What Parsons calls these "puzzles" of "*A* is *A*" cry out for solutions. So why have nearly two thousand years of pondering led to no answer? Because, says Parsons, "There is no answer." "There is no answer at all." Yes, those are Parson's words: "no answer at all." How could that possibly be? "Because," says Parsons, "of the way the world is."[14] Because abstractions may be indispensable. But they don't accurately reflect reality.

Twentieth-century über-philosopher Bertrand Russell, the man whose writings helped shoehorn you into atheism, was tortured by the paradoxes of *A* is *A* in his 1903 book *The Principles of Mathematics*. He puzzled over whether the relationships called "=" and "is" even exist. He twisted and turned over the question, as he put it, of "whether there is such a concept at all."[15] In fact, Russell said, "It may be said, identity cannot be a relation."[16] It can't represent something that exists in the real world. But we have to use it. Why? It's handy as all get out. Up to a point.

Bertrand Russell had a "friend" at Cambridge who was seventeen years his junior. A friend whose three brothers had committed suicide, leaving him and his one remaining brother to question life profoundly. In Russell's opinion, that friend was "the most perfect example I have ever known of genius."[17] The friend's name was Ludwig Wittgenstein. And Wittgenstein would become the airy and incomprehensible god of twentieth-century philosophy. But even Wittgenstein had his doubts about *A* is *A*. In his usual elliptical and indecipherable manner, Wittgenstein put *A* is *A* at the head of the list of "word-formations with which we feel not fully at ease." He said this lack of ease

> manifests itself, e.g., in our always having found the proposition A = A to be something strange and profoundly mysterious. If we are shown a way of not coming up against this proposition, if we are offered a notation that excludes it, then we are prepared straightaway to welcome this and to abandon the law of identity, this putative foundation of the whole of logic.[18]

Can we help Wittgenstein out? Can we help him escape from *A* = *A*? Can we show him "a way of not coming up against this . . . putative foundation of the whole of logic?" Yes.

But why in the world does one *A* ***not*** equal another *A*? If we clone you and get an identical copy, why are you not your clone? Location, location, location. Location in time. Location in space. Location in a big picture. And your place in many smaller pictures nested within that big picture. Not to mention that each of the two yous is composed of different raw materials. And that each of you sets off on a different set of adventures. Being you triggers one mesh of chemical and electron flows in your brain. Looking at your clone triggers another. The two of you are not the same because of what you might call the law of separation. Because of what you might call the law of differentiation. And because of the laws of sociality, the laws of the talking cosmos, the laws of the conversational cosmos. Which leads us to the man who founded *A* = *A*: Aristotle.



## WHEN IS A FROG A RIVER?
## ARISTOTLE WRESTLES HERACLITUS

If *A* is *A*, a philosopher should equal a philosopher. But that's not the way the cosmos works. Similar things set themselves apart from each other. And that includes philosophers. What's more, opposites are joined at the hip. Einstein says that most creative acts come from opposition. They come from pitting yourself against someone with another point of view. They come from the law of differentiation. And that was true of Aristotle and his law of identity, his law of noncontradiction,[19] his construction of the base for *A* is *A*.

Aristotle came up with the idea behind *A* is *A*[20] to fling a finger in the face of another philosopher, a philosopher who, in his words, saw "the whole of this visible nature in motion."[21] Who was Aristotle's straw man, the thesis maker against whom Aristotle aimed his antithesis? Aristotle developed his ideas in opposition to Heraclitus, the founder of the school of perpetual transformation. Heraclitus was responsible for turning change into what Aristotle called a "dogma." And a pernicious dogma at that. Or at least that's the way Aristotle saw it.

Location often leads to differentiation. Athens was the home base of the Lyceum, the school that Aristotle founded in 335 BCE and ran. But Heraclitus was a philosopher from the city of Ephesus, on the opposite shore of the Aegean Sea. And Heraclitus was obsessed with the shifting nature of things. "What was scattered gathers," he said, "What was gathered blows apart." Heraclitus tried to get that message across in slightly different terms in his best-known phrase, "You cannot step twice into the same river."[22] What did Heraclitus mean? The river is always changing. The water into which you put your foot the first time is no longer there the second time you dip your toes into the flow. The swirl of liquid you felt surging around your calves is now somewhere downstream. And in all probability even the patterns of the water that caressed your leg have changed as they've moved a few yards further toward the sea, shifting from the spiral swirl you felt around your calves to a streamlined, straight, "laminar" flow.

Heraclitus proved his proposition that all things change in a rather abrupt way. He died ninety-one years before Aristotle was born, his flesh scattered just as he'd implied it would be. However, location in time is another source of differentiation. And there was a ninety-one-year gap between Heraclitus and Aristotle. But like a whirlpool in a stream, Heraclitus's ideas survived. In fact, they thrived. Heraclitus's concepts were so pervasive that another Athenian philosopher, Cratylus, took Heraclitus's notion of perpetual, second-by-second change a step further.[23] According to University of Pennsylvania philosopher Charles H. Kahn, "Cratylus denied that you could even step in the river once, since you are changing too."[24]

The result, says Aristotle, was that the "most extreme"[25] followers of Heraclitus said it was impossible to fix a name to anything. Is this little green creature hopping across your kitchen table after your trip to a summer pond a frog? According to the Heraclitan change zealots, you can't say yes or no. Why? In Aristotle's words, the Heraclitans "considered that verification was not a thing that is possible."[26] OK, but once again, why? Because the frog is changing. A year ago it was an egg. Two weeks ago it was a tadpole. And by the end of the summer it could well be digested into the muscles and bones of your frog-eating dog. This, says Aristotle, led to an "extreme opinion" among some of the change enthusiasts—the opinion that "one ought to speak of nothing." Cratylus was the change extremist who Aristotle used as a prime example. And Aristotle says that Cratylus "was of [the] opinion that one ought to speak of nothing, but moved merely his finger."[27] In other words, Cratylus reduced all philosophy to helpless hand waving. Or, as Aristotle put it, the change-obsessives' argument meant that you couldn't even consider things "as existing."

This was intolerable for the hard-minded Aristotle. He wanted things to stand still and stay the same long enough to allow him to use reason on them. He was sufficiently generous of mind to admit "that there is some foundation in reason"[28] for the dogma of change. But Aristotle wanted to trounce it nonetheless. The result? Aristotle put forth a principle that would remain fundamental to philosophy, mathematics, and logic for the next 2,300 years. Formally it's called "the law of noncontradiction."[29] Here's how Aristotle put it in his *Metaphysics*: "The same attribute cannot at the same time belong and not belong to the same subject and in the same respect."[30]

Like much of the language of philosophy, Aristotle's law of noncontradiction was in dire need of simplification. It needed an interpreter with a gift for straight talk. And that's what it got. Two thousand years later. In the form of a diplomat for the royal family of Hanover, Germany,[31] a man who helped Hanover's George I become king of England in 1714. A man who met in Hanover with Russia's six-foot-six-inch tsar Peter the Great. A man who also dropped in on the philosopher Spinoza, who became a collaborator with one of the fathers of the wave theory of light, Christian Huygens, and a man who spent time with the father of the microscope, Anton van Leeuwenhoek. In 1673, a hundred years before the American Revolution, this multitalent was sent on a geopolitical mission to England. While he was there, he showed off a calculating machine he had invented to Britain's Royal Society, and he was promptly made a member. Meanwhile, he came up with another breakthrough: calculus. Then he had his reputation smeared by Sir Isaac Newton, who wanted total credit for the invention of calculus for himself.

The man we're talking about is Gottfried Wilhelm Leibniz. And Leibniz became the great simplifier of Aristotle's concept of noncontradiction. Aristotle told us that "the same attribute cannot at the same lime belong and not belong to the same subject and in the same respect."[32] That's a nearly incomprehensible statement. But Leibniz put it a bit more clearly. He came up with "*A* is *A*."[33] Either "*A* is *A*" or it is not "*A*."[34] There is no

Mister In-Between. Much easier to understand. Right?

However you phrase it, Aristotle put the law of noncontradiction, the law of identity—*A* is *A*—at the very center of his philosophy and at the very heart of something else that Aristotle tried to codify[35]—logic. Aristotle promoted identity as the most basic and incontrovertible law in this cosmos. Here are a few of the things that the philosopher to beat all philosophers, Aristotle, said about the law of noncontradiction, his precursor to *A* is *A*: It is "the most certain principle of all things."[36] It is a principle "regarding which it is impossible to be mistaken." It is "the best known" of all principles. It is not just a guess. It is absolutely "nonhypothetical." It is "a principle which everyone must have who understands anything that is." Why? Because of all the principles on the planet, this one is the topper, "the most certain of all." Look, says Aristotle, let's be frank, "It is impossible for anyone to believe the same thing to be and not to be."[37]

So what about Heraclitus, whose principles, says Aristotle, seem to imply that opposites can coexist—that *A* can be *A* and *not A* all at once? Heraclitus's principles imply that a frog can be a former tadpole, a terrific jumper, and a future doggie dinner all at the same time. They imply that if you looked closely for a week or two, you'd see the frog change before your very eyes. Heraclitus may have said things of this sort, Aristotle says, but "what a man says, he does not necessarily believe."[38] Heraclitus, in Aristotle's opinion, could not possibly have really felt deep down that *A* is sometimes not *A*. Why? Because it is "impossible for the same man at the same time to believe the same thing to be and not to be." Case closed.

Well, not quite entirely closed. Look, says Aristotle, "if a man" were foolish enough to claim that *A* is not *A*, "he would have contrary opinions at the same time."[39] And, says Aristotle, no sensible man would walk around denying his own claims and making himself seem idiotic. Right?

The result? Aristotle says that *A* is *A*, the law of noncontradiction, is the most fundamental of all the propositions in philosophy and in daily life. It is "the starting point even for all the other axioms." According to Aristotle's way of thinking, *A* is *A* is a notion that we take for granted every time we open our mouth to say, "What are we going to feed this frog? And whose bedroom is it going to sleep in?" (Note that in those two sentences we just took it for granted that the bewildered beast is a frog. And that it will be the same frog no matter who it sleeps with.) *A* is *A* is an assumption that we take for granted every time we grab the frog and put it back in its shoebox. Our decision to reach out our hand and gently grip a blob of green shows that we believe the frog is actually there. And that the frog we manage to get our hands around is the same frog we'll see the next morning when we open the shoebox again. What's more, we assert that *A* is *A* every time we google "frog food" and take it for granted that we can feed this frog the same sorts of things that our quick Internet search shows other amphibian lovers have fed theirs.



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$A = A$ is fundamental to logic. It is fundamental to mathematics. It is fundamental to science. And it is fundamental to the care and feeding of frogs. But I have sorry news to report. $A = A$ is false. It is sometimes a good approximation. But in the end, it's not 100 percent true. Why? Because Aristotle was right. But so was Heraclitus. Opposites ***can*** be true simultaneously. In fact, they usually are.

It all goes back to location, location, location. It all goes back to differentiation.

Try this bit of reasoning.

*A* does not equal *A* because of location. For example, location in time. The letter ***a*** printed by your computer on a page at 9 a.m. is not the same as the second ***a*** your printer zips out at 9:01. Electrons have shifted positions in their shells, heat has moved entire empires of molecules around. The lighting of your room has shifted as the sun has changed position outside your window. The printer desk on which the ***a*** rides has moved over seventeen miles around earth's axis, has sped 556 miles around the sun, and has jack-rabbited 864.3273285 miles around the core of our galaxy. No way are the two ***a***'s printed at slightly different times the same.

*A* is not simply a shape represented by ink on the mulched and pressed tree pulp we know as paper or on the pixels of a computer screen. And it is not just a logical abstraction. *A* is a complex social interaction. It's an interaction between your eye and a patch of pixels or an ink shape. It's an interaction of your *brain* with that pixel or ink shape. And it's an interaction of the culture embedded in your brain with the squiggles on the screen or on the page. Your culture is the product of 2.5 million years of accumulated thought—the accumulation of insights, emotions, questions, answers, and tools like language. Tools like the alphabet. Tools like *a*, *b*, *c*, and *d*. Your culture is the product of built-in, instinctual instructions in your brain, instructions like those that linguist Noam Chomsky[40] and his pupil Steven Pinker refer to as your linguistic deep structures and your language instinct.[41]

All these things—neurons, synapses, synaptic senders, synaptic receivers, and the facets of culture in the cloud of your mind, a cloud that shifts from second to second—change between the reading of one *A* and another. Your mind is like Heraclitus's river. Your mind, in fact, is like nineteenth-century father of psychology William James's "stream of consciousness,"[42] a bubbling, babbling brook. Your mind constantly produces different currents of associations, different swirls of thought, and different moods.

Then there is the change that location makes in the network of relationships that comes to mind around each *A*. The location of each *A* is different in a gestalt, different in a large-scale structure. Try this big-picture structure to get a feel for how different the mesh of relationships can be mere fractions of an inch apart:

When, in disgrace with fortune and men's eyes,
I all alone beweep my outcast state
And trouble deaf heaven with my bootless cries
And look upon myself and curse my fate,

There are twelve *a*'s in this well-known snippet of Shakespeare. Each one is pronounced differently. That means each *a* has to be tossed from the primary visual cortex in the back of your head to the temporal and frontal lobes up front, where some sense of what in the world it is begins to become clear.[43] Then the *a* is thrown to your motor cortex, which figures out how to send a blast of signals to billions of muscle cells in your larynx[44] and your tongue so that those muscles can contract and relax in a way that produces a sound



that others will recognize as part of a word. Or so your motor cortex can "say" each *a* silently in your head. That's a staggering web of relationships. And it is *different* for each *a* that you pronounce.

Each *a* involves a different team of axons, dendrites, electrons, and muscles. If you speak the lines of Shakespeare out loud, each *a* sets up a different wave blast in the air, the wave blast we call sound. And, most important, each *a* has a very different meaning. Take a look at just this super-short phrase, a phrase with two *a*'s in very different contexts doing very different jobs:

*all alone*

Small as this phrase is, large-scale structure, big-picture structure, gives each *a* a radically different role. And large-scale structure makes each *a* a part of a very different team. The three-letter *all* team makes a very different sound and meaning than the five letter team of *alone*.

Let's shift $A = A$ to physics for a second. A proton = a proton, right? Two protons are identical, *n'est-ce pas*? Not quite. Like the letter *a* in a Shakespearean sonnet, every proton has a unique place in big-picture structures. And that place in the big picture changes the proton's role in the cosmos. Protons are participants in social processes. And those social processes help generate the radical differences between the swatches of space and the clumps of matter in this universe. In the minutes after the big bang, all protons were almost equal. But not quite. Some clumped together in dense zones, zones in which they bounced around, colliding head on and ricocheting at manic speed. Others were just a tad more spread out. And just a tad more leisurely in their crash, smash, slam, and bang. The great *UN*equalizer was what Nobel Prize–winning astrophysicist George Smoot calls "quantum mechanical fluctuations—tiny wrinkles in space-time."[45] Smoot should know. He's the man who headed the team of one hundred scientists on the COBE project, the cosmic background radiation project that discovered the modern traces of these primordial quantum-mechanical wrinkles, wrinkles that stretched and pinched the space-time manifold into a spotty pattern like the patches of color on a spotted cow's back. Just how different were these patches of newborn space-time from each other?

Sufficiently different, in the words of the Department of Energy Office of Science News and Information, to form the "the primordial seed from which, over billions of years, the galaxies and large structures of the present-day universe grew."[46]

Let's go back to our café table at the beginning of the universe. From the big bang to roughly 300,000 years ABB (after the big bang), protons were part of a hot soup, a plasma. But that plasma surged with pressure waves like a stormy sea. And each proton played a different role. If you were a proton, you might be bunching shoulder to shoulder with other protons to make a peak in the pressure wave. I might be off somewhere doing the opposite, putting distance between myself and my neighbors to make one of the pressure wave's dips and gullies, one of the pressure wave's troughs. In addition, you might be participating in the formation of a dense patch of space-time and matter from which a galaxy would eventually grow. And I might be part of the more widely separated slam dance of protons that would someday produce the lacey macramé of empty space between gangs of galaxies. I might be dancing out the early shapes of the spacing pattern that makes the universe on a very large scale look like a lace, like the tracery of a dish-washing detergent foam.

A billion years down the line, you might be surrounded by the spherical surge of a moving electron. You might be the nucleus of a hydrogen atom. And you might be captured by an evolving star. You might be forced to emit light as your electron is excited then is left alone to calm down again, or as your electron is stripped away. Your electron might be turned into a photon that goes on a multi-light-year trip as a kind of sentence, a kind of sonnet—in a very distinct set of frequencies, the unique visual cry of distressed hydrogen.

Meanwhile, if I were a proton, I might be part of a molecule of water, freezing with a mass of my fellow water molecules into a spicule of ice way out in the cold darkness of space.

Both of us would be protons, right? *A* is *A*. *A* = *A*. But we'd each be different. Like the *a*'s in a Shakespearian sonnet, we'd play different roles even if we were side by side. Just as you and I can be side by side in a poker game but each play a different hand, and each play a very different part in the



social drama of the night. Big-picture structure counts. Your unique place in the social mesh changes your role. So does mine. And big-picture structure and positioning in the social mesh are location. Or, to put it in real estate terms, big-picture structure and positioning are location, location, location. And in the end, location, location, location gives every fleck and fiber of this cosmos a different role in a massive weave, a massively shifting, changing, and self-upgrading tapestry.

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There's a bit more to this business of my frog is not equal to your frog. Yes, your frog and mine both eat the same kind of food. And they look very much the same. But each one is unique. Each has a different life history and a different future. Each is composed of different molecules of raw material, and each has a different place in your home and mine. Generalizations about frogs, generalizations that my frog = your frog, are extremely useful. Without them the vet would not be able to operate on your frog or mine. Without them, books on the care and feeding of frogs would be useless. But *A* = *A* is a generalization. It is not precise. It is half a truth. The whole truth? *A* is *A*. But each *A* is different. Aristotle was right. And so was Heraclitus. Opposites are joined at the hip.

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Now let's go back to thinking like physicists and mathematicians for a second. To simplify things, we will strip away the context of the cosmos, its galaxies, its photon floods, and its gamma rays. We will strip away the context of language. We will strip away the context of the human brain. We will strip away the passage of time and its impact on the movement of atoms, molecules, the aging of paper, the aging of ink, and the flow of fresh electron messages through the pixels of your laptop, your iPad, your Kindle®, and your brain.

We will strip away the 3.85 billion years of evolution it took to make a human being. And we will strip away culture and the 2.5 million years or so of evolution it has taken to make language and the use of breath that makes the sound of *a* rich in meaning. We'll ignore your change in moods and associations as you move from reading one word to reading another. And we'll also strip away the phonetic alphabet and its history and evolution.

If, indeed, there is no cosmos, no evolution, no humans, no culture, and if time stands still or is reversible, then *A* may equal *A*. But without the history of the cosmos, without evolution, without humans, without the brain, and especially without language, there is no *A* at all. None!

So *A* = *A* is a simplification, one so radical that it sometimes utterly distorts reality. It skins reality alive. Is *A* = *A* useful? Does logic come in handy? Is math a magnificent symbolic system with which to comprehend what's around us? And is math based on *A* = *A*? Yes. Absolutely. But math and logic are just that—very, very simplified representations. Symbolic systems with massive powers. But symbolic systems that sometimes do enormous injustice to the richness of that which they attempt to represent. Symbol systems that sometimes do enormous injustice to science's greatest mystery, cosmic creativity.

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One frog is never identical to another frog. And the very same frog is a slightly different frog ten minutes from now. Aristotle and Heraclitus were both right. A equals A. But A does not equal A.

## HERESY NUMBER TWO: WHY ONE PLUS ONE DOES NOT EQUAL TWO

Put two apples together on your desk, and what do you have? Two apples. Twice as many apples as just one. And nothing more. One plus one equals two. Right? Sometimes yes. And sometimes no. Sometimes very emphatically no.

Let's go back to our café table at the beginning of the universe. And let's dial back to the very beginning. Once again, you are the wild-eyed visionary. I am the sober voice of reason. Quarks have just come blizzarding from the expanding sheet of space and time. Quarks by the gazillions. You predicted them. You predicted that these very first things would form themselves using the raw material of the speeding space-time sheet. It was an absurd idea. But you were right. And I was flummoxed and frustrated.



Now you tell me that quarks are going to come together in groups of three. And that one plus one plus one will not merely equal three. Not at all. Once the trios of quarks get together, you say, they will change character and give birth to something utterly new, something far more surprising than mere quark three musketeers. And once again, I know the rules of logic and the rules of arithmetic. You were right about a cosmos flickering from nothing. You were right about the precipitation of quarks. But that was just a fluke. I know with every bit of reason in my bones that this time you are wrong. Wrong as wrong can be. One plus one equals two. And one plus one plus one equals three.

Is this nutcase prediction of yours right? You give me a little demonstration. You lay out groups of three quarks on the café table in front of my nose. And you ask a few questions.

What happens if you introduce two up quarks to one down quark? Do you get just three quarks? Just three times as much quarkdom? Far from it, you claim. In fact, you predict a radical transformation. You predict something the cosmos has never seen before. You predict something with impossible properties. And with inconceivable future possibilities. Something that you tell me will someday make the solidity of my hand, the substance of my brain, and the churning hearts of the stars above my head. You tell me to grab two up quarks and one down quark from the middle of the table and let them loose on my dinner plate. Whammo. The three bunch so tightly that it's impossible to tell they were ever three individual quarks at all. And the result is something so galumphulous that this cosmos has never seen its like before. What is the bizarre beast that the three quarks on my dinner plate have transformed into? You explain that it's a proton. This is downright weird. It's the equivalent of laying out three apples on your dinner plate and getting a woolly mammoth.

But you've got another quiz question for me. What happens if you get me to present one up quark to two down quarks? Three friggin' godforsaken quarks, I answer angrily, still stung by your proton trick. Let's be logical. Quarks in, quarks out. But, no. You predict an equally impossible new whomp. An equally unlikely bit of future shock. So I grab one up quark and two down quarks to prove a point—that one quark plus one quark plus one quark equals THREE miserable quarks. But when I let the quarks loose on my bread platter, they rush toward each other and entwine, making yet another absurd abruptness this cosmos has never seen before. Something so strange it baffles me utterly. You try not to look smug. And you tell me it's called a neutron. That's like putting three pats of butter on a bread plate and ending up with a dancing whale.

What the hell is going on here? Cosmic creativity. Raw and unadorned cosmic creativity. A creativity in which *A* does not equal *A* and one plus one does not equal two. The creativity at the heart and soul of the God Problem.

## HERESY NUMBER THREE: PREPARE TO BE BURNED AT THE STAKE (THE SECOND LAW OF THERMODYNAMICS—WHY ENTROPY IS AN OUTRAGE)

> ***The central issue . . . is whether the surprising—one might even say unreasonable—propensity for matter and energy to self-organize "against the odds" can be explained using the known laws of physics, or whether completely new fundamental principles are required. In practice, attempts to explain complexity and self-organization using the basic laws of physics have met with little success.***[47]
>
> —Paul Davies

The second law of thermodynamics shows up in nearly every major and minor science: physics, chemistry, biology, astronomy, cosmology, and far, far more. What is this indispensable and incontrovertible law, the law without which many scientists would feel utterly naked? Where did the second law of thermodynamics come from? A central metaphor. The steam engine. And that's one reason it is wrong. The cosmos is not a steam engine.



But let's skip steam engines and get right down to the nitty-gritty—the second law of thermodynamics itself, a law that's holy, sacred, and revered. What is the second law? All things tend toward disorder. All things fall apart. All things tend toward the random scramble of formlessness and meaninglessness called entropy.

What in the world is entropy? The standard example of entropy is this. Take a sugar cube. There's a bowl of them in the middle of our café table at the beginning of the universe. Pick up the cube and take a close look at this little wonder of sweetness. Nice geometric form, right? Six perfectly square sides. Sharp edges made just a little bit jagged by the sugar crystals. Impressively consistent white coloring. Now feel it with your fingertips. Interesting roughness on the square surfaces, right? And an interesting variation on that roughness on the edges. What's the point? This sugar cube is a nice example of form. A nice example of structure. And a nice example of a big picture. A big picture? Really? Yes. That sugar cube between your thumb and forefinger is the product of roughly 2.5 million years of technological evolution. The tall, reedy, and green sugar cane it came from was raised on a massive plantation, a monocropping farm, an estate probably located on the northeast coast of Brazil. The cane was cut from its roots by a low-paid migrant laborer bent over nearly double grabbing the base of the plant and hacking at the cane with a machete. The cane was transported to a mill by railroad or truck, washed, soaked with water, crushed, and chopped to produce a thin liquid runoff.[48] Then the liquid was put through a centrifuge and boiled away several times in a mill and again in a sugar refinery. Eventually, only small, white sugar crystals were left. Finally a heap of crystals less than half the size of your thumb was pressed into a cube, wrapped in paper, and sent from Brazil[49] through a complex chain of wholesalers and retailers to your café at the beginning of the universe.

Quite an accomplishment. A lot of work has gone into this cube of tasty stuff. All with the goal of pumping pleasure into your taste buds as you drink your sweetened coffee.

Now drop the sugar cube into your water glass. Your full water glass. And watch. Be patient. Give it some time. Or tell me some more of your absurd ideas to pass the time. Take a look again in a quarter of an hour. What do you see? Clear water. No sugar cube. Nothing but liquid transparency. What happened? Entropy. All things tend toward disorder. The molecules of sugar in your glass went from a highly ordered state to a random whizzle of glucose and fructose molecules evenly distributed through the water in your glass.

And that, says the second law of thermodynamics, is the fate of everything in the universe. A fate so inevitable that the cosmos will end in an extreme of lethargy, a catastrophe called "heat death." The cosmos will come apart in a random whoozle just like the sugar cube did. The notion of heat death is a belief so widespread that it was enunciated by Lord Kelvin in 1851 and has hung around like a catechism. Do a search for it in Google Scholar™ and you'll find 4,350 articles focused on "heat death."

But is the second law of thermodynamics true? Do all things tend to disorder? Is the universe in a steady state of decline? Is it moving step by step to randomness? Are form and structure steadily stumbling down the stairway of form into the chaos of a wispy gas?

No. In fact, the very opposite is true. The universe is steadily climbing up. It is steadily becoming more form filled and more structure rich. Huh? How could that possibly be true? Everyone knows that the second law of thermodynamics is gospel. Including everybody who is anybody in the world of physics, chemistry, and even complexity theory.

Let's review what we've seen at our café table at the beginning of the universe. First a something came from a nothing—that something was the pinprick, the singularity, at the beginning of the big bang. That infinitesimal blip turned out to be a rush of time, space, and speed. A time-space manifold unfurling like the biggest bedsheet this universe has ever seen. Then the sheet of nothing but time, space, and speed precipitated like a storm cloud, raining, pouring, hailing, and showering the very first things: quarks. Quarks by the gazillions. Quarks in only six different forms.[50] With gazillions of identical copies of each of these six forms. Precisely identical copies. No matter where they appeared. And all of these precise clones appearing at exactly the same instant. Precipitating with astonishing simultaneity. With mind-boggling synchrony.

Were these quarks formless? Far from it. All came complete with a social rulebook built into their very essence. All knew precisely which other quarks to evade and which other quarks to embrace. And all followed these rules of quark courtesy and protocol with precision, forming instant duos (mesons) and trios (baryons). Most of the trios, the quark threesomes, settled into one of two forms—the proton or the neutron. But here's the deal. Protons and neutrons were so radically different from quarkdom, so eye-buggingly new, that they shocked the digestive solids out of the arch skeptic at the table, me. Is this a tendency toward formlessness? Is this a dissolving sugar cube? Is this a universe tumbling down the staircase of structure? No. This is a universe stepping up. A universe sprinting steadily up toward new structure and new ways of doing things. A universe inching, jumping, loping, and cart-wheeling upward on a staircase of amazements.



When protons and neutrons became the new holy trinities of the material world—elementary particles—I, the down-to-earth grump, was stunned. In fact, I'm still getting over the shock. But I know my logic. When you've got a mess of particles slamming, banging, and bouncing,[51] you are going to run into the second law of thermodynamics. You are going to end up with a random soup. That's it. All things tend toward entropy. All things tend to disorder. Or, to put it differently, all things fall apart. What's more, science has proved this in over a hundred years of research. Right?

But you have something far wackier in mind. Yes, the brand-new cosmos looks like randomness and entropy—it looks like the liquid that was once a sugar cube. But looks can be deceiving, you say. Squint and take a look at the big picture, you tell me, and you'll see something that makes randomness and disorder look ridiculous. Squint and use your extra peripheral vision, you tell me, and you'll see order on a level that defies belief. I follow your orders, squint, and try to get a handle on the cosmos as a whole. At first, all I see is a mixed up, random flurry of protons and neutrons jittering maniacally in the scalding soup of a plasma. All I see is elementary particles slamming and smashing into each other, then ricocheting away at speeds that make the collision of bullets slamming head-on look like gentle slow-motion kisses. And I'm about to tell you that what's in front of my nose has proven you radically wrong. But then I take in the macroscale. And something very different is happening. These gazillions of crashing particles are cooperating in the formation of waves and troughs. Waves and troughs that ripple from one end of the cosmos to the other. The slam-banging, bump-em-car particles are collaborating the way that molecules of water in ocean waves work together. They are rippling as coherently as ropes of clay, ropes that stretch across the cosmos for hundreds of light-years, waves that roll protons and neutrons in tight synchrony, waves that retain their identity until they reach distant corners of the cosmos hundreds of thousands of light-years from the point where they began.

These particle tsunamis are the pressure waves we twizzled into a few minutes ago. And they are so regularly and harmoniously—yes, harmoniously—spaced that cosmologists call them musical.[52] Thanks to social behavior on the grandest scale, astrophysicists say this early cosmos and its plasma rang like a massive gong.[53] Or, to put it in the words of the most prestigious peer-reviewed journal in North America, *Science*, "The big bang had set the entire cosmos ringing like a bell."[54]

In other words, the plasma shows a form of coordinated social behavior that defies belief. Any rational, logical thinker would know that a cosmos of elementary particles descended from nothing would swish and swivel at random. But randomness, a concept whose gaffs, gaps, and gashes we'll soon see, fails to materialize. Thanks to large-scale structure, big-picture structure, and social behavior, the particles of this cosmos rock and roll to their own self-generated beat. They defy the rules of arithmetic. Protons plus neutrons does not just equal protons plus neutrons. It equals music. A primitive precursor of the music that you and I listen to on iPod®s and Pandora®. Now this is positively spooky. It's like adding a zillion apples and oranges and getting a hurricane—a spiral twist of air that retains its geometric shape and identity as it picks up cars, cows, and rooftops. It's like adding a zillion water molecules and getting the massively coordinated swells and troughs of a tidal wave in the sea.

Is this harmony of pressure waves, this symphonic spacing of universe-spanning ripples, this mass choreography of elementary-particle pulses, entropy? Is it a tendency toward disorder? Is it what a turn-of-the-twenty-first-century thermodynamics critic, Professor Emeritus of Chemistry at Los Angeles's Occidental College Frank L. Lambert, calls mere "energy dispersal"?[55] Is this entropy at work? No. Bear with me while I repeat—it's large-scale structure. It's a strange big picture. And it's social behavior. Social behavior riddled with shape shock, riddled with form. And it's so antientropic that those in the scientific world who are trying desperately to rescue entropy from the ubiquity of form and structure call it "negentropy."[56]



Remember the first two rules of science: the truth at any price including the price of your life and look at things right under your nose as if you've never seen them before, then proceed from there. Question your assumptions! Entropy is a very big assumption.

But why in the world is it so far off the mark?

## HERESY NUMBER FOUR: RANDOMNESS IS WRONG—THE SIX MONKEYS AT SIX TYPEWRITERS ERROR

> *The chances that merely by chance they [DNA molecules] should have become arranged in the meaningful ways in which they are arranged are beyond much doubt less than the chances that a pile of rocks rolling down a hillside will arrange themselves by chance on a railway embankment in such a way as to spell out in English the name of the town where the embankment is.*
>
> —Michael Polanyi, Fellow of the Royal Society[57]

We are at our café table at the beginning of the universe. And we are bored. Painfully bored. I'm playing with a swizzle stick. You are building pyramids of sugar cubes. Why are things so dull? For over 370,000 years we've watched the cosmos shimmy with a sizzling-hot musical plasma. We've watched the particles of the cosmos doing a dance that makes Olympic synchronized swimmers look disorganized and spastic. But, frankly, it is getting a bit worn. Then, after 379,000 years of this same old same old, you drop your cube twiddling, wave a hand in front of my dazed eyes to get me out of my coma, and pipe up again with something I haven't seen in eons—enthusiasm. You have a funny feeling. It just hit you that another cosmic act of one plus one does not equal two is about to happen. And, as usual, your idea is goofy as hell. The bump-em-car smashup of the plasma, you are certain, is about to slow down. And when the plasma's particles slow, one proton plus one electron is going to equal something far more than just a proton and an electron rattling around at random in the vacuum of space. Actually, at this point there is no empty space, no wide-open vacuum. The slam and bang of particles is too tightly packed. However, you are convinced that entropy is about to look ridiculous.

And you are eerily right. At roughly the 380,000-year mark after the big bang, the particles in the plasma slow down. We call that deceleration "cooling." The skittering protons, neutrons, and electrons separate, and give each other more space.[58] But more space does not mean solitude. It does not mean time off from social gatherings. And it does not mean randomness. In fact, it means the very opposite. The puny particles called electrons discover for the first time in their 380,000-year existence that they are not satisfied on their own. Whizzing in their vicinity are particles 1,837 times more massive than they are.[59] Hulking giants. At least relatively speaking. These galumphulous Gargantuas are protons. And the tiny flits called electrons find that they have an electromagnetic hunger, an electromagnetic craving for a sort of coziness this universe has never known before. What's more, the hulking giants of the new cosmos, protons, discover that they, too, feel they are missing something. They discover that they, too, have an electromagnetic longing at their core.

This is so illogical it's absurd. Look, I explain to you, if you picture a proton as the size of the Empire State Building, an electron is the size of your fist. Let me repeat, a proton is more than 1,837 times more massive than an electron. So any rational and sober thinker can see that there is no way in hell that protons and electrons are going to develop electromagnetic lusts. And there's no way that electrons, which are, relatively speaking, the size of your pinkie, are going to flirt with protons that are, relatively speaking, one hundred dragons high. Look, even if one proton *did* manage to hook up with one electron somewhere in this cosmos, it would be a freak event, a fluke, a one-time-only perversion that could not and would not ever happen again. But you are not sober and rational. You have strange visions, visions of a universe that glories in rule breaking. You have visions of a universe that reinvents itself. You have visions of a cosmos that is profoundly and peculiarly social. But once again, you are about to be on target and I am about to be dead wrong. Why? Reason has deceived me.



Hold on to your seat. Roughly 380,000 years after the big bang, electrons discover that their needs fit the longings of protons perfectly. No matter where the electron is and no matter what its life history, pick any proton in this universe at random, flip it an electron from anywhere you please, and they embrace. What's more, their fit is more precise than anything that even the makers of the ultimate high-precision scientific device, CERN's Large Hadron Collider,[60] have ever been able to achieve.

If this were a truly random universe, this fit simply should not be. The metaphor that most often explains randomness in pop culture and in informal discussion among scientists is the image of six monkeys at six typewriters. Monkeys do not know how to type. But the beasts occasionally bump an elbow, a foot, or a chin on the keyboard, bapping out a thoroughly haphazard letter of the alphabet. Give them a few billion years, says the six-monkeys model of randomness, and the illiterate beasts will eventually type out the works of Shakespeare. Give them a bit more time, and they'll randomly peck out the evolution of the cosmos. From utter disorder, order can emerge through an accumulation, a pileup of arbitrary accidents.

Let's ponder this notion of arbitrary accident for a second. If this is a six-monkeys-at-six-typewriters universe, a random universe, zillions of particles jostling and jolting around each other should come up with zillions of different ways to be together, zillions of different ways to date, mate, marry, and combine. Or they should find no way to socialize at all, no way to connect. They should be so radically different that they mismatch each other like pieces taken from very different jigsaw puzzles or like shards taken from different shattered teacups. But the random universe exists only in our imagination. Things are not infinitely varied. Things are not riddled, crinkled, patterned, and punched with an infinite zoo of wildly wangling differences. Elementary particles don't come in sizes from infinitesimal to the size of black holes. Particles are not rhomboid, rumpled, corduroyed, uglied up with noses on sixteen sides, wriggling with tentacles, or writhing with jelly-fish-like shapes. Instead of a random mix of permutations and combinations, elementary particles have astonishing uniformity. The total number of different kinds of elementary particles in the cosmos comes to less than four hundred.[61] Only four hundred kinds of nanobits in a cosmos of $10^{87}$ particles. And the kinds of teams these particles make when they first mingle and mate are even smaller. That is utterly shocking.

So it turns out that the last thing you'd expect does indeed happen. Electrons do indeed discover that their inanimate lusts match the loneliness of protons perfectly. And electrons and protons do glump together. They do pair up in proton-electron twosomes. What's worse, when electrons discover how naturally they fit around protons, the result is a radically new set of properties. Radically new, but radically *few*. It's the handful of properties we call an atom: hardness, durability, and the ability to play with others in the sandbox of space, to team up in ways this cosmos has never seen before. How many kinds of atoms does a cosmos of zillions of particles sliding into each other's arms produce? If things were really random, the species of newly born atoms should be wacky, crazed, and without end. But our universe does not blat out more than a zillion to the zillionth power new forms of atoms, as the probabilistic equations of randomness would imply. Far from it. It produces just three rigidly constrained species of atoms. One is called hydrogen. One is called helium. And the third is called lithium. Only three different kinds of these new astonishments, these new particle teams, these atoms, in a universe of zillions of particles? And all of these atoms appearing pretty much at the same time? With astonishing supersynchrony? That doesn't make any sense. It doesn't follow the rules of randomness.

Look, even just two cubes tossed around in a cup, dice, have thirty-six possible outcomes. How can an entire cosmos seething with more protons, neutrons, and electrons than we have words to describe, how can a universe of nearly infinite dice and nearly infinite tosses, produce just three varieties of atoms? This is staggering conformity and self-control. It is not mere trial and error. It is not mere mix and match or blunder and chance. It is not six monkeys at six typewriters. So what is it? It's the paradox of the supersized surprise. It's the mind snarler at the core of cosmic creativity. It is the question at the heart of the God Problem.



## A BRIEF HISTORY OF THE GOD PROBLEM: WERE KEPLER, GALILEO, AND NEWTON CREATIONISTS?

The God Problem—the problem of how the cosmos creates—is not as old as you might imagine. Why? Because most of the fathers of modern science felt the answer was obvious. Kepler, Galileo, and Newton believed in God. They believed in an intelligent designer. In fact, the greats of early science were creationists. They believed in the biblical account of the creation of the world. With a few minor modifications.

Early in the 1600s, Johannes Kepler, an intense-looking mathematics teacher at a religious seminary in Graz, Austria, got the chance of a lifetime. He was offered a job as mathematician to the Holy Roman emperor in Prague. He took it. Then he squeezed out extra time to pursue an obsession. He worked as assistant to one of the most phenomenal astronomers and compilers of data on stars and planets of all time. That phenom was a Dane acting as the imperial astronomer in Prague,[62] an astronomer who had replaced a nose he'd lost in a duel with a bionic nose made of silver and gold[63]: Tycho Brahe. Meanwhile, Kepler invented a new kind of refracting telescope, watched the stars and the planets at night, wrote down his observations, puzzled over their mysteries, scraped away at Brahe's ever-growing mass of data on the pinpricks of light in the nighttime sky, and wrote letters to another man obsessed with the same puzzles in the distant Italian city of Pisa: Galileo Galilei.

Kepler kept this up for decades. What did he get for his years and years of pattern seeking? He discovered that the orbits of the planets were elliptical. And he stripped bare the three laws of planetary motion.[64] Kepler pulled off this glimpse of nature's inner workings by using one of the most intriguing tools of science, a tool that would still be crucial to Albert Einstein three hundred years later—geometry. To be specific, Kepler worked out the infernally tricky patterns of the five known planets of the day—the loops and wiggles traced in the sky by Jupiter, Mars, Saturn, and Venus, plus the movements of Earth around the sun—by squeezing geometrically shaped boxes into what he thought might be the planets' orbits. By squeezing geometric shapes into the planets' "spheres." Why did Kepler try to solve what he called "the mystery of the cosmos"[65] with geometric shapes? Because, said Kepler, "Geometry . . . is God himself."[66]

Did Kepler puzzle over the God Problem? Did he ask how the cosmos creates without a hulking, bearded king of heaven in a bathrobe? No, Kepler was a creationist and a believer in an intelligent designer.

In the beginning, said Kepler, there was nothing but God. And God had geometry at his heart. God had curves, straight lines, triangles, squares, and circles in every inch of his immeasurable consciousness. "Why waste words," wrote Kepler in his 1619 *Harmonices Mundi*, his *Harmony of the World*, "Geometry, which was before the origin of things was coeternal with the divine mind and is God himself."[67]

So Kepler's God mapped out the heavens using guess what? Geometry. With geometry, God created. But Kepler missed out on the heart of the God Problem—how does the cosmos create *itself*? Kepler calculated with absolute precision that in 3993 BCE, during the summer solstice, *God* had created.[68] Created what? The universe, presumably cranking out the entire thing in seven days, just like the Bible said.[69] And how, in Kepler's view, did the creator God pull this off? He used the same geometry that the Greek mathematician Euclid had perfected in Alexandria, Egypt, over two thousand years ago in 300 BCE. Geometry, said Kepler, "supplied God with the patterns for the creation of the world."[70] Presumably God made light, the sun, the stars, the plants, the animals, and the Garden of Eden pretty much as the Bible claimed. But he did it with a compass and a straightedge. He did it with geometry.

Then, says Kepler, God made man in his own image. He made Adam. Needless to say, Adam, in Kepler's view, was shaped, seized, and shaken by geometry. So geometry, said Kepler, "passed over to Man along with the image of God."[71]

The result? Said Kepler, the ability to grasp mathematics and geometry was built into the very foundation of the human mind. Or, to put it in Kepler's words, man's math skill, "the recognition of quantities . . . is innate in the mind."[72] Math is riveted from birth into your thinking machinery and mine. If you struggled in agony to grasp math in high school and college, you might disagree. But Kepler believed that geometry is central to the way that you see the book in front of your eyes, the ceiling above your head, the

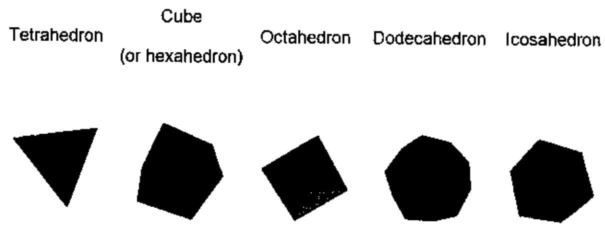


walls on either side of you, and everything else from the curls in the tails of chipmunks to the curves of girls in tight skirts and to the hip-shoulder ratio of men who work out more than you and I do. Says Kepler, "the recognition of quantities . . . dictates what the nature of the eye must be."[73] Yes, even your eyeball was built by math, built by geometry.

In studying the newest data coming in from the astronomy of Tycho Brahe and from his own observations, then puzzling out their patterns with geometry and writing up his results in sixteen books, what did Kepler feel he was accomplishing? He was presenting his reports, his dispatches, his bulletins, what he called his "*envoi* on the work of God the Creator."[74] He was reading God's mind. And he was peeping through the cracks of the material world to see something Kepler felt that God himself wanted man to discover. Kepler was scoping out what he called the "patterns for the creation of the world,"[75] the deep structures that God had used to create sticks and stones, bones and beasts, dust, dirt, dramas, and dreams. But most important, Kepler was groping for the patterns and deep structures that the creator had used to craft the heavens and their mirror,[76] the thoughts of human beings.

Every scientist who makes breakthroughs does it with the use of a tool, a central metaphor. What was Kepler's central metaphor? Circles, triangles, and the five Platonic solids. Geometry. And why does metaphor work? How do things you can draw with pen and paper, things you can sketch with the fluorescent pixels of a computer screen, or things you can imagine with the three pounds of meat we call a brain, how do these things manage to crack the codes of slowly moving dots of light in the heavens and of jittering particles on the earth? The mystery of metaphor will prove vital to the secret heart of the God Problem. So will deep structures. But we'll save the role of metaphor for later.

What was Kepler's contribution to solving the God Problem? He passed down the concept that the cosmos is based on very simple patterns, Kepler's "patterns for the creation of the world." Repeated patterns. Patterns that can be grasped by drawing pictures. Patterns you can get a grip on by making wooden models of things with four sides, six sides, twelve sides, and even twenty sides: the tetrahedron, the cube, the dodecahedron, and the icosahedron.




The five Platonic solids. *Courtesy of DTR, Wikimedia Commons.*

Would Kepler prove to be right?

## GALILEO'S NATURE FETISH: POKING THE POPE

Meanwhile, 422 miles away in the Italian city-state of Pisa, lived the most important thinker and inventor with whom Kepler swapped letters—Galileo Galilei, the chairman of the mathematics department at the University of Pisa.[77] The man who master physicist Stephen Hawking says "more than any other single person, was responsible for the birth of modern science."[78] What was Galileo's take on the God Problem? How did he think the cosmos creates? Galileo seemed more concerned with how God runs the world on a day-to-day basis than with how it all came to be.

In fact, in Galileo's opinion, the problem of cosmic creativity did not exist. Why? Because "God placed the sun at the center of heaven and . . . therefore He brings about the ordered motions of the moon and the other wandering stars by making it turn around itself like a wheel."[79] It's very simple. God put together a cosmos. He crafted it the way a wheelwright crafts a wagon wheel. There is no further question. No mystery. There is no God Problem.

Meanwhile, Galileo was up against a God Problem of his own. The Inquisition was on his tail. And the Inquisitors had made a big name for themselves by arresting an astronomer who believed that the heavenly bodies are worlds like ours and that they house life. The Inquisitorial executioners had "stopped the tongue" of this astronomical speculator "with a leather gag" on February 17, 1600,[80] and had burned him alive in a public square,



Rome's Campo de' Fiori—the ironically named Field of Flowers. That roasted, charred, and martyred astronomer was Giordano Bruno. Galileo did not want to follow in Bruno's fried and sizzled footsteps. So he wrote to a woman with pull, a woman he hoped would help him dodge the blaze of the Inquisitors' bonfire, the Grand Duchess Christina of Tuscany, daughter of Catherine de Medici and wife of another Medici, the grand duke of Tuscany.

And Galileo argued for ignoring holy books. Why? There was a better way to get to God. The writers of the Bible, Galileo said, had manipulated the details to produce mass appeal. Explained Galileo, "To accommodate the understanding of the common people it is appropriate for Scripture to say many things that are different (in appearance and in regard to the literal meaning of the words) from the absolute truth." To understand God, he said, don't be fooled by the creator's propaganda. Don't look at holy writ. Look at the world God has created.

Nature, said Galileo, is the real holy deal. She follows God's laws to the last jot and tittle. Back to Galileo: "Nature is inexorable and immutable, [she] never violates the terms and the laws imposed upon her, and does not care whether or not her recondite reasons and ways of operating are disclosed to human understanding."[81] Holy books may get God's intentions wrong. But nature always gets them right.

Said Galileo, to read the mind of God, open your eyes and look at what's under your nose. "In disputes about natural phenomena," Galileo wrote, "one must begin not with the authority of scriptural passages but with sensory experience and necessary demonstrations." Why? Because, Galileo explained, "the Holy Scripture and nature derive equally from the Godhead." In other words, holy scripture is "the dictation of the Holy Spirit" and the natural world is "the most obedient executrix of God's orders." Nature is absolutely scrupulous about sticking to the divine commandments, the commandments that make stars wheel and that make cannonballs fall.

The bottom line? "God reveals Himself to us no less excellently in the effects of nature than in the sacred words of scripture."[82]

So what did Galileo contribute to a secular and godless solution to the grand question of how the universe creates? He insisted that you and I must not slip into airy reasoning and abandon the realities right under our noses.

If you want to know the patterns with which God or cosmic creativity runs the world, if you want to know the rules and laws of our earth and of the heavens above, you have to open your eyes. Facts count more than theory. And "demonstrations," real-world experiments, reveal more than any letter from St. Paul or biblical account of the life of Isaiah.

In Austria, Johannes Kepler was using geometry as his central metaphor. Galileo, too, relied on a central metaphor, one that had been used for close to three thousand years—laws. Laws dictated by a central authority, a Lord. And Galileo used a second metaphor. He imagined that if he carried out what he called an "experiment"[83] on a table top, his strangely limited test could reveal the principles underlying the motions of avalanches, raindrops, bullets,[84] and the moons of Jupiter.[85] He imagined that when he rolled a ball down a tilted plank with a ruler mounted below it, measured its movement with that ruler,[86] timed the ball's journey by singing a marching tune,[87] then worked out the math of the ball's motion, that same math would fit the motions of all things on heaven and earth. He imagined that the metaphor of a ball on a table could reveal the rules by which God maintained his dictatorial powers over the entire cosmos.

This was a big, big stretch. A stretch into the mystery of metaphor. Why should rolling a ball on a table-top gizmo tell you anything about something vastly different: a star, a dot of light in the sky? Why should something you do between four walls down here on earth, down here in Galileo's house in Pisa or in his other house in Padua, have any relation to the nighttime darkness above your head? But that wasn't the end of Galileo's big stretches. He imagined that the Lord's rules popped forth from workroom[88] experiments with particular clarity when he probed the things in front of his eyes with another metaphorical tool, geometry.[89]

The "grand book [of] the Universe," Galileo said, "is written in the language of mathematics."[90] But Galileo's mathematics had very few numbers. And it had no formulae, no equations.[91] What did it have? Explained Galileo, "Triangles, circles, and other geometrical figures."[92] Things you could picture. Things you could draw. Why geometrical figures? Because the only respectable math among intellectuals in Galileo's day was geometry. Geometry and simple ratios between numbers. Arithmetic was something employed by lowly merchants in the streets. And the West as yet had no algebraic equations of the kind we would recognize today. The equal sign had been invented in 1557 by Oxford's Robert Recorde.[93] But it had not yet come into fashion. "The language of mathematics," Galileo explained, is written in characters, and those characters are "triangles, circles, and other geometrical figures." Without those "geometrical figures," he warned, "it is impossible to understand a single word of it."[94] A single word of what? A single word of the "grand book [of the] universe."[95]



That's a lot of metaphors. A lot of comparisons. The universe is a book. The cosmos is written in a language. The characters of that language are the triangles, circles, and other figures of geometry. That's a lot of highly improbable leaps. Why in the world was Galileo resorting to metaphor?

Three peculiar assumptions were Galileo's contribution to the God Problem:

(1) That the universe is governed by laws like the laws that governed Galileo's three hometowns, Padua, Pisa, and Florence.[96]

(2) That an experiment in a home workroom could say something meaningful about the strangest and most distant of things, things whose size might dwarf that of the balls Galileo experimented on.[97] And

(3) That the essence of the experiment could be caught in geometry. In other words, that mathematical scratches of ink on pieces of mashed tree pulp—paper—could express the essence both of tabletop experiments and of heavenly things.

Did Galileo's strange assumptions work? Would they pass the test of time? And, most important to the God Problem, if they did work, why?

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Isaac Newton started his scientific career thirty-five years after Kepler and Galileo. And, like Kepler and Galileo, Newton was a creationist and a believer in intelligent design. God is "the Maker and Lord of all things,"[98] Newton said. What's more, "He constitutes duration and space."[99] And "duration and space" were two of the central mysteries that Newton-the-scientist explored. Said Newton, God is the reason things have come to be. He is the source of all creation.[100] So how, in Newton's view, does God create?

It's back to the metaphor of God the authority figure, a God who is in Newton's words "the divine legislator,"[101] a God who "governs all things."[102] For Newton, God was not an abstraction. He was not a mere figure of speech. He was nearly as human as you and me. God, said Newton, is "a living, intelligent, and powerful being."[103] God, Newton added, is "supreme . . . most perfect . . . eternal and infinite, omnipotent, and omniscient."[104] And Newton declared in his culture-changing masterpiece, his 1687 *Philosophiae Naturalis Principia Mathematica*, better known as the *Principia*, that "this most beautiful system of the Sun, planets, and comets, could only proceed, from the counsel and dominion of an intelligent and powerful Being."[105] What's more, God came up with utter amazements and laid them out before us by extremely human means. By quasi-governmental means: again, by command and by "like wise counsel."[106] What in the world is "like wise counsel?"

Counsels—groups of men who gather to give advice, clusters of consultants—were normal for the highest lords of Newton's day—emperors and kings. But they are a peculiar proposition for a cosmos, a strange way for an all-powerful God to go about the business of creation. Who did Newton think God consulted? Who did he think the Great Omniscience bounced ideas around with before he crafted the ultimate immensity? Newton's heaven was wildly unscientific. It was teeming with God's courtiers. Before the beginning there was what Newton described as "the Perfect Trinity . . . Father, Son, and Holy Ghost."[107] Eventually they were joined by "the prophetic Angel Gabriel." And later, long after the expulsion from the Garden of Eden, the "Saints" and "the forty Martyrs . . . [who were the] most powerful ambassadors to God." What's more, Newton implies that there are mobs of holy warriors, the "hosts." "Christ" is not only "the Prince of Princes," but "the Prince of Hosts."[108] Christ is the leader of vast armies. So Newton's heaven was a densely populated neighborhood. And the "Son" and the "Holy Ghost" were probably in on the divine consultations at the beginning of the universe. But the basic mechanism of creation was a flat-out do-this-or-else, an executive order.



Not a very creative solution to the problem of how the cosmos creates. To Newton, the cosmos is as it is because of the biggest jack-in-the-box in history. The ultimate *deus ex machina*—God.[109] God said it, so it was so. Yes, Newton used the God Copout.

But Newton also contributed a more down-to-earth metaphor to our understanding of the creativity of the cosmos. It was an anthropomorphic metaphor, but one you could wrap your hands around. Literally. "We know him [God]," Newton said, "only by his most wise and excellent contrivances of things, and final causes."[110] Newton gave us God the contriver. God the engineer in chief. God the maker of machines. Why was the cosmos such an astonishing place? Because it was an invention. An incredibly precise gadget fitted together by God. And what did Newton think of when he used a word like "contrive"? What did he himself contrive?

Newton was obsessed with the precision machinery of his age. When he was a kid, he had his own set of tools, which he used to make two instruments that translated the physical motion of mere matter into a measure of time—a water clock and a sundial. In fact, he made many dials. And those dials were among the very first precision measuring instruments in human history. Measuring instruments of a kind that the Babylonians, the Greeks, and even Kepler never had.

In his childhood, Newton also worked out a simple way to measure wind power. He jumped and measured how far the wind carried him. Then he spent hours and days watching workmen build a new-technology windmill near his family's farm on the manor of Woolsthorpe near the town of Colsterworth.[111] Young Isaac watched the mill when it was working, examined it when the wind died and when its internal wheels stopped turning, and finally, when he was fifteen years old, built a perfect working model, one whose linen blades turned when he blew on them or when he blasted them with air from a bellows. Newton's model windmill even crushed grains of wheat and turned them into flour. Then Newton translated the windmill into another medium, into the use of a new power source—a mouse running on a treadmill.[112] To top it all off, Newton invented his own form of mechanized transport—"a mechanical carriage—having four wheels, and put in motion with a handle worked by the person sitting inside."[113]

The great American novelist Nathaniel Hawthorne, writing up Newton's childhood obsession with machinery in 1869, said that as a kid, Newton "showed a capacity to translate something ephemeral into a more solid language."[114] Measuring the distance the wind carried you when you tried to jump straight up and down, then using that measure to gauge the wind's strength and speed was an act of translation. Turning the power of the wind into the motion of a grinding stone was an act of translation. And turning grains of wheat into flour was yet another act of translation. Translation is yet another clue to the God Problem.

But there were more acts of translation to come in Newton's life. And more uses of metaphor. Let's inch back to what Newton imagined God the Contriver might be. What other gadgets were fresh in Newton's mind when he wrote his central book, the *Principia*? Newton used the example of the pendulum clock,[115] of yet another pendulum-powered gizmo, a pendulum hung over a ruler,[116] and of "machines." What machines did Newton have in mind? We all know about Newton's interest in the inner workings of "clocks and such like instruments." But Newton did not see clocks the way that you and I do. The word "gear" for a wheel with teeth had not yet been invented.[117] So Newton perceived clocks as machines "made up from a combination of wheels." More important to Newton were devices that amplified the power of your arms and hands: "The pulley, or . . . a combination of pulleys. . . . The force of the screw [think of a drill] to press a body. . . [via] the hand that turns the handles. . . . And the wedge [that] presses or drives the two parts of wood it cleaves . . . [thanks to] the mallet," thanks to the hammer.[118]

What's the trick to the pulley, the screw, the drill, and the wedge? For example, what's the secret to the wedge that's used to split a tree trunk into planks? Translation. All of them translate one kind of movement into another, one kind of force into another. Says Newton, "The power and use of machines consist only in this, that by diminishing the velocity we may augment the force."[119] The screw, the pulley, the drill, and the wedge translate speed into slamming or piercing strength. They turn speed into power. Or, in the case of clockwork, Newton's "machines" translate the motion of a pendulum and a spring into the turning of hands that the neural synapses of our brain then translate into the strange concepts we call hours and minutes.



Newton's machines, to use Nathaniel Hawthorne's words, "show a capacity to translate something ephemeral into a more solid language."[120]

Newton's metaphor of the machine maker and of the contrivance crafter's creation—a mechanism—would stick like glue. Today, scientists are obsessed with finding an explanatory "mechanism" to open the mysteries they are trying to pierce. Without a mechanism, they often won't accept a new idea. For example, as we'll see a bit later, Charles Darwin was not the man who first proposed the idea of evolution. His grandfather Erasmus had laid out the concept of evolution sixty-two years before the publication of Darwin's *Origin of Species*. So why is Darwin the god of evolutionary theory? Because he provided a mechanism—natural selection.

But the concept of mechanism is a metaphor. It's based on Newton's pulleys, wedges, windmills, and clocks. And it involves a huge stretch—imagining that the patterns of our tools and of our contraptions can tell us something profound about the stars in the skies and about the workings of our minds and eyes. Is that assumption true?

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To Newton, the problem of cosmic creativity had a simple solution: God. God was the great contriver in the sky. God was the heavenly mechanic crafting a universe that worked like a machine. But many in the scientific community are getting antsy about the limitations of Newton's machine metaphor. They are roiling with discontent over the shortcomings of the mechanistic approach. And they are right. It may be time to challenge the machine model of how the cosmos creates. And it may be time to explore the value of that other Newtonian achievement, translation. Translation and the limitations of the machine metaphor will provide yet more clues to the solution of the God Problem.

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Remember, Newton was a creationist. So were Kepler and Galileo. In fact, until 1950, very few if any major thinkers would pose the God Problem the way you are posing it. But there is a list of people who would come up with clues to cosmic creativity: Gottfried Leibniz, Georg Hegel, Karl Ernst von Baer, George Boole, Hans Driesch, and Herbert Spencer. Not to mention George Henry Lewes, Bertrand Russell, and Giuseppe Peano. Each of these men (and, alas, they are all men, not women) would come at the God Problem from a different point of view. But like the five blind men trying to figure out the elephant, each of them would be right. Each of them would see the problem in a different way, each of them would use different tools to solve the God Problem, and, in the process, each of them would come up with another facet of a multifaceted truth, another piece of the elephant. And yet all their answers would miss something. Something very big. What?

All of these men would feel that they could discover some of the core tricks that a creator God or a godless nature uses to run the cosmos. And all would feel that if they tried with all their might and dedicated their lives to the task, they could do it by using the tools of science. But, in reality, none of them would ask the question of how the cosmos creates in quite the way that you are asking it. Why? Because until the 1950s, they would be missing something vital to a step-by-step tale of how a cosmos of nothing lifts itself into a something, and a pretty elaborate something at that. They would be missing a big picture, a narrative thread. They would be missing a story of how the cosmos began. They would be missing the big bang.

## GAMOW VERSUS HOYLE: THE WAR BETWEEN BIG BANG AND STEADY STATE

How do we crack the code of what Immanuel Kant in 1755 called the "essential capacities in the natures of things to raise themselves to order and perfection"?[121] How do we crack the code of cosmic creativity? How do we solve the God Problem? We start with a primary power tool of explanation: a narrative, a big picture, a story. A story that was in its infancy when you entered science at the age of ten in 1953. A story that was at the heart of a battle. That story fighting for its right to be was called the big bang.

How did the big bang get into this? And how did you get into the big



bang? Let's shuffle backward in time for a minute. Let's skediddle to the year before your bar mitzvah. You are twelve years old. And, alas, you do not feel particularly smart. You were late to learn to read. And you were so slow at doing paperwork that your first-grade teacher thought you were mentally retarded. In fact, she sent you off for psychological testing to prove it. But you teach yourself to play chess. Why? Because it's something that intelligent people do. And, since you cannot play baseball, party, date, play poker, or do anything normal, you are hoping for acceptance in at least one category on this feeble little planet. You are hoping to be intelligent. Intelligent people play chess.

Your mom has tried to help you escape from the kids who've been using you as a football and from the teachers who have been bullying you at PS 64. So she has put you in a new grammar school, an experimental school at Buffalo State Teachers College, an educational "School of Practice" in which kids from every extreme, kids who are vandals and kids who are loftily bright, have been assembled as guinea pigs for new teaching methods. And you have finally met a few people more or less your age who are bright as laser beams, kids of staggeringly high intelligence. These prodigies come over to your big bedroom overlooking the trees of Delaware Park and you play chess with each one of them. They beat you. Humiliatingly. In roughly five to seven moves. Game after game after game.

One of these ultrabrainy new friends even tells you that he can checkmate you without looking at the board. He lays on one of the two double beds in your room and stares up at the ceiling plaster while you set up the chessboard on the tan shag-looped carpet where he can't see it. You sit on the rug next to the chessboard, and you announce the position to which you are moving your pawns and knights. Your friend, Michael Wolfberg, can't see the pieces and can't see the board. But he beats you in five to seven moves. Several years later, Wolfberg will go off to MIT.

But you? To your credit we must say at least one thing. You never give up. You keep on trying. But when it comes to standard marks of intelligence like playing chess, you are a loser.

Your mom thinks otherwise. When you fixate on the work of Anton van Leeuwenhoek at the age of ten, she takes you to a store that sells used lab equip-