emerged.

Key words: Borel–Kolmogorov paradox; Grundbegriffe; History of probability; Kolmogorov complexity; Measure theory; Soviet mathematics.

AMS Subject Classifications: 01A60, 60-03, 60A05

'I, for one, have followed all my life the precept that truth is sacred, that it is our duty to seek it out and to defend it, regardless of whether it is pleasant or not.'

Andrei Nikolaevich Kolmogorov
(25 April 1903 - 20 October 1987)

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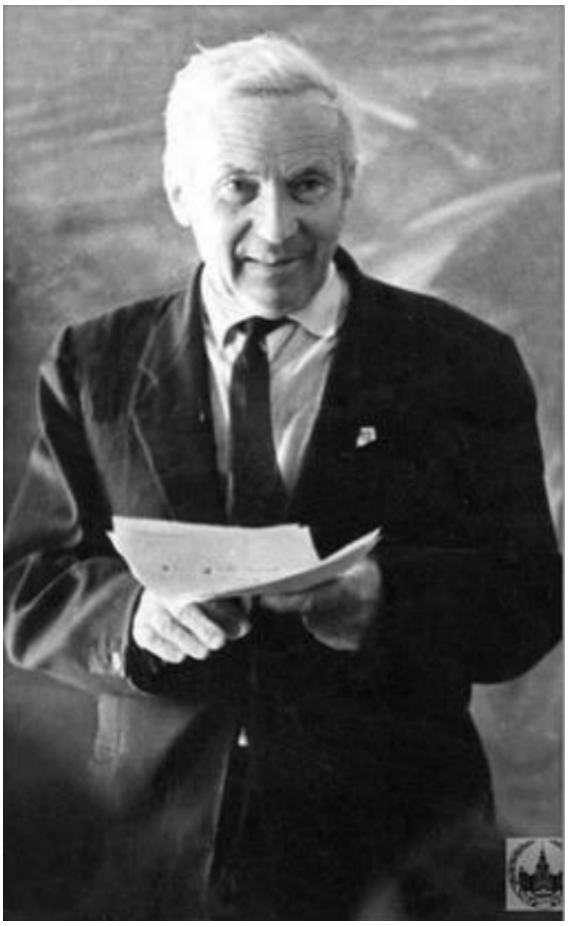


Figure 1: A. N. Kolmogorov. Source: Wikimedia Commons

1. Do aliens prefer hotter climates?

Suppose aliens land uniformly at random on a perfectly spherical Earth[1]. By "uniformly," we mean that every patch of equal surface area is equally likely. Now we are told that the landing point lies on a 'great circle.' Is the distribution along that circle uniform?

To answer this, imagine that an alien is standing somewhere on Earth, somewhere on the planet's curved surface. Now, suppose you randomly select a point on Earth that lies on the equator. The question takes a simpler form: if you walk along the equator, is every spot equally likely to be the chosen point? The answer seems obvious: yes, of course. Every point on the equator should be equally probable.

Now let us look at the same problem from a different 'angle'. Suppose the chosen point lies on the Prime Meridian, the longitude line running from the North Pole through Greenwich to the South Pole. If instead of the equator you walk along this line, is every spot equally likely? Again, it is an obvious 'yes'.

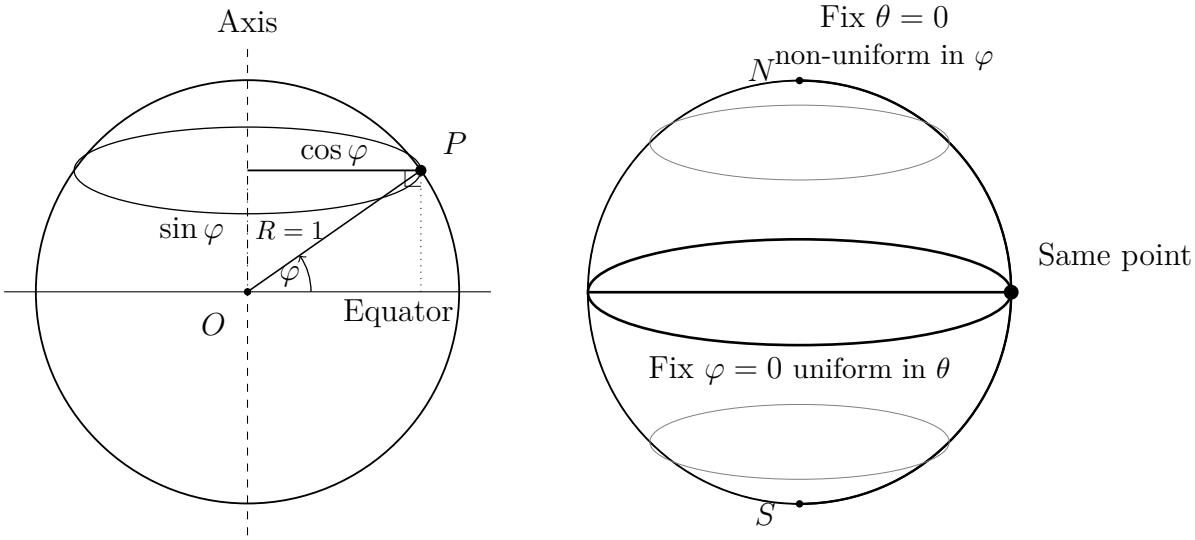
But thereby hangs a tale: this is the set-up of a famous puzzle that troubled mathematicians in the early 20th century. The equator and the Prime Meridian *intersect*: they

[1]This analogy used in a recent popular account of Kolmogorov's work (Gerovitch, 2023)

share a common point. In fact, by rotating the globe, any great circle can be made to coincide with the equator, and any point on that circle can be described in different coordinate systems. And yet, when we calculate the probabilities mathematically, we get *different answers* depending on which description we use. This is the Borel-Kolmogorov paradox, named after Émile Borel and Andrei Nikolaevich Kolmogorov. To understand how Kolmogorov resolved it, and in doing so, transformed probability from a philosophical puzzle into rigorous mathematics, we need to dive into the geometry of spheres and conditional probability.

The mathematics of the sphere. Any point on a unit sphere (a sphere with radius 1) can be described using two angles. The first is φ, the latitude angle, measuring how far north or south of the equator you are (ranging from $-90°$ to $+90°$). The second is θ, the longitude angle, measuring how far east or west you have traveled (ranging from $0°$ to $360°$). If points are scattered uniformly on the sphere, meaning every patch of equal area is equally likely, and if latitude $\varphi \in [-\pi/2, \pi/2]$ and longitude $\theta \in [0, 2\pi]$, the joint density of a uniformly chosen point on the sphere is:

$$f(\varphi, \theta) = \frac{\cos\varphi}{4\pi}. \tag{1}$$



(a) Latitude circle radius $\cos\varphi$ **(b) Different conditional limits**

Figure 2: Geometry of the sphere and the Borel–Kolmogorov paradox

The $\cos\varphi$ term in (1) reflects the shrinking circumference of circles of latitude as one moves away from the equator. The equator ($\varphi = 0°$) is the widest circle, with radius 1. As you move toward the poles, the circles shrink. At $60°$ north latitude, the circle has radius $\cos(60°) = 0.5$, exactly half the size of the equator. At the North Pole ($\varphi = 90°$), the circle shrinks to a single point, because $\cos(90°) = 0$. This means a small angular patch near the equator covers *more actual surface area* than the same angular patch near the poles. To keep the distribution uniform over *surface area*, the probability density per degree must be higher near the equator.

Now we can calculate the probability when we 'condition'[2] on being at a particular location. If we condition on being at a fixed longitude (say, $\theta = 0°$)[3], the limiting conditional density is:

$$f(\varphi \mid \theta = 0°) = \frac{\cos\varphi}{2}, \tag{2}$$

which is *not* uniform! Points are more likely near the equator than near the poles. However, if we condition on being at a fixed latitude, (say, $\varphi = 0°$):

$$f(\theta \mid \varphi = 0°) = \frac{1}{2\pi}, \tag{3}$$

which *is* uniform: every point around the equator is equally likely. But, you can rotate the sphere and turn the equator into a meridian. That is, a great circle can be described as "the circle where $\varphi = 0°$" or equally well as the meridian that is "the intersection of all longitude lines." It's the same circle! How can the probability distribution on it be both uniform and non-uniform? This is the Borel–Kolmogorov paradox (Meehan and Zhang, 2021; Gal, 2014; Sankaran, 2013).

Simply speaking, when we condition on a zero-probability event (like "being exactly on the equator," which is a one-dimensional curve on a two-dimensional surface and thus has zero area), we are really conditioning on a 'measure-zero' set, and that operation is not well-defined without further specification. From a modern measure-theoretic viewpoint, the paradox arises because conditional probabilities on measure-zero sets are not uniquely defined unless the conditioning σ-algebra and the associated regular conditional distribution are specified.

But we can still approach the same problem via taking a *limit*. Think of horizontal bands getting thinner and thinner around the equator. As the bands shrink toward zero width, we approach '$\varphi = 0°$' and get a uniform distribution. On the other hand, if you take a 'vertical approach', taking vertical slices getting thinner and thinner around a particular longitude, as the slices shrink, we approach "$\theta = 0°$" and get the $\cos\varphi$ distribution.

These are different approaches involving different limits, and they naturally lead to different answers. The conditioning event 'on the great circle' is *ambiguous* until we specify *how* we are approaching this zero-probability event. One of Kolmogorov's great contributions to probability was to place probability on rigorous mathematical foundations using measure theory, where these subtleties could be precisely defined and understood.

2. The man behind the Mathematics

2.1. A tragic beginning

Andrei Nikolaevich Kolmogorov was born on April 25, 1903, in Tambov, Russia, about 500 kilometers southeast of Moscow. His birth was marked by tragedy: his unmarried mother, Maria Yakovlevna Kolmogorova, died in childbirth. Little is known about his father,

[2]In plain English, conditioning means: "How should I update my probabilities given I have some information?"

[3]Conditioning on $\theta = 0°$ involves a measure-zero event; the limiting conditional density is obtained by conditioning on a narrowing band around $\theta = 0°$.

but he was probably named Nikolai Matveyevich Katayev, who was an agronomist involved in revolutionary politics who disappeared and was likely killed during the Russian Civil War in 1919 (Kendall *et al.*, 1990; Shiryaev, 1989; Rioul, 2022). The orphaned child was raised by his two aunts at his grandfather's estate in Tunoshna, near Yaroslavl. His grandfather was a well-to-do nobleman, and young Andrei received an excellent education, first at a village school run by his Aunt Vera Yakovlevna. Despite the early tragedies, Kolmogorov said that he had a happy childhood, surrounded by love, kindness, and attention (Tikhomirov, 1988).

Even as a child, Kolmogorov showed remarkable mathematical ability. At age five, he was appointed "editor" of the mathematical section of the school journal, charmingly titled *The Swallow of Spring*. At age six, he made his first mathematical discovery: the pattern in sums of odd numbers. The sum of the first n odd numbers, $1 + 3 + \ldots + (2n - 1)$, always equals n^2. A six-year-old had independently discovered a theorem known to the ancient Greeks. Shiryaev recounts another remarkable story from Kolmogorov's childhood.[4] As a five-year-old boy, Kolmogorov solved this and arrived at an absolutely correct figure. As a school-student, he invented 'perpetual motion machines' multiple times, and his designs were so elaborate that he was able to fool his school teachers every time.

2.2. Moscow and mathematical awakening

In 1910, at the age of seven, Kolmogorov moved to Moscow with his aunt. He graduated from high school in 1920, during the tumultuous early years of Soviet Russia, and enrolled simultaneously at Moscow State University (studying mathematics and history) and the Mendeleev Institute of Technology (studying metallurgy). When he was 10-14 years old, Kolmogorov was deeply fascinated by Biology and Physics, and later by History and Sociology. He apparently thought of and even drafted a utopian constitution for a community that could ensure higher justice in practice. Interestingly, he was captivated by chess, and participated in competitions, but soon abandoned it forever.

His interest in History was profound, and lifelong, and for a time the young Kolmogorov was torn between mathematics and history. How he came to choose mathematics remains an interesting, possibly apocryphal story, though repeated across multiple sources.

When he was a 17-year-old student, he made his first scientific report to Prof. S. V. Bakhrushin's seminar, about the landholding practices in 15th–16th century Novgorod. Prof. Bakhrushin, a leading historian, recognized his discovery, and Kolmogorov asked whether it could be published. When the professor discovered he'd based his analysis on a sample of just five landowners, he said, "You have found only one proof, that is very little for a historian. You need at least five!" Kolmogorov reportedly replied that he'd analyzed all the data available.[5] Besides drafting a thesis on Russian history, he wrote a treatise on Newtonian mechanics, and somewhere in between also interrupted his studies to become a train conductor, all as a teenager.

Kolmogorov was 17 years old when he entered Moscow State University in 1920, and

[4]In his own words, 'There is a button with four holes in it. Thread should go through at least two of them to fix the button. In how many ways can this be done?"

[5]The report he wrote was discovered in his papers and published posthumously; it seems Kolmogorov did rely on statistical methods for his conclusion.

immediately began making original contributions as an undergraduate. At the time, one of Luzin's central open problems was whether the Fourier series of every square-integrable function converges almost everywhere. In 1922, aged just 19, Kolmogorov constructed a function in $L_1([-\pi, \pi])$, the strictly larger class of merely integrable functions, whose Fourier series diverges almost everywhere (Kolmogorov, 1923), and sharpened this in 1926 to divergence everywhere. Rather than resolving Luzin's conjecture, this result clarified how delicate it was: L_1 integrability is simply too weak to guarantee convergence, and the L_2 question remained open for another four decades. It was finally settled by Carleson (Carleson, 1966) for L_2, and extended by Hunt (Hunt, 1968) to all L_p with $p > 1$. Kolmogorov's counterexample and the Carleson–Hunt theorem together constitute the definitive boundaries of this circle of problems in harmonic analysis, and the original result brought Kolmogorov immediate international recognition at an age when most mathematicians are still learning the subject.

He graduated from Moscow State University in 1925, and began his thesis with Nikolai Luzin, and fell under his influence. Luzin was a charismatic mathematician who led a circle of brilliant students they jokingly called "Luzitania", a pun on Luzin's name and the British ocean liner. The students would gather for what they called "joint beating of hearts," passionate discussions of mathematics late into the night. They developed playful terminology: "partial irreverential equations" instead of partial differential equations, "fine night differences" instead of finite differences.

Beginning in 1925, while working on formalizing 'intuitionist logic' with Luzin, Kolmogorov started publishing pathbreaking and foundational papers on probability. This included the famous Kolmogorov inequality that strengthens Chebyshev's inequality, and the Kolmogorov three series theorem that provides the necessary and sufficient conditions for almost sure convergence of a random series $\sum_n X_n$ by requiring convergence of three deterministic series. These results would later inspire the theory of martingales. When Kolmogorov graduated in 1929, he had already published 18 papers on logic, analysis, and probability.

The year 1929 would also be a remarkable epoch in his life: it marked the beginning of his lifelong friendship with the mathematician Pavel Alexandrov. That summer they took a long boat trip on the Volga, to lake Sevan in Armenia, and once again in 1931. In 1935, they bought a house together in Komarovka, outside Moscow, where they hosted many renowned mathematicians for discussions.

3. A polymath's legacy

Kolmogorov's influence extended across an astonishing range of fields. He was, undoubtedly, one of the last universalists. When asked if there can be someone like him in the future, versatile in so many fields with so much impact, Shiryaev (1989) lists only four encyclopedic mathematicians: Poincaré, Hilbert, von Neumann, and Kolmogorov. In pure mathematics, he worked on topology with Pavel Alexandrov, wrote his influential 1925 paper "On the principle of the excluded middle" in intuitionistic logic, and contributed to functional analysis and approximation theory. He made important advances in trigonometric series and developed the Kolmogorov-Arnold-Moser (KAM) theorem in dynamical systems. Working with his student Vladimir Arnold, he produced a partial solution to Hilbert's 13th problem in 1957 (Arnold, 1993; Tikhomirov, 1988). In applied mathematics, his work touched celestial mechanics, differential equations, and mathematical linguistics. He developed ap-

plications to biology, geology, and metallurgy. In statistics and probability, he published over 300 research papers and supervised more than 60 PhD students. It is hard to think of another mathematician of the 20th century with such breadth and depth. When the famous American statistician J. Wolfowitz stood up to address the audience at the 1963 conference at Tbilisi, he said: 'I came to the USSR with the specific purpose of finding out whether Nikolaevich Kolmogorov is an individual or an institution' (Parthasarathy, 2019).

Shiryaev (1989) captures this breadth memorably:

> "If we take a Russian mathematical encyclopedia, we find Kolmogorov axioms, K duality, K integral, K criterion, K inequality, K space, K equation, K–Smirnov criterion, K–Chapman equations. If you take any encyclopedia on probability and mathematical statistics, you will find Kolmogorov axiomatization, K self-similarity, K law of two-thirds, K criterion, K matrix, K model, K distribution, K statistic, K law of five-thirds, K spectral theory."

Kolmogorov's contributions to mathematics are, in a word, unfathomable: spanning more than sixty years and encompassing fields as disparate as topology, logic, celestial mechanics, turbulence, and algorithmic information theory, they defy any compact summary. What follows is necessarily a selective account, focusing on those results in mathematics, statistics, and probability that have proved most enduring and that best illuminate the singular character of his mathematical vision.

3.1. The foundations of probability (1933)

> "It is difficult to overstate the impact of the Grundbegriffe on the development of the subject; essentially the history of probability theory splits in 1933 between pre-Kolmogorov and post-Kolmogorov"
>
> *N. H. Bingham*
> *(Kendall et al., 1990)*

Kolmogorov's most famous work was his slim 1933 monograph *Grundbegriffe der Wahrscheinlichkeitsrechnung* (Foundations of the Theory of Probability) (Kolmogorov, 1933). In about 62 pages[6], he transformed probability from a collection of informal methods into a rigorous mathematical theory.

His approach was simple yet revolutionary: probability is a measure on a set. He defined three axioms. First, non-negativity: for any event A, the probability $P(A)$ must be greater than or equal to zero. Second, normalization: the probability of the entire sample

[6]The original 1933 Springer monograph had 62 main pages. The 1950 English translation (Foundations of the Theory of Probability, Chelsea) runs longer because of added material and formatting differences.

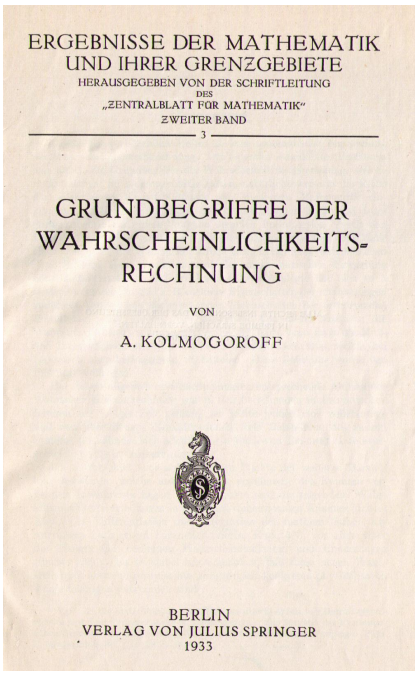


Figure 3: Title page of 'Grundbegriffe der Wahrscheinlichkeitsrechnung' by A. N. Kolmogoroff. Berlin, Springer, 1933. Source: Wikimedia Commons

space is 1, written as $P(\Omega) = 1$. Third, additivity[7]: for mutually exclusive events A and B, the probability that A or B occurs equals $P(A) + P(B)$.

From these simple axioms, all of probability theory could be derived. It was as if Euclid had returned to organize geometry, but this time, for the mathematics of uncertainty. As Parthasarathy (1988) notes, 'To this day, it has stood the test of time and constitutes the cornerstone around which the entire edifice of statistical theory and computation is erected.'

To appreciate what this achieved, it helps to recall the state of probability before 1933. The classical foundation, dominant for two centuries, defined probability as a ratio of equally likely cases. This worked well for dice and cards. In continuous settings, it became circular or ambiguous. Bertrand's paradoxes (1889) exposed this sharply: ask for the probability that a random chord of a circle exceeds the side length of the inscribed equilateral triangle, and you get different answers depending on what "random" means, with no principled way to choose. The Borel–Kolmogorov paradox in §1 is a close cousin. Frequentist approaches, championed by von Mises, grounded probability in limiting relative frequencies, but required an idealized infinite sequence as a primitive object. Conditioning on zero-probability events had no rigorous basis in either framework. Borel had introduced countable additivity into probability in 1909, and Fréchet, Steinhaus, Bernstein, and Cantelli had pushed toward measure-theoretic treatments in the decades that followed. But no one had assembled these pieces into a complete, self-contained axiomatic system. As Shafer and Vovk (2006) put it,

[7]One technically important detail: the additivity axiom in the *Grundbegriffe* is σ-additivity (countable additivity), not merely finite additivity. That is, for any countable collection of mutually exclusive events $A_1, A_2, \ldots$, we have $P(\bigcup_{i=1}^{\infty} A_i) = \sum_{i=1}^{\infty} P(A_i)$. This is the ingredient that makes limit theorems—the strong law of large numbers, the central limit theorem—derivable within the framework. Finite additivity alone is insufficient.

the *Grundbegriffe* was a work of synthesis as much as of new mathematics: its achievement was to recognize that the right pieces were already on the table, and to take responsibility for declaring the theory complete.

3.2. Random walks and Markov processes

In 1931, Kolmogorov published "Analytic Methods in Probability Theory," laying the foundations for the theory of Markov processes (Kolmogorov, 1931). A Markov process is one where the future depends only on the present state, not on the history of how you got there.

Think of a person taking random steps: at each moment, they step north, south, east, or west with equal probability. Where they step next depends only on where they are now, not on the path they took to get there. This is a random walk, and random walks are everywhere. Stock prices (approximately) follow random walks. Molecules diffusing through a liquid follow random walks. The electrical signals in your neurons, the fluctuations in population sizes, the spread of diseases, all can be modeled as stochastic (random) processes.

The mathematical framework Kolmogorov developed includes the Chapman-Kolmogorov equations, which describe how probabilities evolve over time:

$$P_{ik}(t_1 + t_2) = \sum_j P_{ij}(t_1) P_{jk}(t_2) \tag{4}$$

In words: the probability of getting from state i to state k in time $t_1 + t_2$ equals the sum over all intermediate states j of the probability of going $i \to j$ in time t_1, then $j \to k$ in time t_2. Nearly a hundred years later, virtually every domain of applied probability was reshaped by the developments set in motion by the simple, elegant, and fundamental 1931 paper.

3.2.1. Approximation of distributions by infinitely divisible laws

A remarkable consequence of Kolmogorov's 1956 work (Kolmogorov, 1956) is that, as Arak (1980) succinctly puts it, "*the sum of a large number of independent identically distributed random variables has a distribution which is close to being infinitely divisible.*"

Recall that a distribution is *infinitely divisible* if, for every $n \in \mathbb{N}$, it can be written as the n-fold convolution of some distribution with itself; denote the class of all such distribution functions by $\mathcal{D}$. One of the central problems in this area was to characterise all infinitely divisible laws. Kolmogorov obtained a canonical representation of the log-characteristic function for the finite-variance case (Tikhomirov, 1988). Using a different method, Lévy later removed the finite-variance restriction, and Khinchin subsequently showed that Lévy's general result could be recovered by Kolmogorov's original method, leading to what is now called the Lévy–Khinchin canonical representation.

Kolmogorov's 1956 theorem (Kolmogorov, 1956) asks how uniformly well $\mathcal{D}$ approximates n-fold convolutions of an arbitrary distribution. Let $\Phi_n(\,\cdot\,, F)$ denote the distribution function of the sum of n i.i.d. copies drawn from $F(\cdot)$.

Theorem 1: There exists a universal constant C such that for every distribution function

$F(\cdot)$ and every $n \in \mathbb{N}$, there exists $\Psi(\cdot) \in \mathcal{D}$ with

$$\sup_t \left|\Phi_n(t, F) - \Psi(t)\right| \leq C\, n^{-1/5}.$$

The exponent 1/5 was subsequently improved in a sequence of contributions: Prokhorov (1955) and Meshalkin (1961) obtained intermediate bounds, Kolmogorov himself returned to the problem in Kolmogorov (1962), and the sharp exponent 2/3 was eventually established by Arak (1982a,b), and shown to be optimal.

3.3. The Kolmogorov–Smirnov test and Kolmogorov's distribution

Any standard course in nonparametric statistics introduces the Kolmogorov–Smirnov test: the one-sample goodness-of-fit test for a completely specified null hypothesis, and the two-sample test for comparing two continuous distributions that may differ in any way. Both rest on a single fundamental result in mathematical statistics due to Kolmogorov.

Let ξ be a random variable with continuous distribution function $F(\cdot)$, and let $x_1 \leq x_2 \leq \cdots \leq x_n$ be an ordered sample of n independent realisations. The empirical distribution function is:

$$F_n(x) = \begin{cases} 0 & x < x_1, \\ k/n & x_k \leq x < x_{k+1}, \\ 1 & x \geq x_n. \end{cases}$$

Glivenko established that $\sup_x |F_n(x) - F(x)| \to 0$ almost surely. In the same journal issue, Kolmogorov went considerably further, deriving the exact limiting distribution of the rescaled statistic $D_n = \sqrt{n}\, \sup_x |F_n(x) - F(x)|$:

Theorem 2: Let $F(\cdot)$ be continuous. Then as $n \to \infty$, uniformly in $\lambda > 0$,

$$P\{D_n < \lambda\} \;\longrightarrow\; \Phi(\lambda) = \sum_{k \in \mathbb{Z}} (-1)^k \exp\Big(-2k^2\lambda^2\Big).$$

The function Φ is now called *Kolmogorov's distribution.* It is worth noting that the question of how to quantify the discrepancy between F_n and F had attracted von Mises and Cramér, yet neither obtained the limiting law. It is a measure of the result's practical importance that the Kolmogorov–Smirnov test has become one of the most widely used procedures in nonparametric statistics.

3.4. Turbulence: The chaos in fluids

In 1941, while much of the world was consumed by war, Kolmogorov published revolutionary work on turbulence, the chaotic, swirling motion of fluids. When you watch smoke rise from a candle, it initially rises smoothly, then breaks into swirling, unpredictable patterns. When you observe a fast-flowing river, you see eddies within eddies, chaos at every scale. This is turbulence, and it's one of the hardest problems in physics.

Kolmogorov developed a statistical theory of turbulence (Kolmogorov, 1941b,c,a), including what is now called the "Kolmogorov 5/3 law" (K41), which predicts a $-5/3$ energy

spectrum. For turbulent flow at high Reynolds numbers, the energy spectrum follows a power law:

$$E(k) \propto k^{-5/3} \tag{5}$$

where k is the wave number (spatial frequency) and $E(k)$ is the energy at that scale.

This means energy cascades from large eddies to smaller and smaller eddies in a specific mathematical way. The 5/3 law has been verified experimentally in everything from atmospheric flows to ocean currents to laboratory experiments. Nearly 85 years later, Kolmogorov's turbulence theory remains fundamental to fluid dynamics.

3.5. Kolmogorov's superposition theorem and Hilbert's 13th problem

Hilbert's 13th problem asked whether every continuous function of three variables could be represented as a superposition of continuous functions of *two* variables. The conjecture seemed self-evident to many, and Hilbert even proposed a specific analytic function he believed would serve as a counterexample to reducibility. In 1956 Kolmogorov proved that any continuous function of *four* variables is representable as a superposition of continuous functions of three, a result he considered his most technically demanding, requiring the longest sustained concentration of his career. The final step was taken shortly after by his third-year undergraduate student V. I. Arnol'd, who resolved the case of functions on universal trees in $\mathbb{R}^3$, thereby disproving Hilbert's conjecture entirely. Kolmogorov then found a cleaner construction yielding the following sharp result:

Theorem 3: For any integer $n \geq 2$ there exist continuous functions $\psi_{ij} : [0,1] \to \mathbb{R}$, $1 \leq i \leq 2n+1$, $1 \leq j \leq n$, such that every continuous $f : [0,1]^n \to \mathbb{R}$ admits the representation

$$f(x_1, \ldots, x_n) = \sum_{i=1}^{2n+1} \chi_i \left(\sum_{j=1}^{n} \psi_{ij}(x_j) \right),$$

where the outer functions $\chi_i : \mathbb{R} \to \mathbb{R}$ are continuous and depend on f.

In other words, any multivariate continuous function can be built from univariate functions and a single bilinear operation (addition), refuting the expectation that genuine multivariate complexity is unavoidable. This structural insight has been used directly in deep learning: Liu *et al.* (2025) proposed the Kolmogorov–Arnold Networks (KAN), an architecture that utilizes the theorem by placing learnable univariate spline functions on the edges of the network graph rather than fixing scalar activation functions at nodes, offering improved interpretability and promising results on problems with known compositional structure.

3.6. Information and complexity

During his 1962 visit to the ISI in Kolkata, Kolmogorov developed what we now call *Kolmogorov complexity*, independently discovered around the same time by Ray Solomonoff and Gregory Chaitin. The complexity of an object is the length of the shortest computer program that can generate it.

Consider these two sequences of 64 digits:

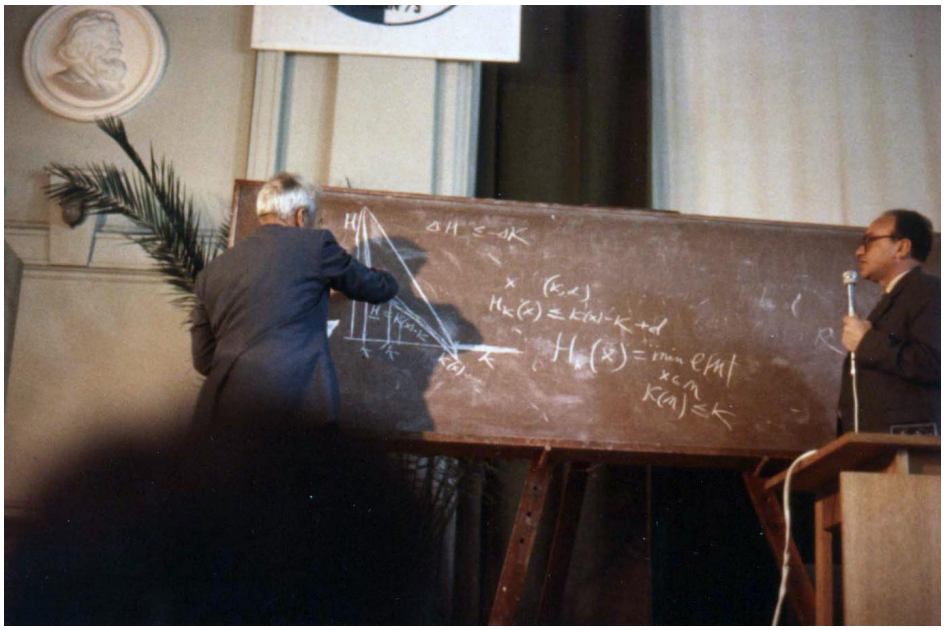


Figure 4: Kolmogorov giving a lecture on Kolmogorov complexity. Source: Wikimedia Commons

Sequence A: 01010101010101010101010101010101010101010101010101010101010101010101
Sequence B: 11001001011100111001111010111001111011110000100101011011010110 11

Which is more complex? Sequence A can be generated by a simple program: "Print '01' thirty-two times." Very short! Sequence B has no obvious pattern. The shortest program that generates it might be: "Print '1100100101110011...[all 64 digits]..."' The program is as long as the sequence itself. In Kolmogorov's framework, K(Sequence A) is small: a simple, compressible pattern. K(Sequence B) is large: complex, incompressible, random.

This idea has profound implications. It gives a rigorous definition of randomness, explains why some things compress well and others don't, and provides a measure for how much "information" an object contains. Kolmogorov complexity even offers an answer to a philosophical question: what is the difference between a law of nature and a coincidence? A law is a simple pattern (low Kolmogorov complexity) that describes many observations. A coincidence is a complex pattern (high Kolmogorov complexity) with no shorter description.

4. Kolmogorov at ISI, Kolkata

In 1962, Kolmogorov visited the Indian Statistical Institute in Kolkata (then Calcutta) from April 14 to May 12, conducting seminars and a series of lectures in Calcutta and at the summer course in Bangalore (Ganguly, 2018). The ISI was a remarkable institution, founded in 1931 by P. C. Mahalanobis, and had become a world center for statistics and probability. In February 1962, the ISI was planning its first convocation. C. R. Rao asked the young probabilists at the institute, S. R. S. Varadhan, K. R. Parthasarathy, and R. Ranga Rao, who they would like to invite from the USSR. The answer was immediate: Kolmogorov.

Rao approached Mahalanobis, who "put the right word in at the right time" to the USSR Academy of Sciences. Kolmogorov agreed to come, but with one condition. He would

Figure 5: P. C. Mahalanobis welcomes A. N. Kolmogorov at Amrapali on April 24, 1962. Source: P. C. Mahalanobis Memorial Museum & Archives, ISI Kolkata. Reproduced with permission for academic use only.

not fly. He had problems with his ears and refused to travel by air. Kolmogorov found an elegant solution. He would join a Soviet oceanographic expedition, and when the ship reached Bombay (now Mumbai), he would disembark, take a train to Calcutta (now Kolkata), and give his lectures at the ISI.

And so he did. During the long sea voyage, Kolmogorov worked on a problem that had fascinated him: ***what is a random number***? How do you define randomness? How do you generate random numbers, and what is the complexity involved in describing them? On that boat, somewhere on the Indian Ocean, Kolmogorov developed the ideas that would later become *Kolmogorov complexity*, a fundamental concept in computer science and information theory (*vide* §3.6). When he arrived in Calcutta, he prepared a note on his work and submitted it to *Sankhyā̃*, the ISI's journal, where it was published in 1963 (Kolmogorov, 1963; Parthasarathy, 2019).

Kolmogorov was also an avid swimmer, and the long sea voyage allowed him to take a plunge every now and then, for relaxation and stimulation (Parthasarathy, 1988). Parthasarathy also recounts that Kolmogorov went on to suggest that institutes and universities in India should be along the coastline, so that the students and faculty can go for a swim before plunging into deeper mathematics.

The institute held its first convocation on February 12, 1962, in the mango grove on campus, chaired by Prof. K. B. Madhava (Vice-President) in the absence of President Sir C. D. Deshmukh. The convocation address was delivered by R. A. Fisher himself. Honorary degrees of Doctor of Science were conferred on five eminent persons: S. N. Bose, R. A. Fisher, Jawaharlal Nehru, W. A. Shewhart, and Kolmogorov. As Kolmogorov had not yet arrived in India, his degree, along with that of Prime Minister Nehru, was conferred in absentia (Ganguly, 2018). Notably, K. R. Parthasarathy and J. Sethuraman, two of the young probabilists who had proposed inviting Kolmogorov, received their PhDs at this same ceremony.

When Kolmogorov arrived in Kolkata on April 14, a Special Convocation was organ-

ised on April 28, 1962, presided over by S. N. Bose (Vice-President of the ISI), to formally present the degree to him in person. On the occasion, P. C. Mahalanobis addressed the gathering:

> "I welcome Academician Kolmogorov on behalf of the Indian Statistical Institute and I should like to greet him in the Indian way. At our First Convocation in last February, we announced the award of the honorary degree to two persons who could not be present, our Prime Minister Jawaharlal Nehru, and Academician Kolmogorov. We are very happy that Academician Kolmogorov could come here, although somewhat behind schedule, and we are glad to have this opportunity to welcome him."

The citation was then read by C. R. Rao, Head of the Research and Training School (Anonymous, 1962, p. 85).

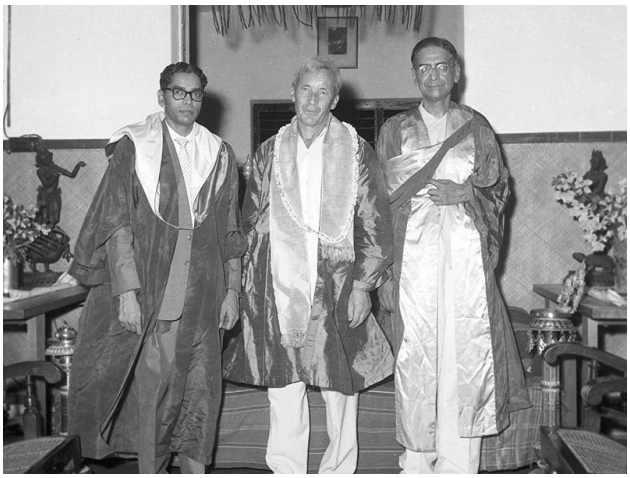


Figure 6: A. N. Kolmogorov with C. R. Rao and P.C. Mahalanobis at the Special Convocation of the Institute on April 28, 1962. Source: P. C. Mahalanobis Memorial Museum & Archives, ISI Kolkata. Reproduced with permission for academic use only.

The ISI in the 1960s was an extraordinary place. Mahalanobis's residence, Amrapali, had become a meeting place of great minds from across the world. Among those who visited were R. A. Fisher, W. A. Shewhart, Norbert Wiener, J. B. S. Haldane, Niels Bohr, P. M. S. Blackett, J. D. Bernal, Frédéric Joliot-Curie and Irène Joliot-Curie, Jan Tinbergen, Ragnar Frisch, Joan Robinson, and Julian Huxley (Ganguly, 2018). It had installed the first indigenous computer in India (1953) and operated two of the first digital computers in South Asia, an HEC-2M from England (1956) and a URAL from the Soviet Union (1959). The institute also employed translators who converted Russian mathematical papers into English, reflecting India's position in the Soviet orbit during the Cold War.

There is a funny, possibly anecdotal, story about Kolmogorov's visit, that I first heard from my advisor (Prof. J. K. Ghosh) and later read on Prof. Debraj Ray's blog (Ray, 2013). The story goes that ISI Kolkata had translators among their employees whose job was to translate Russian works into English for the faculty, and one of them was present during

the speech. After Kolmogorov spoke, there was awed silence during the question-and-answer session. Finally, the translator stood up and delivered an elaborate homily, in Russian, that went on for a good minute or two:

> "Professor Andrei Nikolaevich Kolmogorov, it is because of the presence of individuals such as yourself that I owe my livelihood. Not just mine, but that of my wife and children, who, but for the grace of your genius, would never have had the opportunities they enjoy. . . "

He went on in this vein, a heartfelt tribute to the great mathematician who had made his career as a translator of Russian mathematics possible. When the translator finished, Kolmogorov said: "Excuse me, but my English isn't very good. Could you repeat please?" The translator had been speaking in Russian. Kolmogorov, perhaps not catching that this was meant as a public tribute rather than a question, asked for an English translation of the Russian homage (Ray, 2013).

Figure 7: Andrei N. Kolmogorov during his 1962 visit to the Indian Statistical Institute, Kolkata. Seated in front; standing behind him (left to right) are K. R. Parthasarathy, B. P. Adhikari, S. R. S. Varadhan, J. Sethuraman, C. R. Rao, and P. K. Pathak. Source: Autobiography of S. R. Srinivasa Varadhan

As K. R. Parthasarathy, one of the probabilists who suggested inviting Kolmogorov, later reflected: "It is interesting in the history of Indian mathematics that at the birth of a very important concept, *Sankhyā* played an important role." Indian mathematical journals of the period were venues of genuine international significance; Arthur Wightman's foundational paper on axiomatic quantum field theory, for instance, appeared in the Journal of the Indian Mathematical Society.

The Abel laureate probabilist S. R. S. Varadhan recalls in a 2018 interview (Zeitouni, 2018) that when Kolmogorov visited the Indian Statistical Institute in 1962, he agreed to serve as an external examiner for his doctoral thesis. At the arranged lecture, which ran

far longer than planned, members of the audience began quietly leaving; Kolmogorov, angered by what he perceived as disrespect, threw down the chalk and walked out. He later remarked that in Moscow seminars ran for hours and that "when Kolmogorov speaks, people should listen" (Zeitouni, 2018). At the time of Kolmogorov's visit, S. R. S. Varadhan, K. R. Parthasarathy, R. Ranga Rao, and J. Sethuraman were young research scholars at ISI, in the early stages of their doctoral work, forming a remarkable cohort that would go on to shape modern probability theory.

Figure 8: A. N. Kolmogorov Bhavan at the Indian Statistical Institute, Kolkata. Construction of the building began in 2001 (Ganguly, 2018). Picture courtesy: Prof. Mrinal Kanti Das

To this day, one of the main buildings at ISI Kolkata is named "A. N. Kolmogorov Bhavan" in his honor, with construction having begun in 2001 (Ganguly, 2018).

5. The Soviet context: Mathematics under Stalin

5.1. The Luzin affair

> 'The past is a foreign country; they do things differently there.'
>
> L. P. Hartley, The Go-Between, 1953.

When talking about the genius of Kolmogorov, it is perhaps not irrelevant to talk about the extraordinarily hostile environment for science that prevailed in the Soviet Union under Stalin's rule, and especially after the advent of Lysenkoism (Lorentz, 2002). The trials

that scientists had to endure often forced upon them difficult choices — choices that should not be judged from our place and time. The past is distant, intangible, and fundamentally different from the present. Whatever window we have onto it shapes what we see through it.

In 1936, the beloved teacher Nikolai Luzin, one of Moscow University's outstanding mathematicians, was accused of plagiarism and of being a "servant to fascistoid science" and an enemy of the Soviet people. This was during Stalin's Great Purge, when such accusations typically led to imprisonment or execution (Lorentz, 2002; Rioul, 2022; Khimchenko, 2001).

Figure 9: Nikolai Luzin (9 December 1883 – 28 February 1950). Source: Wikimedia Commons

Kolmogorov and other former students were called to testify. They did testify against Luzin. Whether they were coerced, whether they believed the charges, or whether personal acrimony played a role remains a matter of historical debate. Archival evidence suggests that political pressures were intense, and many mathematicians faced difficult choices under the Soviet regime. None of the students ever spoke publicly about the affair afterward (Arnold, 1993; Shiryaev, 1989). Curiously, Luzin was not arrested or expelled from the Academy of Sciences. He lost some positions but continued working. Recent archival evidence from the 1990s suggests that Stalin personally concluded Luzin posed no real threat.

The bitterness, however, lingered for years; in 1946, after Luzin voted against Alexandrov's election to the Academy of Sciences, Kolmogorov struck his former teacher in the face on the floor of the Academy. The immediate provocation was a remark by Luzin that was understood by all present as a personal attack on Kolmogorov and Alexandrov's relationship (Graham and Kantor, 2009). This episode was later reported to the Kremlin, where Stalin recommended no action, though the Academy itself stripped Kolmogorov of his administrative positions, including the directorship of the Mathematical Research Institute (Lorentz, 2002; Graham and Kantor, 2009).

The affair left its mark on Kolmogorov. He became known as one of the very few "non-political mathematicians with real power" in the Soviet system, someone who could navigate between scientific discovery and political constraint, advancing mathematics while avoiding the fate of so many intellectuals in Stalin's Russia.

It would be too simple, however, to portray Kolmogorov only as a victim of ideological coercion. His relationship with Luzin was probably already strained well before the events of 1936. In his last interview (Khimchenko, 2001), Kolmogorov recalled how Luzin had, with great insistence, convinced the young Pavel Alexandrov that he was destined to solve the Continuum Problem, planting in him an expectation so heavy that it led to a personal crisis and a temporary desire to abandon mathematics. Personal tensions and intellectual disagreements thus predated the political drama, and the political events of 1936 fell on ground that was already disturbed.

5.2. Science in service of the State

The Soviet state demanded that science serve practical purposes. The official stance was that the government had all correct answers; competing ideas were rejected. Yet somehow, Kolmogorov and his students developed probability and statistics into powerful tools.

At the height of Lysenkoism, Soviet biology was reshaped by the doctrine that heredity could be molded by environment and that classical Mendelian genetics was a "bourgeois" fraud. Trofim Lysenko was an agronomist who rose to extraordinary political power under Stalin, effectively controlling Soviet biological research from the 1930s through the 1960s, and whose rejection of genetics set Soviet biology back by a generation (Lorentz, 2002). Lysenko's slogan that "**science is the enemy of chance**" expressed not merely a biological claim but an ideological suspicion toward probabilistic reasoning itself (Rioul, 2022). In February 1940 Kolmogorov published a short note defending Mendelian laws, arguing on mathematical grounds that the experimental claims advanced by Lysenko's supporters were fully consistent with classical genetics; when Lysenkoism became official doctrine in 1948, he was compelled to retract publicly (Rioul, 2022). After a 1936 *Pravda* denunciation of Soviet mathematicians for publishing their best work abroad, Kolmogorov arranged for a Russian edition of the *Grundbegriffe*, and in the ensuing years major scientific work increasingly appeared in Soviet journals (Rioul, 2022).

Yet, as G. G. Lorentz later remarked, the position of mathematicians, precarious though it could be, was often less catastrophic than that of writers and poets, whose work was more immediately exposed to political interpretation (Lorentz, 2002). The broader Stalinist period had already witnessed the execution of Nikolai Gumilev in 1921, the death of Osip Mandelstam in a transit camp in 1938, and the suicide of Marina Tsvetaeva in 1941; Vladimir Mayakovsky had taken his own life in 1930. Mathematics, by contrast, sometimes afforded a narrow shelter in abstraction, even if it could not entirely shield its practitioners from ideological pressure. As we discussed earlier, during the 1936 Luzin affair, Kolmogorov testified to Luzin's scientific achievements while simultaneously referring to his alleged "moral and political decadence," a formulation that illustrates the uneasy balance between loyalty and conformity (Rioul, 2022).

During World War II, Kolmogorov applied his statistical theories to artillery fire and developed a stochastic distribution scheme for barrage balloons to protect Moscow during the

fierce Battle of Moscow. His 1938 paper on "smoothing and predicting stationary stochastic processes" would later find major applications during the Cold War, though these were, of course, classified.

His contributions were recognized even within the Soviet system. In 1939, he was elected Academician of the USSR Academy of Sciences. In 1941, he received the Stalin Prize, followed by the Lenin Prize in 1965. Later, international recognition followed: the Wolf Prize in 1980, one of the highest honors in mathematics, and the Lobachevsky Prize in 1987.

5.3. Pavel Alexandrov: Partnership and protection

> "In the country house where P. S. Alexandrov and A. N. Kolmogorov held their famous gatherings for many years, there was a seminar room with a blackboard. Several years after Kolmogorov's death it had not been erased, and still had in his hand, in English, the motto:
>
> **MEN ARE CRUEL, BUT MAN IS KIND.**"
>
> Khimchenko (2001)

Throughout his life, Kolmogorov's closest relationship was with mathematician Pavel Alexandrov. The friendship that started during a boat trip on the Volga, would last 53 years, until Kolmogorov's death. In 1935, Alexandrov and Kolmogorov bought a house together in Komarovka, outside Moscow. They invited many renowned mathematicians there for discussions. A year before his death, Kolmogorov confided: "For me, these 53 years of intimate and indissoluble friendship were the reason why my whole life was filled with happiness, and the basis of this happiness was the permanent consideration that Alexandrov made for me" (Rioul, 2022).

Their relationship was most probably romantic (Graham and Kantor, 2009, p. 170), though they lived in a time and place where homosexuality was not accepted, let alone openly discussed. This fact would become a vulnerability that the Soviet authorities exploited throughout their lives. Rioul considers it plausible that the authorities threatened to reveal their relationship in order to compel their compliance (Rioul, 2022). Graham and Kantor note more broadly that the Soviet secret police gathered information on all prominent people, including scholars, noting their sexual and personal habits, and that such knowledge was routinely used to obtain the behaviour they wished (Graham and Kantor, 2009).

The political pressures of the Soviet era left marks on Kolmogorov's public record that are difficult to ignore. Kolmogorov and Alexandrov participated in the 1936 campaign against Luzin, the very man who had shaped both of their careers. Kolmogorov, who had previously questioned the scientific foundations of Trofim Lysenko's theories of heredity, did

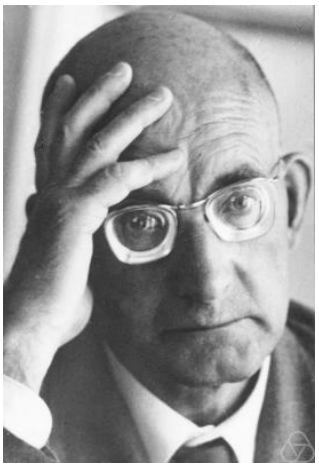


Figure 10: Pavel Sergeyevich Alexandrov (7 May 1896 – 16 November 1982). Source: Wikimedia Commons

not sustain that position publicly when the state required otherwise; Lysenko's work is now regarded as pseudoscience (Rioul, 2022). In the postwar years, he and Alexandrov put their names to a letter in *Pravda* denouncing Alexandr Solzhenitsyn.

NO PARDON FOR TREASON

"We learned with deep satisfaction that Solzhenitsyn has been deprived of Soviet citizenship and bounced out of our country. Soviet intelligentsia are characterized above all by their high civic consciousness, feeling of duty to people and state, respect for traditions and emblems of the people and pride in the high achievements of the Soviet people building communism. In his creations, published in the West, A. Solzhenitsyn blackens our social structure, desecrates the memory of those fallen in the battles of the Great Patriotic War and purposefully gives a distorted picture of the life of Soviet people. In his way he not only violates Soviet laws but also trespasses in the inner sanctum of our people. He has put himself outside of our society. Such persons have no place in our country."

Excerpt from a joint letter by Pavel Alexandrov and Andrei Kolmogorov condemning Alexander Solzhenitsyn, published in Pravda*, February 16, 1974. The letter was written under pressure from Soviet authorities, who used pressure to compel the mathematicians' participation.*

Rioul (2022) as well as Graham and Kantor (2009) reported that Kolmogorov on several occasions tried to explain his inconsistencies and what must have seemed like disloyalties to colleagues, saying, "Sometime I will explain everything to you." Shortly before his death he stated that he would "fear 'them' [the secret police] to his last day". This might help the reader today to make sense of what otherwise seems inexplicable: how could one of the greatest minds of the century participate in supporting junk science, and condemning a courageous dissident?

5.4. The weight of difficult choices

Theoretical computer scientist Scott Aaronson has written thoughtfully about what he calls "the Kolmogorov option" (Aaronson, 2017): the strategy of building fortresses of truth in places the ideological authorities do not particularly understand or care about, like pure mathematics, while avoiding direct confrontation with beliefs a culture considers necessary for its operation. The idea is not a moral verdict but a description of a strategy, one that many scientists under totalitarian regimes have navigated in different ways.

The historical record shows that Kolmogorov testified against Luzin in 1936, complied with demands to endorse Lysenko's doctrine, and co-signed the 1974 letter in *Pravda* condemning Solzhenitsyn. It also shows that in 1940, at personal risk, he published a note defending Mendelian genetics on mathematical grounds, that he financed the research stays of young mathematicians from his own funds, that he founded a school for mathematically gifted children, and that, according to Rioul (Rioul, 2022), he quietly protected Jewish researchers during periods of intense antisemitism in Soviet mathematics. These things coexisted.

What the record does not resolve, and what this essay cannot resolve, is the question of how these coexistences should be weighed. The circumstances that Soviet scientists faced under Stalin and after, where a person's most intimate relationships could be used as instruments of state compulsion, are not ones that admit easy comparisons across cultures or historical periods. Kolmogorov built mathematics of enduring value under conditions of extreme constraint, and he protected, as best he could, the people and the work he cared most about. The rest belongs to history.

6. The human side

Parthasarathy described Kolmogorov as "a great humanist," recalling how he was visibly moved by the poverty he witnessed in India, photographed ordinary people at work, reflected publicly on the coexistence of poverty and plenty, and showed deep concern for children and their education (Parthasarathy, 1988). Parthasarathy also remembered him as "an outdoor mathematician," to whom key ideas came while walking in the woods, swimming in the sea or a lake, rowing, or skiing down mountain slopes (Parthasarathy, 1988). Mathematics for Kolmogorov was not confined to the desk; it unfolded in motion, in landscape, and in conversation.

The Kolmogorov School: Beyond his research, Kolmogorov was passionate about education. In 1963, he founded a specialized mathematical boarding school, Kolmogorov School No. 18 (now the Kolmogorov School at Moscow State University). He personally taught up to 26 hours per week, leading not just classroom lessons but famous Sunday hikes, 40-kilometer walks with students, filled with mathematical discussions, philosophical debates, and literary conversations. These would end with dinner at his dacha in Komarovka, which he shared with his lifelong friend, the mathematician Pavel Alexandrov. Kolmogorov reformed the mathematics curriculum across the Soviet Union and wrote textbooks for grades 6–10 that influenced mathematical education for generations. He contributed over 80 articles to the Great Soviet Encyclopedia, making advanced mathematics accessible to general readers.

Kolmogorov never spoke about his personal life in public, but we know he married

Anna Dmitrievna Egorova in 1942. Trained as a teacher, she shared his deep interest in education and remained a steady presence in his life for more than four decades. Those who knew him remarked that she managed the practical affairs of daily life with quiet devotion, allowing him the freedom to pursue his wide-ranging intellectual projects. The marriage endured until his death in 1987, and she later played an important role in preserving his papers and personal archive. His relationship with Pavel Alexandrov, with whom he bought a house in 1935 and lived for decades, was likely more than friendship, though this remains a matter of historical interpretation.

What is clear is that Kolmogorov was a man of broad cultural interests: history, literature, philosophy, and poetry. He was not a narrow specialist but a Renaissance figure who saw mathematics as part of the larger tapestry of human knowledge. In 1971, at age 68, he joined an oceanographic expedition aboard the research vessel *Dmitri Mendeleev*. He worked with students well into old age, even as Parkinson's disease took its toll. In his final years, nearly blind, he continued thinking about mathematics.

He died on October 20, 1987, in Moscow, and was buried in Novodevichy Cemetery, the resting place of many of Russia's most celebrated artists, writers, and scientists.

7. Envoi: The harmony of uncertainty

A portrait that hangs in Komarovka. (Artist unknown.)

Figure 11: Source: Khimchenko (2001) as well as the video library, 'On the centenary of the great Russian scientist Andrei Nikolaevich Kolmogorov (25.IV.1903–20.X.1987)'.

Vladimir Arnold, one of Kolmogorov's most famous students, once said: "Kolmogorov, Poincaré, Gauss, Euler, Newton, are only five lives separating us from the source of our science" (Arnold, 1993). Five lives. From Newton, who created calculus and discovered the laws of motion and gravitation, to Kolmogorov, who created the mathematics of randomness and uncertainty, just five lifetimes span the distance.

Kolmogorov spent his life showing that randomness isn't the absence of pattern but a deeper kind of order. The Borel–Kolmogorov paradox, far from being a flaw in mathematics, revealed the subtle structure underlying probability. Turbulent fluids, seemingly chaotic, follow precise statistical laws. Random sequences can be defined by their complexity. Uncertainty itself can be axiomatized. Kolmogorov believed, as he once said, that "every mathematician believes that he is ahead of the others. The reason none state this belief in public is because they are intelligent people."

Perhaps he was ahead. Perhaps his genius lay in seeing that the universe, even in its randomness, has an inner harmony, and that mathematics could reveal it.

From the geometry of the sphere to the turbulence of fluids, from the random motion of particles to the complexity of information, from the tragedy of his birth to the triumph of his ideas, Kolmogorov's life was itself a kind of proof: that even amid chaos, uncertainty, and historical upheaval, the human mind can discern patterns, create beauty, and seek truth.

I close with a brief exchange from his final interview with the filmmaker Aleksandr Nikolaevich Marutyan, recorded for the 1983 film *Stories on Kolmogorov*:

> **K.:** Are you familiar with Shklovskii's *The Universe, Life, and the Mind*?
> **M.:** Yes.
> **K.:** He maintains that the development of every culture, if it is not aborted by some catastrophic events—and we all know what might befall humankind now—culminates in a stage of *loss of interest in technology*. Perhaps he really is right.
> **M.:** What does "loss of interest in technology" mean? You mean that people occupy themselves more with humanistic problems?
> **K.:** Not really humanistic problems. But it must be possible to return to a more basic and child-like joy in living. Do you know the German writer Hesse?
> **M.:** Yes.
> **K.:** In *Das Glasperlenspiel*, Hesse depicts such a society, and quite brilliantly, I would say. A society which has lost interest in technological progress.

Appendix

1903–1920: Childhood & revolution

- Born April 25, 1903 in Tambov. Mother dies in childbirth.
- Father disappears in Civil War (1919).
- Age 6: Discovers pattern $1 + 3 + 5 + \cdots + (2n - 1) = n^2$.
- Raised by aunts at grandfather's estate.

1920–1935: Student & rising star

- **1920**: Enters Moscow State University.
- **1922** (age 19): Fourier series diverging almost everywhere $\rightarrow$ international fame.
- **1925**: 8 papers including intuitionist logic, probability theory.
- **1929**: Meets Pavel Alexandrov – 53-year partnership begins.
- **1931**: Professor. Publishes Markov processes, Chapman-Kolmogorov equation.
- **1933**: *Grundbegriffe der Wahrscheinlichkeitsrechnung* – revolutionizes probability with three axioms.

1936–1945: Terror & war

- **1936**: Luzin Affair – political pressures force difficult choices; testifies against mentor. Stalin's Great Purge begins.
- **1940**: Defends Mendelian genetics against Lysenkoism.
- **1941**: Germany invades USSR. Publishes turbulence theory (K41, 5/3 law). Applies mathematics to Moscow defense.
- **1941–44**: Siege of Leningrad (872 days, $\sim$1 million dead).
- **1942**: Marries Anna Dmitrievna Egorova.

1945–1962: Post-war achievements

- **1948**: Lysenko triumphs – forced to retract genetics support.
- **1950s**: Introduces ε-entropy. KAM theorem (dynamical systems).
- **1953**: Stalin dies – gradual thaw.
- **1957**: With Arnold, partial solution to Hilbert's 13th problem.
- **1962**: Visits ISI Kolkata (April–May) by ship; develops Kolmogorov complexity during voyage. Special Convocation April 28. Lectures in Calcutta and Bangalore. Publishes in *Sankhyā* (1963).

1963–1987: Elder statesman

- **1963**: Founds School No. 18 for mathematically gifted children.
- **1970s**: Sophistication theory (refinement of Kolmogorov complexity).
- **1974**: With Alexandrov, signs *Pravda* letter condemning Solzhenitsyn (under pressure).
- **1980**: Wolf Prize.
- **1987**: Dies October 20 (age 84) from Parkinson's disease.
- **1991**: Soviet Union dissolves (4 years after his death).

Major historical events he lived through

WWI (1914–18)	Age 11–15
Russian Revolution (1917)	Age 14
Civil War (1918–21)	Age 15–18; father killed
Stalin's Purges (1936–38)	Age 33–35; directly affected
WWII (1941–45)	Age 38–42; applied work for defense
Siege of Leningrad (1941–44)	Age 38–41
Stalin's Death (1953)	Age 50
Cold War (1947–91)	Age 44–84; entire mature career

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