CHAPTER 9

Nothing Is Something

I don't mind not knowing. It doesn't scare me.

—RICHARD FEYNMAN

Isaac Newton, perhaps the greatest physicist of all time, profoundly changed the way we think about the universe in many ways. But perhaps the most important contribution he made was to demonstrate the possibility that the entire universe is explicable. With his universal law of gravity, he demonstrated for the first time that even the heavens might bend to the power of natural laws. A strange, hostile, menacing, and seemingly capricious universe might be nothing of the sort.

If immutable laws governed the universe, the mythical gods of ancient Greece and Rome would have been impotent. There would have been no freedom to arbitrarily bend the world to create thorny problems for mankind. What held for Zeus would also apply to the God of Israel. How could the Sun stand still at midday if the Sun did not orbit the Earth but its motion in the sky was actually caused by the revolution of the Earth, which, if suddenly stopped, would produce forces on its surface that would destroy all human structures and humans along with them?

Of course, supernatural acts are what miracles are all about. They are, after all, precisely those things that circumvent the laws of nature. A god who can create the laws of nature can presumably also circumvent them at will. Although why they would have been circumvented so liberally thousands of years ago, before the invention of modern communication instruments that could have recorded them, and not today, is still something to wonder about.

In any case, even in a universe with no miracles, when you are faced with a profoundly simple underlying order, you can draw two different conclusions. One, drawn by Newton himself, and earlier espoused by Galileo and a host of other scientists over the years, was that such order was created by a divine intelligence responsible not only for the universe, but also for our own existence, and that we human beings were created in her image (and apparently other complex and beautiful beings were not!). The other conclusion is that the laws themselves are all that exist. These laws themselves require our universe to come into existence, to develop and evolve, and we are an irrevocable by-product of these laws. The laws may be eternal, or they too may have come into existence, again by some yet unknown but possibly purely physical process.

Philosophers, theologians, and sometimes scientists continue to debate these possibilities. We do not know for certain which of them actually describes our universe, and perhaps we shall never know. But the point is, as I emphasized at the very beginning of this book, the final arbiter of this question will not come from hope, desire, revelation, or pure thought. It will come, if it ever does, from an exploration of nature. Dream or nightmare, as Jacob Bronowski said in the opening quote in the book—and one person's dream in this case can easily be another's nightmare—we need to live our experience as it is and with our eyes open. The universe is the way it is, whether we like it or not.

And here, I think it is *extremely significant* that a universe from nothing—in a sense I will take pains to describe—that arises naturally, and even inevitably, is increasingly consistent with everything we have learned about the world. This learning has *not* come from philosophical or theological musings about morality or other speculations about the human condition. It is instead based on the remarkable and exciting developments in empirical cosmology and particle physics that I have described.

I want thus to return to the question I described at the beginning of this book: Why is there something rather than nothing? We are now presumably in a better position to address this, having reviewed the modern scientific picture of the universe, its history, and its possible future, as well as operational descriptions of what "nothing" might actually comprise. As I also alluded to at the beginning of this book, this question too has been informed by science, like essentially all such philosophical questions. Far from providing a framework that forces upon us the requirement of a creator, the very meaning of the words involved have so changed that the sentence has lost much of its original meaning—something that again is not uncommon, as empirical knowledge shines a new light on otherwise dark corners of our imagination.

At the same time, in science we have to be particularly cautious about "why" questions. When we ask, "Why?" we usually mean "How?" If we can answer the latter, that generally suffices for our purposes. For example, we might ask: "Why is the Earth 93 million miles from the Sun?" but what we really probably mean is, "How is the Earth 93 million miles from the Sun?" That is, we are interested in what physical processes led to the Earth ending up in its present position. "Why" implicitly suggests purpose, and when we try to understand the solar system in scientific terms, we do not generally ascribe purpose to it.

So I am going to assume what this question really means to ask is, "How is there something rather than nothing?" "How" questions are really the only ones we can provide definitive answers to by studying nature, but because this sentence sounds much stranger to the ear, I hope you will forgive me if I sometimes fall into the trap of appearing to discuss the more standard formulation when I am really trying to respond to the more specific "how" question.

Even here, from the perspective of actual *understanding,* this particular "how" question has been supplanted by a host of operationally more fruitful questions, such as, "What might have produced the properties of the universe that most strikingly characterize it at the present time?" or, perhaps more important, "How can we find out?"

Here I want to once again beat what I wish were a dead horse. Framing questions in this way allows the production of new knowledge and understanding. This is what differentiates them from purely theological questions, which generally presume the answers up front. Indeed, I have challenged several theologians to provide evidence contradicting the premise that theology has made no contribution to knowledge in the past five hundred years at least, since the dawn of science. So far no one has provided a counterexample. The most I have ever gotten back was the query, "What do you mean by knowledge?" From an epistemological perspective this may be a thorny issue, but I maintain that, if there were a better alternative, someone would have presented it. Had I presented the same challenge to biologists, or psychologists, or historians, or astronomers, none of them would have been so flummoxed.

The answers to these sorts of fruitful questions involve theoretical predictions that can be tested via experiments to drive our operational knowledge of the universe forward more directly. Partly for this reason, I have focused on such fruitful questions up to this point in this book. Nevertheless, the "something from nothing" question continues to have great currency, and therefore probably needs to be confronted.

Newton's work dramatically reduced the possible domain of God's actions, whether or not you attribute any inherent rationality to the universe. Not only did Newton's laws severely constrain the freedom of action of a deity, they dispensed with various requirements for supernatural intervention. Newton discovered that the motion of planets around the Sun does not require them to be continually pushed along their paths, but rather, and highly nonintuitively, requires them to be pulled by a force acting toward the Sun, thus dispensing of the need for the angels who were often previously invoked as guiding the planets on their way. While dispensing with this particular use of angels has had little impact on people's willingness to believe in them (polls suggest far more people believe in angels in the United States than believe in evolution), it is fair to say that progress in science since Newton has even more severely constrained the available opportunities for the hand of God to be manifest in his implied handiwork.

We can describe the evolution of the universe back to the earliest moments of the Big Bang without specific need for anything beyond known physical laws, and we have also described the universe's likely future history. There are certainly still puzzles about the universe that we don't understand, but I am going to assume that readers of this book are not wedded to a "God of the Gaps" picture, whereby God is invoked whenever there is something specific about our observations that seems puzzling or not fully understood. Even theologians recognize that such recourse not only diminishes the grandeur of their supreme being, but it also opens that being up to being removed or further marginalized whenever new work explains or removes the puzzle.

In this sense, the "something from nothing" argument really tries to focus on the original act of creation and asks whether a scientific explanation can ever be logically complete and fully satisfying in addressing this specific issue.

It turns out that, given our current understanding of nature, there are three different, separate meanings for the "something from nothing" question. The short answer to each is "quite plausibly yes," and I shall discuss each in turn in the rest of this book as I attempt to explain why or, as I have argued just now, better yet how.

Occam's razor suggests that, if some event is physically plausible, we don't need recourse to more extraordinary claims for its being. Surely the requirement of an all-powerful deity who somehow exists outside of our universe, or multiverse, while at the same time governing what goes on inside it, is one such claim. It should thus be a claim of last, rather than first, resort.

I have already argued in the preface to this book that merely defining "nothingness" as "nonbeing" is not sufficient to suggest that physics, and more generally science, is not adequate to address the question. Let me give an additional, more specific argument here. Consider an electron-positron pair that spontaneously pops out of empty space near the nucleus of an atom and affects the property of that atom for the short time the pair exists. In what sense did the electron or positron exist before?

Surely by any sensible definition they didn't. There was potential for their existence, certainly, but that doesn't define *being* any more than a potential human being exists because I carry sperm in my testicles near a woman who is ovulating, and she and I might mate. Indeed, the best answer I have ever heard to the question of what it would be like to be dead (i.e., be nonbeing) is to imagine how it felt to be before you were conceived. In any case, if potential to exist were the same as existence, then I am certain that by now masturbation would be as hot button a legal issue as abortion now is.

The Origins Project at Arizona State University, which I direct, recently ran a workshop on the Origin of Life, and I cannot help but view the present cosmological debate in this context. We do not yet fully understand how life originated on Earth. However, we have not only plausible chemical mechanisms by which this might be conceivable, but we are also homing in closer and closer every day to specific pathways that might have allowed biomolecules, including RNA, to arise naturally. Moreover, Darwinian evolution, based on natural selection, provides a compellingly accurate picture of how complex life emerged on this planet following whatever specific chemistry produced the first faithfully self-replicating cells with a metabolism that captured energy from their environment. (As good a definition of life as I can come up with for the moment.)

Just as Darwin, albeit reluctantly, removed the need for divine intervention in the evolution of the modern world, teeming with diverse life throughout the planet (though he left the door open to the possibility that God helped breathe life into the first forms), our current understanding of the universe, its past, and its future make it more plausible that "something" can arise out of nothing without the need for any divine guidance. Because of the observational and related theoretical difficulties associated with working out the details, I expect we may never achieve more than plausibility in this regard. But plausibility itself, in my view, is a tremendous step forward as we continue to marshal the courage to live meaningful lives in a universe that likely came into existence, and may fade out of existence, without purpose, and certainly without us at its center.

Let's now return to one of the most remarkable features of our universe: it is as close to being flat as we can measure. I remind you of the unique facet of a flat universe, at least on scales where it is dominated by matter in the form of galaxies, and where a Newtonian approximation remains valid: in a flat universe, and only in a flat universe, the average Newtonian gravitational energy of every object participating in the expansion is precisely zero.

I emphasize that this was a falsifiable postulate. It didn't have to be this way. Nothing required this except theoretical speculations based on considerations of a universe that could have arisen naturally from nothing, or at the very least, from *almost nothing*.

I cannot overstress the importance of the fact that, once gravity is included in our considerations of nature, one is no longer free to define the total energy of a system arbitrarily, nor the fact that there are both positive and negative contributions to this energy. Determining the total gravitational energy of objects being carried along by the expansion of the universe is *not* subject to arbitrary definition any more than the geometric curvature of the universe is a matter of definition. It is a property of space itself, according to general relativity, and this property of space is determined by the energy contained within it.

I say this because it has been argued that the statement that the average total Newtonian gravitational energy of every galaxy in a flat, expanding universe is zero is arbitrary, and that any other value would be just as good, but that scientists "define" the zero point to argue against God. So claimed Dinesh D'Souza, anyway, in his debates with Christopher Hitchens on the existence of God.

Nothing could be further from the truth. The effort to determine the curvature of the universe was an undertaking carried out over half a century by scientists who devoted their lives to determining the actual nature of the universe, not to imposing their own desires upon it. Even well after the theoretical arguments about why the universe should be flat were first proposed, my observational colleagues, during the 1980s and even early 1990s, remained bent on proving otherwise. For, after all, in science one achieves the greatest impact (and often the greatest headlines) not by going along with the herd, but by bucking against it.

Nevertheless, the data have had the last word, and the last word is in. Our observable universe is as close to being flat as we can measure. The Newtonian gravitational energy of galaxies moving along with the Hubble expansion *is* zero—like it or not.

I would now like to describe how, if our universe arose from nothing, a flat universe, one with zero total Newtonian gravitational energy of every object, is precisely what we should expect. The argument is a little subtle—subtler than I have been able to describe in my popular lectures on the subject—so I am happy to have the space here to carefully try to lay it out.

First, I want to be clear about what kind of "nothing" I am discussing at the moment. This is the simplest version of nothing, namely empty space. For the moment, I will assume space exists, with nothing at all in it, and that the laws of physics also exist. Once again, I realize that in the revised versions of nothingness that those who wish to continually redefine the word so that no scientific definition is practical, this version of nothing doesn't cut the mustard. However, I suspect that, at the times of Plato and Aquinas, when they pondered why there was something rather than nothing, empty space with nothing in it was probably a good approximation of what they were thinking about.

As we saw in chapter 6, Alan Guth has explained precisely how we can get something from this kind of nothing—the ultimate free lunch. Empty space can have a non-zero energy associated with it, even in the absence of any matter or radiation. General relativity tells us that space will expand exponentially, so that even the tiniest region at early times could quickly encompass a size more than large enough to contain our whole visible universe today.

As I also described in that chapter, during such a rapid expansion, the region that will eventually encompass our universe will get flatter and flatter even as the energy contained within empty space grows as the universe grows. This phenomenon happens without the need for any hocus pocus or miraculous intervention. This is possible because the gravitational "pressure" associated with such energy in empty space is actually negative.

This "negative pressure" implies that, as the universe expands, the expansion dumps energy *into* space rather than vice versa.

According to this picture, when inflation ends, the energy stored in empty space gets turned into an energy of real particles and radiation, creating effectively the traceable beginning of our present Big Bang expansion. I say the traceable beginning because inflation effectively erases any memory of the state of the universe before it began. All complexities and irregularities on initially large scales (if the initial preexisting universe or metaverse were large, even infinitely large) get smoothed out and/or driven so far outside our horizon today that we will always observe an almost uniform universe after enough inflationary expansion has taken place.

I say almost uniform because I also described in chapter 6 how quantum mechanics will always leave some residual, small-density fluctuations that get frozen during inflation. This results in the second amazing implication of inflation, that small-density fluctuations in empty space due to the rules of quantum mechanics will later be responsible for all the structure we observe in the universe today. So we, and everything we see, result out of quantum fluctuations in what is essentially nothingness near the beginning of time, namely during the inflationary expansion.

After all the dust is settled, the generic configuration of the matter and radiation will be that of an essentially flat universe, one in which the average Newtonian gravitational energy of all objects will appear to be zero. This will almost always be the case, unless one could very carefully fine-tune the amount of inflation.

Therefore, our observable universe can start out as a microscopically small region of space, which can be essentially empty, and still grow to enormous scales containing eventually lots of matter and radiation, all without costing a drop of energy, with enough matter and radiation to account for everything we see today!

The important point worth stressing in this brief summary of the inflationary dynamics discussed in chapter 6 is that something can arise from empty space *precisely* because the energetics of empty space, in the presence of gravity, are *not* what common sense would have guided us to suspect before we discovered the underlying laws of nature.

But no one ever said that the universe is guided by what we, in our petty myopic corners of space and time, might have originally thought was sensible. It certainly seems sensible to imagine that a priori, matter cannot spontaneously arise from empty space, so that *something,* in this sense, cannot arise from *nothing*. But when we allow for the dynamics of gravity and quantum mechanics, we find that this commonsense notion is no longer true. This is the *beauty* of science, and it should not be threatening. Science simply forces us to revise what is sensible to accommodate the universe, rather than vice versa.

To summarize then: the observation that the universe is flat and that the local Newtonian gravitational energy is essentially zero today is strongly suggestive that our universe arose though a process like that of inflation, a process whereby the energy of empty space (nothing) gets converted into the energy of something, during a time when the universe is driven closer and closer to being essentially exactly flat on all observable scales.

While inflation demonstrates how empty space endowed with energy can effectively create everything we see, along with an unbelievably large and flat universe, it would be disingenuous to suggest that empty space endowed with energy, which drives inflation, is really *nothing*. In this picture one must assume that space exists and can store energy, and one uses the laws of physics like general relativity to calculate the consequences. So if we stopped here, one might be justified in claiming that modern science is a long way from really addressing how to get something from nothing. This is just the first step, however. As we expand our understanding, we will next see that inflation can represent simply the tip of a cosmic iceberg of nothingness.