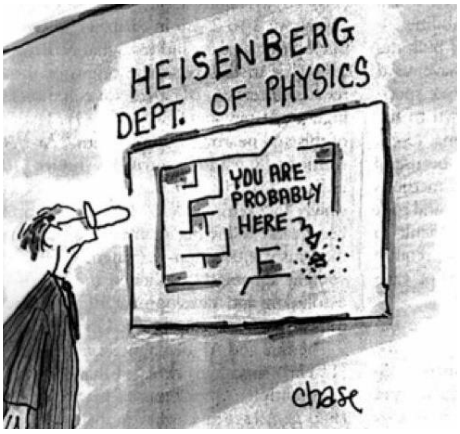
Are you sure?

By the time you read this, the UK will have left the EU – or will we? There's a general election coming – or is there? Politics, not only in Britain, hasn't experienced such uncertainty for a long time, and predictions of what will happen even in the next week or month are completely unreliable (which doesn't stop people making them, of course).

Uncertainty is a fact of life that we encounter all the time. It has its place in science too, contrary to the popular image that science deals in undisputed concrete facts: "Science has proved…" is supposed to be a convincing line in advertisements, arguments at the pub, and attempts to dismiss something you don't personally believe in. But it just isn't so.

After Sir Isaac Newton and his contemporaries developed theories of motion, gravity and other forces, and other famous scientists later provided explanations of electricity and magnetism, the universe was believed to operate like perfect clockwork, governed by laws that could be written down in precise mathematical form. That view was shattered by experiments around a hundred years ago demonstrating that, when you make observations at the very tiny level of atoms and molecules, strange things happen. Instead of definite confident predictions, we have to speak of probabilities and a range of possible outcomes. This was the birth of quantum theory and the introduction of lots of new ideas and new words to understand and express a reality that defies precise description, including the Heisenberg Uncertainty Principle that provides an estimate of the degree of precision (reliability) we can expect in a physical measurement: "Heisenberg probably rules OK" used to be a popular joke.



Fortunately for the vast majority of us, in normal everyday life the Heisenberg uncertainty is so incredibly small that it has no practical importance for us in our understanding of the behaviour of things like cars, food, and footballs. It does matter a lot, however, for those working at sub-microscopic dimensions, including many in molecular biology, genetics, chemistry, particle physics, and microengineering.

For example, over the years electronic components have been steadily miniaturised, and a current smartphone has vastly more processing power than the room-sized mainframe computers I used in my first research. Recently there has been much talk of so-called quantum computers in which this miniaturisation is taken to its extreme and the components are individual molecules. Major success has just been claimed in rapid calculations on a prototype quantum computer that would supposedly take many years on even the fastest conventional computer. The trouble is

that quantum computing is subject to quantum level random behaviour and, in its simple form, is therefore unreliable. It's likely to be some years before this development becomes a practical reality.

One of Albert Einstein's most famous quotations is "God does not play dice with the universe". While this has been used both by atheists and by their opponents to support their viewpoints (Einstein was enigmatically neither a conventional religious believer nor an atheist), the emphasis is surely on the dice and the picture of randomness and chance, almost like gambling, that is conjured up by the counter-intuitive weirdness of quantum theory. Einstein didn't like quantum theory and never really accepted it, although he couldn't convincingly argue against it and even some of his own work that earned him a Nobel Prize provided evidence to support it. We can't explain scientific observations at the molecular level without quantum theory, and yet we know our current understanding in these terms is incomplete and seriously lacking, because the two big current theories of physics – quantum theory describing the microscopic scale, and relativity describing the cosmic scale – just don't fit together properly. The so-called Theory of Everything (used as the title for the 2014 biographical film about Stephen Hawking) still eludes scientists as a single explanation covering both extremes and everything in between. Science can't get rid of uncertainty but has to encompass it; it's an integral part of how things are.

The mathematical language of uncertainty is the area of statistics, with terms like probability, deviation, and expectation. It finds practical application in many modern technological developments such as image recognition and extracting useful information from "noisy" data affected by random influences masking low-level measured signals such as radio telescope images or low-light photo and video. Interestingly, the statistical theory that is most widely and successfully used in these areas was developed by an 18th century Presbyterian minister, Thomas Bayes, and is known as Bayesian statistics. It describes probability in terms of a degree of belief in some proposed explanation, based on initial information and then modified by further information that becomes available. This is just one of many examples throughout history of a positive interaction between Christian belief and scientific understanding and application.

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