REALITY CHECK
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Why Is There Something Rather Than Nothing?

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Why is there something rather than nothing? This question is often the last resort of the theist who seeks to argue for the existence of God from science and finds all his other arguments fail. In his 2004 book *Why There Is Something Rather than Nothing*, philosopher Bede Rundle calls it "philosophy's central, and most perplexing, question." His simple (but book-length) answer: "There has to be something."

Clearly, many conceptual problems are associated with this question. How do we define *nothing*? What are its properties? If it has properties, doesn't that make it *something*? The theist claims that God is the answer. But, then, why is there God rather than nothing? Assuming we can define *nothing*, why should nothing be a more natural state of affairs than something?

In fact, we can give a plausible scientific reason based on our best current knowledge of physics that something is more natural than nothing! Of course, that requires providing a physical definition of *nothing*. Can I imagine a physical system that has no properties? Yes, as long as you do not insist on playing word games with me by calling the lack of properties a property.

Suppose we remove all the particles and any possible non-particulate energy from some unbounded region of space. Then we have no mass, no energy, or any other physical property. This includes space and time, if you accept that these are relational properties that depend on the presence of matter to be meaningful.

While we can never produce this physical nothing in practice, we have the theoretical tools to describe a system with no particles. The methods of quantum field theory provide the means to move mathematically from a state with n particles to a state of more or fewer particles, including zero particles. If an n-particle state can be described, then so can a state with $n = 0$.

Let us start with a monochromatic electromagnetic field, which is described quantum mechanically as system of n photons of equal energy E. The mathematical description of the field is equivalent to a harmonic oscillator whose quantum solution is a series of energy levels equally spaced like the rungs of a ladder by an amount E, each rung representing a field with one more photon than the field represented by the rung below. Stepping down the ladder you find that the bottom rung corresponding to a field of zero photons is not zero energy but rather $E/2$. This is called the zero-point energy.

This result is true for all bosons, particles that have zero or integral spin. On the other hand, fermions that have half-integral spin, such as the electron and quark, have a zero-point energy of $-E/2$ (negative energy is no problem in relativistic quantum mechanics; in fact, it is required by the simple mathematical fact that a square root has two possible signs).

In the current universe, *bosons* outnumber *fermions* by a factor of a billion. This has led people to conclude that the vacuum energy of the universe, identified with the zero point energy remaining after all matter is removed, is very large. A simple calculation indicates that the energy density of the vacuum is 120 orders of magnitude greater than its experimental upper limit. Clearly this estimate is wrong. This calculation must be one of the worst in scientific history! Since a non-particulate vacuum energy density is proportional to Einstein's cosmological constant, this is called the cosmological constant problem.

Instead of using numbers from the current universe, we can visualize a vacuum with equal numbers of bosons and fermions. Such a vacuum might have existed at the very beginning of the big bang. Indeed this is exactly what is to be expected if the vacuum out of which the universe emerged was supersymmetric—that is made no distinction between bosons and fermions.

This suggests a more precise definition of *nothing*. Nothing is a state that is the simplest of all conceivable states. It has no mass, no energy, no space, no time, no spin, no bosons, no fermions—nothing.

Then why is there something rather than nothing? Because something is the more natural state of affairs and is thus more likely than nothing—more than twice as likely according to one calculation. We can infer this from the processes of nature where simple systems tend to be unstable and often spontaneously transform into more complex ones. Theoretical models such as the inflationary model of the early universe bear this out.

Consider the example of the snowflake. Our experience tells us that a snowflake is very ephemeral, melting quickly to drops of liquid water that exhibit far less structure. But that is only because we live in a relatively high temperature environment, where collisions with molecules in thermal motion reduce the fragile arrangement of crystals to a simpler liquid. Energy is required to destroy the structure of a snowflake.

But consider an environment where the ambient temperature is well below the melting point of ice, as it is in most of the universe far from the highly localized effects of stellar heating. In such an environment, any water vapor would readily crystallize into complex structures. Snowflakes would be eternal, or at least will remain intact until cosmic rays tear them apart.

What this example illustrates is that many simple systems are unstable, that is, have limited lifetimes as they undergo spontaneous phase transitions to more complex structures of lower energy. Since "nothing" is as simple as it gets, we would not expect it to be completely stable. In some models of the origin of the universe, the vacuum undergoes a spontaneous phase transition to something more complicated, like a universe containing matter. The transition nothing-to-something is a natural one, not requiring any external agent.

As Nobel laureate physicist Frank Wilczek has put it, "The answer to the ancient question 'Why is there something rather than nothing?' would then be that 'nothing' is unstable."

Victor J. Stenger's next book, The Comprehensible Cosmos: Where Do the Laws of Physics Come From? *will be out this year. His Web site is at www.colorado.edu/philosophy/vstenger.*