which says that the larger a sample, the more closely the sample characteristics match those of the parent population.

Insurance companies had been limiting the number of policies they sold. As policies are based on probabilities, each policy sold seemed to incur an additional risk, the cumulative effect of which, it was feared, could ruin a company. Beginning in the eighteenth century, companies began their current practice of selling as many policies as possible, because, as Bernoulli's law of large numbers showed, the bigger the volume, the more likely their predictions are to be accurate.

JULIA COLLINS

From bridges to DNA

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When Leonhard Euler proved to the people of Königsberg in 1735 that they could not traverse all of their seven bridges in one trip, he invented a new kind of mathematics: one in which distances didn't matter. His solution relied only on knowing the relative arrangements of the bridges, not on how long they were or how big the land masses were. In 1847, Johann Benedict Listing finally coined the term 'topology' to describe this new field, and for the next 150 years or so, mathematicians worked to understand the implications of its axioms.

For most of that time, topology was pursued as an intellectual challenge, with no expectation of it being useful. After all, in real life, shape and measurement are important: a doughnut is not the same as a coffee cup. Who would ever care about 5-dimensional holes in abstract 11-dimensional spaces, or whether surfaces had one or two sides? Even practical-sounding parts of topology such as knot theory, which had its origins in attempts to understand the structure of atoms, were thought to be useless for most of the nineteenth and twentieth centuries.

Suddenly, in the 1990s, applications of topology started to appear. Slowly at first, but gaining momentum until now it seems as if there are few areas in which topology is not used. Biologists learn knot theory to understand DNA. Computer scientists are using braids — intertwined strands of material running in the same direction — to build quantum computers, while colleagues down the corridor use the same theory to get robots moving. Engineers use one-sided Möbius strips to make more efficient conveyer belts. Doctors depend on homology theory to do brain scans, and cosmologists use it to understand how galaxies form. Mobile-phone companies use topology to identify the holes in network coverage; the phones themselves use topology to analyse the photos they take.

It is precisely because topology is free of distance measurements that it is so powerful. The same theorems apply to any knotted DNA, regardless of how long it is or what animal it comes from. We don't need different brain scanners for people with different-sized brains. When Global Positioning System data about mobile phones are unreliable, topology can still guarantee that those phones will receive a signal. Quantum computing won't work unless we can build a robust system impervious to noise, so braids are perfect for storing information because they don't change if you wiggle them. Where will topology turn up next?

CHRIS LINTON

From strings to nuclear power

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Series of sine and cosine functions were used by Leonard Euler and others in the eighteenth century to solve problems, notably in the study of vibrating strings and in celestial mechanics. But it was Joseph Fourier, at the beginning of the nineteenth century, who recognized the great practical utility of these series in heat conduction and began to develop a general theory. Thereafter, the list of areas in which Fourier series were found to be useful grew rapidly to include acoustics, optics and electric circuits. Nowadays, Fourier methods underpin large parts of science and engineering and many modern computational techniques.

However, the mathematics of the early nineteenth century was inadequate for the development of Fourier's ideas, and the resolution of the numerous problems that arose challenged many of the great minds of the time. This in turn led to new mathematics. For example, in the 1830s, Gustav Lejeune Dirichlet gave the first clear and useful definition of a function, and Bernhard Riemann in the 1850s and Henri Lebesgue in the 1900s created rigorous theories of integration. What it means for an infinite series to converge turned out to be a particularly slippery animal, but this was gradually tamed by theorists such as Augustin-Louis Cauchy and Karl Weierstrass, working in the 1820s and 1850s, respectively. In the 1870s, Georg Cantor's first steps towards an abstract theory of sets came about through analysing how two functions with the same Fourier series could differ.

The crowning achievement of this mathematical trajectory, formulated in the first decade of the twentieth century, is the concept of a Hilbert space. Named after the German mathematician David Hilbert, this is a set of elements that can be added and multiplied according to a precise set of rules, with special properties that allow many of the tricky questions posed by Fourier series to be answered. Here the power of mathematics lies in the level of abstraction and we seem to have left the real world behind.

Then in the 1920s, Hermann Weyl, Paul Dirac and John von Neumann recognized that this concept was the bedrock of quantum mechanics, since the possible states of a quantum system turn out to be elements of just such a Hilbert space. Arguably, quantum mechanics is the most successful scientific theory of all time. Without it, much of our modern technology — lasers, computers, flat-screen televisions, nuclear power — would not exist. ■

CORRECTIONS

In the Comment article 'Buried by bad decisions' (*Nature* **474,** 275–277), the statement "we will save lives by pushing a trolley into a person but not a person into a trolley" refers to an incorrect reference. The correct one is J. D. Greene *et al.* *Science* **293,** 2105–2108 (2001).

The Comment article 'Crowd control in Rwanda' (*Nature* **475,** 572–573) should have stated that family-planning aid dropped from 30% to 12% of overall health aid, not overall aid.