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The Collapse of Mechanistic Philosophy

A small error at the beginning of something," said Thomas Aquinas, "is a great one at the end." One such error is the common failure to distinguish between causation and predictability (i.e., determinism). While every action or event has a cause, most actions and events are not even "in principle" predictable. Our failure to make this distinction permits mechanistic philosophy to masquerade as science.

TIME AND CHANCE HAPPEN TO THEM ALL

Common sense assumes a real difference between things that happen by chance and things that happen in a predictable or mechanical fashion. Things that happen by chance can only be *described* after the fact. Things that happen in a predictable or mechanical fashion can also be *explained* in terms of natural laws.

An ordinary tennis ball illustrates this difference. We can all predict that when we throw or hit a tennis ball across the net, it will soon hit the ground somewhere on the other side. An excellent tennis player can predict with pretty fair accuracy precisely where the tennis ball will land. And if the tennis ball is being shot out of a ball machine, any high school physics student could predict when and where the ball would land just by measuring the force imparted and the angle and direction in which the ball was aimed. Students today can do this because three centuries ago Isaac Newton discovered the mathematical laws of mechanics and gravity. Since these laws explain what is and isn't relevant to the motion of any given object, they allow us to predict what will happen.

More specifically, Newton's laws tell us that the mass of the ball, the force imparted, and the direction and angle it is aimed fully determine (and hence, predict) where and when the ball will land. Well, not exactly: if this were posed as a problem for college physics majors they might be asked to add factors such as air resistance and wind direction to their predictions. But because of Newton, they would never need to know the color of the ball, the time of day, whether the ball machine was manufactured in the United States or China, or countless other identifiable factors in the immediate proximity. Once we have accurately measured a handful of relevant factors, we have all the information necessary for an accurate prediction of where and when the ball will hit the ground.

Now let us change the situation slightly. Think of the same ball machine shooting the tennis ball down a fairly steep dirt road strewn with rocks, several switchbacks, and drop-offs. Once again, we can predict where the ball would first hit the ground. But where it would come to rest as it rolled and bounced down the road, perhaps careening over the edge of a rocky cliff, is an entirely different matter. This time a college degree in physics would be of little help. Why? It is not because there are gaps in the causal chain or other "supernatural" forces acting on the bouncing ball. No, the causal forces here are no different from those in the first situation.

The critical difference is that in the first example, a small error in the initial measurements will have a small consequence in the final outcome, whereas in the second example, a small error in the initial measurements will have an unpredictably large consequence. The difference between the two is that every rock and switchback in the second example constitutes a threshold or "tipping point."

In the first example, a sudden gust of wind might cause the ball to land slightly to the left of our prediction, but it would not completely invalidate our prediction. However, in the second example, the tiniest of errors at the beginning of our calculations would totally invalidate our prediction. A tennis ball careening down an irregular, rocky dirt road is like a ball in a pinball machine. While there are no magical or mystical elements in either case, in both cases there are cascading chain reactions. If the tennis ball hits a rock or the pinball hits a pin ever so slightly to the right of center, one causal sequence will be initiated. But if it hits ever so slightly to the left of center, another entirely different sequence will emerge. In one case, it may send the tennis ball sharply to the left and then into a smooth culvert running all the way to the bottom of the road. But in another case, it may send the tennis ball sharply to the right and then over a cliff. And even if the ball only moves slightly to the right or left when it hits the first rock, each and every rock in the road constitutes a threshold or a "tipping point" just as capable of initiating a sequence of events with equally unpredictable results.

Contemporary scientists call these sorts of examples nonlinear systems. The name may be new, but the idea is ancient. If Tom and Harry are being chased by a bear and their only option is to leap twenty feet over a very deep chasm, and if Tom can jump precisely twenty feet, while Harry can jump precisely nineteen feet, eleven inches, this slight difference in jumping abilities will produce radically different results—Tom lives and Harry dies! When tennis balls are careening down mountain roads, the extremely large number of relevant factors (the precise location, size, and shape of every rock) coupled with numerous thresholds (nonlinear events) makes it humanly impossible to predict where the ball will come to rest. Yet, while it would be impossible to predict what happens in such cases, anyone with a good slow-motion camera could easily record, and then describe, every step in the cascading chain of events.

Of course, the unpredictability of a tennis ball bouncing down a rocky dirt road is of little significance. But the havoc caused to human plans by thresholds and tipping points is not always trivial. Here are two examples.

In the 1980 presidential election, Jimmy Carter was challenged by Ronald Reagan. During the campaign, Reagan and many others had repeatedly characterized Carter's foreign policy as being "weak" and criticized him for being too willing to sacrifice our national honor when faced with challenges from abroad. The Iranian revolutionaries' seizure of diplomatic hostages in Tehran became the prime example of Carter's inaction and (apparent) weakness. And for many, it seemed to confirm everything Reagan was saying about Democrats.

However, we now know that Carter had set in motion a rescue mission and was only biding his time. By April of 1980, American intelligence agents posing as European businessmen had infiltrated the ranks of the Revolutionary Guards holding the hostages, and they had detailed information about precisely where in the embassy the hostages were being held and other important information about their daily routines. There were even reports that some members of the Revolutionary Guards had been "flipped" (changed sides) and were ready and willing to assist the Americans in their escape.

On April 24, after all the groundwork had patiently been laid, Carter gave the order to begin the rescue. Though the carefully planned and practiced rescue would only require six helicopters to fly all the captives to safety, eight helicopters took off from an aircraft carrier just in case something went wrong. But even these precautions were insufficient. Shortly after take-off, one of the eight helicopters developed a rotor problem and was forced to turn back. Halfway through the flight, the helicopters were caught in a haboob, a rare meteorological phenomenon in which winds generated by a thunderstorm create clouds of dense dust many miles away without any warning. This caused the loss of one more helicopter. Still, the mission had the six helicopters needed for a successful rescue, and success here would have made the "wimp" charge look ridiculous; all the negative predictions about Carter's chances of reelection would be out the window. But success was not to be had. The mission was aborted when a hydraulic pump on one of the six remaining helicopters failed—the result of a crack in a ten-cent aluminum nut!

About two millennia earlier, Virgil's description of the founding of Rome rested upon perfectly understandable but equally unpredictable events. Though Virgil was more of a poet than a historian, his story rings true. It begins when Aeneas's son innocently goes hunting and the nostrils of his hounds catch the scent of a stag sacred to the Rutulians. When Aeneas's son lets an arrow fly, it reaches its target, but not in such a way as to kill the stag there and then, but in a way that would allow the fatally injured animal to "creep moaning into his stall . . . all stained with blood." The hardy country folk immediately take up arms to seek vengeance.

But why did the hounds happen to catch the scent of this particular stag and not one of the countless others that inhabited the forest? Why did the arrow fatally wound, but not immediately kill, the sacred stag? Why did the stag have just enough life left to make it back to his stall rather than die during the journey, thereby masking the identity of its assailant? We might agree on a description of how the battle for Rome began. But on the morning of Aeneas's son's hunting trip, no one could have predicted the prodigious consequences that would follow.

And how did it end? Weary of war, the two armies agreed to settle the dispute with one-on-one combat between two champions, Aeneas for the Romans and Turnus for the Rutulians. When both saw level ground, they ran swiftly toward one another, each throwing his spear, but neither managed to down his opponent. Then they clashed in close combat. They were evenly matched in skill and strength, but when their swords met, Turnus's sword shattered "like brittle ice, and now its fragments gleamed back at him from the yellow sand."[1]

But why did Turnus's sword shatter? Virgil says it was because Turnus mistakenly grabbed his charioteer's sword as he ran to meet Aeneas, not his

1. Virgil, *Aeneid* XII.735–65.

father's sword that he had used in all of his previous battles. Of course, the cascading chain of events didn't begin there. Why did he grab the wrong sword? Did his charioteer misplace the proper sword? When he reached for his father's sword, was Turnus distracted by the flight of a bird (i.., an evil omen)? Did the fast and rocky ride of the chariot knock Turnus's sword from its scabbard, forcing him to grab his charioteer's sword instead?

All of these questions define crucial tipping points (thresholds) that, as Virgil said, make it "hard to distinguish chance and prowess in the fight's confusion."[2] The Preacher in Ecclesiastes agrees: "Again I saw that under the sun the race is not to the swift, nor the battle to the strong, nor bread to the wise, nor riches to the intelligent, nor favor to the men of skill; but time and chance happen to them all" (Eccl 9:11).

A common sense understanding of each of these examples—a tennis ball bouncing down a rocky dirt road, the 1980 presidential election and the founding of Rome—would include at least three points. First, some events can be fully *described*, but never *explained*. Second, even though there is a *cause* for everything that happens, in these cases the final outcome was neither *determined* nor *predictable*.[3] Third, each of the outcomes *could have been otherwise*. However, many Enlightenment thinkers challenged all of these commonsense points. The next section will consider their arguments and what we will call "mechanistic philosophy."

LAPLACE'S DEMON

"Time and chance happen to them all," said the Preacher. But, then, the Preacher lived a long time ago, back in the days when people believed that the sun orbited a stationary earth in the center of a two-thousand-year-old universe. Today we know so much more. "Sure," objectors would say, "no one living a thousand years ago imagined that we would be able to predict the paths of comets, much less be able to instantaneously communicate with people halfway around the world or even with space ships passing by Saturn. So before adopting the three points of 'common sense,' think of all that we

2. Ibid.

3. "The theory of natural selection can describe and explain phenomena with considerable precision, but it cannot make reliable predictions, except through such trivial and meaningless circular statements as, for instance: 'The fitter individuals will on the average leave more offspring.' Scriven (1959) has emphasized quite correctly that one of the most important contributions to philosophy made by the evolutionary theory is that it has demonstrated the independence of explanation and prediction." Mayr, *Toward a New Philosophy of Biology,* 31–32.

have learned! We now know that the earth revolves around the sun, which is on the outer edge of a medium-sized galaxy, which is but one of billions of galaxies in a universe that is billions of years old, and in which *everything* is strictly determined by the laws of nature. So while it may still be difficult to precisely predict the outcome of many events, *in principle* these predictions are fully within the capabilities of modern science."

In 1814 Pierre-Simon Laplace, a mathematician and physicist, famously formulated this objection to the three points of common sense:

> We may regard the present state of the universe as the effect of its past and the cause of its future. An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in *a single formula* the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes [emphasis added].[4]

According to this view, all of reality is fully determined, and therefore the unpredictability that we commonly attribute to "time and chance" is *in fact* due wholly to our lack of knowledge. While the relevant causal factors determining the winners of elections and wars (or even the precise resting place of a tennis ball bouncing down a rock-strewn mountain) may be too complex for human calculation, in fact, everything is mechanistically determined. According to Laplace, what the Preacher called "chance" is not a permanent part of reality, but only the (temporary) result of our lack of scientific understanding. Since every action is caused, our inability to predict an event's outcome is wholly the result of human ignorance because nothing in reality takes place by chance. Or as philosophers like to say, "chance" names an epistemological category, not an ontological category. If we knew enough, we would understand that given the same initial conditions, nothing could have been otherwise.[5]

Not surprisingly, many people reject Laplace's deterministic vision since it seems to call into question much that we all hold dear, including human freedom. And Christians have their own objections. Without freedom, humans would not have the unique dignity of being created "in the image of God." And some have even worried about the implicit idolatry

4. Laplace, *A Philosophical Essay on Probabilities,* 4.

5. "The word 'chance,' then, expresses only our ignorance of the causes of the phenomena that we observe to occur and to succeed one another in no apparent order." Quoted in Gillispie, *Laplace,* 51.

of transferring the traditional attributes of God—omniscience and omnipotence—to Science (with a capital S). Nonetheless, many Enlightenment thinkers think that the arguments in favor of a mechanistic philosophy are more powerful than these objections.

Their first argument is based on history. Many events which were once attributed to supernatural causes or transcendent human freedom are now explicable in terms of perfectly ordinary and "natural" causes. The Greeks prayed to Neptune for safe passage across the Aegean in their triremes (warships); today we check for storms on images from satellites. In New Testament times the Jews attributed epileptic seizures to demons; today we explain them in terms of brain lesions. Fifty years ago school teachers scolded restless and disruptive children; today we treat them with Ritalin, which is far more effective. Though some people still pray for divine intervention to solve their problems, now scientists using fMRI (functional magnetic resonance imaging) can locate the specific area in the brain that "prays." And while it is not yet possible to explain why some people pray to Jesus and others to Allah, the "spiritual peace" they experience is explained by the dopamine in their brain.

And even the "free will" to choose one's own religion is now coming under scrutiny by brain scientists. Again, using fMRI, scientists are able to predict a person's decision up to seven seconds prior to the subject's consciousness of his or her own "choice."[6] Of course, the decisions being considered are rather trivial (e.g., hitting a flashing button with either the left or right hand), but these experimental studies are still in their infancy. So there is every reason to believe that in the future our so-called "significant" decisions will become explicable in terms of brain functions. And when that happens, scientists will be able to *explain* why some people pray to Jesus, while others pray to Allah, or at least, that's the updated version of Laplace's first argument.

The second argument in favor of mechanism is more philosophical and goes like this: Only uncaused events are in principle unpredictable. But to say that something is uncaused is to say that it came from nothing. Yet by definition "nothingness" doesn't exist. Nothing simply "poofs" into or out of existence. Despite our lack of any definitive medical research, we know that if someone gets cancer there must be a cause, even if scientists have yet to discover what the cause is.

Try to imagine a senator arguing before Congress, "We have spent billions of dollars looking for the cause of cancer. Yet in many cases we are no closer to discovering its cause than we were thirty years ago. Therefore,

6. See Callaway, "Brain Scanner Predicts Your Future Moves."

the only reasonable conclusion is to stop wasting money looking for causes where none exist." The senator's argument is a classic non sequitur. His premises may both be true. But his conclusion—"these cancers have no cause"—does not follow. Instead, what follows from the senator's premises is that "these cancers have causes that are *yet to be discovered*."

Before responding to these arguments for mechanism, a brief digression concerning motives is in order. Francis Bacon famously said that knowledge is power. And he was at least in part correct: the kind of knowledge that allows us to explain and predict also gives us control and power. When and if we discover the biological laws that govern the growth of cancers, those cancers will no longer be under the control of Providence; instead, they will be under *human* control.

But we must not be too hard on the Enlightenment. There is nothing wrong with using our God-given talents to mitigate human pain. In many cases it is meek, right, and proper to seek power and control over nature. The Bible itself enjoins humans to tend, cultivate, and steward God's good creation. And as Thomas Aquinas (the great medieval philosopher and theologian to whom we will refer frequently throughout this book) said: "the dignity of causality is imparted even to creatures."[7] While God is the primary cause of all that exists and happens, humans are real secondary causes who are able to control much of their environment. We will say much more about this in later chapters, but for now we happily acknowledge that we live in a world where we should not only *pray* for those who are ill, but we should also *work* on their behalf building hospitals, educating and training doctors, and supporting research institutions in their search for the causes of cancer. And as we work to bring cancer and other effects of the fall under the control of modern science, we must not begrudge the Enlightenment thinkers rightful praise for their achievements.

Of course, some attempts to obtain mastery over God's creation are acts of rebellion and faithlessness. But this gives Christians no right to impute impure motives to Laplace. Perhaps in part he was seeking to "play the role of God." But, then, this is true of all of us at various points in our lives. And it would be contrary to a major theme of this book to pretend we were able to quantifiably measure, and then compare, Laplace's faulty motivation with our own more godly motivation. Humans will never be in a position to

7. *Summa Theologica* I.22.3. Barth approvingly quotes this same passage from Aquinas in *Church Dogmatics* II.2, 512. Again, God gives independence to creatures "not by a lack of power but by an immensity of goodness; he has wished to communicate to things a resemblance to him in that they would not only exist but be the cause of others." Aquinas, *Summa Contra Gentiles* III.70.7. See also the whole of ibid., III.69.

explain why most things happen, including why Laplace was motivated to defend universal determinism. The only prudent course is to pray that our *own* motives are those of good stewards, not those of faithless rebels.

THE DEMISE OF LAPLACE'S DEMON

In scientific quarters, things have changed since the time of Laplace; science with a small "s" has slain the demon of universal determinism. The mechanical clockwork of Newtonian physics has given way to quantum mechanics. Absolute space and time have given way to general relativity. And Newton's geometrically precise parabolic curves have given way to the chaos of double pendulums. One contemporary scientist puts it like this:

> To summarize, no man can go faster than the speed of light; no man can make simultaneous measurements of two conjugate variables with infinite precision; and no man can compute or measure any continuum variable precisely. In consequence, we can no longer disguise the fact that deterministic Newtonian dynamics has been dealt a lethal blow. Relativity eliminated the Newtonian illusion of absolute space and time; quantum theory eliminated the Newtonian dream of a controllable measurement process; and chaos eliminates the Laplacian fantasy of deterministic predictability.[8]

While it took both genius and persistence to undo the philosophical assumptions that were attached to Newtonian physics, at this point it is not difficult to understand why contemporary physics has returned to the commonsense distinction between describing and explaining, caused and determined/predictable, and acknowledging that many things could have been otherwise.

Quantum mechanics is full of surprises that we will not even begin to consider here. But its fundamental point is no more mysterious than the echolocation of bats or the sonar of submarines. Imagine that you are blind, but also that your hearing is very good. In fact, it is so good that like a bat you can "see" by listening for echoes. (While in college I knew a blind student who by snapping his fingers was able to find his way around campus without ever bumping into walls or closed doors.) Now as long as the physical force of the sound waves sent out are sufficiently small relative to the objects one is "observing," then there is theoretically no limit to what even a blind person can "see."

8. Ford, "What is chaos," 354.

But as the force of sound waves sent out approaches the mass of the objects one is attempting to observe, one's "vision" quickly deteriorates. To make our point less abstract, imagine a person who "saw" by throwing out thousands upon thousands of Ping-Pong balls, waiting for their rebound, and then calculated the shape and location of the objects from which the balls rebound. Certainly "vision" by Ping-Pong balls would be rather crude when compared to "vision" by echolocation," and even more crude when compared to "vision by photons (light). But if we imagine the balls becoming smaller and smaller and we also imagine a steady increase in the rapidity and precision with which the balls are dispensed, then there is no conceptual reason that Ping-Pong-ball vision couldn't rival the echolocation of bats.

However, there is one purely conceptual limit to all kinds of "vision"—whether by Ping-Pong ball, sound, or light. Determining whether a door is open or closed by throwing Ping-Pong balls is not difficult. But imagine trying to determine the location of another object of comparable size, that is, imagine a person using Ping-Pong-ball vision to locate another Ping-Pong ball. If a person could approach absolute precision in the direction and force with which the Ping-Pong balls were thrown, then at least theoretically we could locate another Ping-Pong–ball-sized object with one very big caveat—*our information would always be out-of-date*. The reason is obvious—one Ping-Pong ball bouncing off another Ping-Pong–ball-sized object will significantly alter the location of the object we are trying to "see." By the time our outgoing balls return, the location of our target ball will have changed.

At this point, a stubborn Laplacian may object: "But wait. Since we know the velocity with which the Ping-Pong balls are being thrown ,by timing how long they take to return we can calculate the distance of the rebound. And by measuring where the balls strike our detectors, we can determine whether the struck object will move in a straight line or at an angle. From these two pieces of data, like a good billiards player, it is a simple calculation to determine where the object we hit will be at any specified time in the future. Therefore, our observations need *not* be out-of-date after we make the proper corrections!"

Oh, how hard old assumptions die! The Laplacian argument begs the crucial question by assuming that the observer already knows the shape and mass of the object they are trying to "see." True, if we imagine a highly skilled billiards player shooting at billiard balls he is not in a position to see, by watching for rebounds of the visible cue ball he could calculate where the invisible ball was, both before and after it is struck. But this assumes that he already knows the mass and shape of the object that is causing the rebound. However, if the mass and shape of an invisible object a person is trying to locate by this "echo" method is *unknown* (and not orders of magnitude bigger than the cue ball), then the rebounding cue ball will tell him nothing about the present location of the unknown object.

In other words, if a billiards player *already knows* the shape and mass of the objects at which he is taking aim, then from the rebound it is possible to calculate the future location of the object hit. However, if the object struck is of an *unknown* shape and mass, then the rebound tells us nothing about the future location of the struck object.

Simply, but in no way disparagingly, put, one of the things quantum mechanics does is apply the commonsense truths concerning Ping-Pong-ball vision to ordinary vision by light. Humans cannot see in the dark. The only time we can see if a door is open or closed is when light is bouncing off the door and into our eyes. This much is obvious. But what we and Newtonian physicists usually forget, and what quantum scientists remember, is the second prerequisite for seeing to be accurate and up-to-date—namely, the object being observed must be orders of magnitude larger than the light with which we make our observations.

Though physicists tell us that in some experimental contexts light behaves like a material object (a photon) and in other experimental contexts it behaves as a wave, we will keep things simple by picturing photons as extremely small Ping-Pong balls. When we try to gather accurate and up-to-date information[9] about an electron "orbiting" the nucleus of an atom, our attempts will always be frustrated by the fact that the very source of our information (photons from the observer's light source bouncing off of electrons) significantly alters the location of what is being observed. Unless physicists discover something significantly smaller than photons, it will always be conceptually incoherent to claim that *everything* is predictable.

The behavior of photons, electrons, and other subatomic particles is unpredictable because we cannot make an observation without altering the data in unforeseen ways. And even if we suppose that scientific progress continues indefinitely into the future so that scientists discover (or make) something a fraction of the size of photons, one class of events will still remain unpredictable—namely, the behavior of these newly discovered and/or humanly constructed miniphotons.

9. Physicists tell us that by properly arranging an experiment it is possible to accurately locate the position of a photon, but in so doing we disturb its momentum. On the other hand, it is possible to rearrange the experiment so that we can accurately determine the momentum of a photon, but then we cannot locate its position. What cannot be done is to set up an experiment where we accurately determine *both* the location and momentum of a photon.

"Seeing" what we use to *see with* is as impossible as a swimmer catching her own waves. As Gilbert Ryle[10] pointed out over a half century ago, the problem with the claim that everything is *in principle* predictable is not merely empirical; it is also conceptual. We do not need to make careful observations of Olympic-class swimmers to figure out that they will never be able to swim so fast as to catch their own waves—the faster they swim, the faster their waves will proceed!

There is little controversy about what has thus far been said about quantum mechanics. But there is significant disagreement about how it should be interpreted. The majority opinion (called the Copenhagen interpretation) argues that events or behaviors are in principle unpredictable *because* they are uncaused.

The minority opinion (we will call it the Realist interpretation) argues that we must never conflate what can be humanly *known* with what *is* the case. Even though we will never be able to know what caused an electron to "jump" from one orbit to the next, we know that nothing comes from nothing. Just as common sense assumes that no one gets cancer without a cause (even though that cause is not and may never be known), so too electrons don't "jump" without a cause (even though, for reasons we'll consider momentarily, we will never know what that cause is).

We'll consider the Copenhagen interpretation first.

Though the Copenhagen interpretation was first formulated by Neils Bohr and other scientists, their arguments are really philosophical and are grounded in their answer to that old conundrum: If a tree falls in the forest and no one hears it, does it make a sound? Copenhagen scientists assume that the answer is No. Following Berkeley, a famous eighteenth-century philosopher and bishop, they assume that "to be is to be perceived."

Suppose a scientist says that he has discovered that on April 15, 2001, the entire universe doubled in size. Not only did we suddenly become twice as tall, but all the measuring instruments by which we measure people became twice as big. And lest anyone try to measure their increase in height by timing how long a beam of light takes to travel from their head to their foot, included in this scientist's discovery is the claim that the speed of light has become twice as fast. Should anyone take such a theory seriously? Since Einstein, the answer has been No.[11] A difference that by stipulation can

10. Ryle, *Concept of Mind*, 197.

11. Prior to Einstein, many scientists and some philosophers believed in what Newton called absolute space and time. We will consider Newton's ideas in more detail in chapters 4 and 5. But for now, it is not controversial to say that Einstein's theories have completely undercut the "scientific" support for an idea of absolute space and time in

never make a difference is not a *real* difference! Or, to put the issue in the affirmative—if it walks like a duck, flies like a duck, smells like a duck, etc., then it's a duck! So too Copenhagen scientists argue that if we agree (as all physicists do) that it is in principle impossible for us to ever *know* the cause of an electron's jump, then it is meaningless to claim that it *has* a cause. In short, to be unknowable is to be nonexistent.

Philosophical realists disagree. There is now good reason to believe that other galaxies contain stars with planets orbiting them just as the earth orbits our sun. There is also good reason to believe that some (if not all!) of these extraterrestrial planets will never be explored by humans. Does that mean that on the back side of these planets (which by supposition humans never observe) nothing exists—no rocks, water, or molecules? If we start with Bishop Berkeley's assumption—that to be is to be perceived—then that's precisely what we are forced to conclude.[12] Philosophical realists are unwilling to grant assumptions that do great violence to common sense. So too, physicists who are philosophical realists are unwilling to conclude that the jump of electrons from one orbit to the next *has* no cause just because we can never *observe* the cause. What *exists* and what can be *known*, they say, must never be conflated.[13]

Yet, it is reasonable to ask: Why cannot the cause of an individual electron's jump be known? Again, Copenhagen physicists answer: Because no cause exists. Realists, on the other hand, answer: Because the universe is so intertwined and interconnected that when we consider things as small as electrons, we would have to know precisely the state of *everything* in the physical universe before we would be able to predict when a particular electron would make its jump. Similar problems arise inside the nucleus of an atom. As Heisenberg argued, an alpha particle will never be emitted without a cause, but we can never predict when it will "jump" because

> the forces in the atomic nucleus that are responsible for the emission of the *a*-particle . . . contain the uncertainty which is brought about by the interaction between the nucleus and the rest of the world. If we wanted to know why the *a*-particle was emitted at that particular time we would have to know the microscopic structure of the whole world including ourselves, and that is impossible.[14]

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comparison to which the rest of the universe could be said to have doubled.

12. Berkeley himself did not draw this conclusion because he argued that God "saw" everything.

13. The physicist/theologian Stanley Jaki is just one example.

14. Heisenberg, *Physics and Philosophy*, 89–90. See also F. S. C. Northrop's introduction to this book, where he distinguishes between determinism and causation—"every

Here's some indication of the magnitude of the problem. One mathematician calculated that even when considering things as relatively large as billiard balls, attempts to predict the outcome of a chain reaction nine collisions long would require us to factor in the gravitational pull of a man standing next to the table. And if we tried to predict the outcome of fifty-six billiard ball collisions, we would have to factor in the gravitational pull that an electron at the edge of the universe exerts.[15]

We've come full circle. Why is it, we asked at the beginning, that Jimmy Carter lost the 1980 election? The proximate cause of mission failure was a ten-cent nut in one of the hydraulic pumps: If it had not been for *that* particular flawed nut finding its way into *that* particular helicopter at *that* particular time, there is good reason to think that the general perception of weakness and indecisiveness in the Carter White House would have been radically altered.

But if we should then ask about the cause of the proximate cause, the answer is lost in the darkness of history. After a point, all we can conclude is that "time and chance" happen to us all. In other words, at some point we will be forced to tell a story that goes something like this: Five years ago when *this* nut was riding down the conveyer belt, a fly landed on the nut inspector's left shoulder, causing the inspector to momentarily turn his attention to the left at the precise moment the fateful nut was to be inspected. Had that particular fly landed on the nut inspector's right shoulder, his keen eye would have spotted the defective nut—which would have then become as historically insignificant as the hundreds of other defective nuts in the rejection bin. But it was not to be! The neurons in that fly's tiny brain caused it to go left rather than right, and the fateful nut continued to its destiny, down a path marked with countless additional thresholds and tipping points, any of which (from a purely human perspective) *might* have defeated destiny.

Of course, no human will ever know the actual history of this fateful nut. But such a story rings true to many, especially to Christians who believe that the hairs on their head are numbered.

THE CHAOS OF A DOUBLE PENDULUM

At the start of the nineteenth century, Laplace and scientists in general assumed that small mistakes in measurement at the beginning of an experiment would have small effects at the end of the experiment. But as we

deterministic system is a causal system, but not every causal system is deterministic." *Physics and Philosophy* , 11.

15. Taleb, *Black Swan,* 178.

already noted, consequences can be hugely disproportional to the size of an initial error. The fact that observations and measurements will never be precisely accurate means that in a world riddled with thresholds and tipping points, the old saying is true: close only counts in horseshoes and hand grenades!

But there is a second problem with the dream of Laplace, which is a uniquely modern discovery. It is called the three-body problem. The problem is nicely illustrated by a very simple machine whose actions are utterly unpredictable. It's called a double pendulum, and numerous simulations and real examples of such machines can be found on the Web with a simple Google search. Double pendulums are nothing more than one pendulum attached to the bottom of a second pendulum. Though the behavior of a single pendulum is quite predictable, a double pendulum is not, and the reason is purely mathematical.

Remember Laplace's boast—with sufficient data we would be able to calculate the future position of everything *in a single formula*. But we now know that there is no single formula for calculating the gravitational interactions of three bodies, let alone the 10^{80} interacting bodies that make up our universe.

Newton famously (or infamously, depending upon one's theological perspective) believed that the modern astronomy for which he was primarily responsible proved the existence of God. Newton's formulas flawlessly predicted the motion of a single planet around the sun. Furthermore, these predictions could be extended as far into the future as one cared to extend them because the elliptical orbit of a single planet is stable—that is, it indefinitely repeats itself after each orbit.[16] But astronomical observations at the time showed that the orbits of Jupiter and Saturn were not stable—that is, after each orbit they were moving closer to each other, and other things being equal, they would eventually collide. So why hasn't this happened? Newton argued that the only reason Jupiter and Saturn had not and would not collide was that God occasionally intervened to "fine tune" his clock.[17]

When Napoleon and Laplace met a little over a century later, Napoleon asked him about the place of God in his astronomical theories. Laplace

16. Mercury is an exception. The axis of its elliptical orbit rotates slightly. This is called the precession of Mercury's perihelion.

17. "Leibniz charged that Newtonian views were contributing to a decline of natural religion in England. The implication that God occasionally intervened in the universe, much as a watchmaker has to wind up and mend his work, derogated from his perfection. Clarke admitted that God had to intervene in the universe, but only because intervention was part of his plan. Indeed, the necessity of God's occasional reformation was, for Newtonians, proof of God's existence." Hetherington, *Planetary Motions,* 169. See also Koyre, *Closed World to Infinite Universe*, chapter 11.

famously replied: "Sir, I have no need of that hypothesis." And why was he able to eliminate God from Newtonian astronomy? Again, the problem for Newton was the gravitational interaction of the sun, Jupiter, and Saturn. While Newton discovered the formula for predicting the motion of either the sun and Jupiter *or* the sun and Saturn, he did not discovered a single formula for predicting the gravitationally entangled motion of the sun, Jupiter, *and* Saturn.

Now we might guess that Laplace, the father of the imaginary demon who was going to predict everything with a single formula, had made mathematical progress and discovered an elusive single formula for predicting the motion of three interacting bodies. But that is *not* what Laplace did. Instead, with prodigious patience, he used paper, pen, and Newton's own formula to show why the planets in our solar system don't eventually collide with one another. First, based on the known positions of the sun and Jupiter, he calculated their centers of gravity. Then he used this calculated center of gravity to determine the future position of Saturn. Based on this, he calculated the mutual center of gravity of Saturn and the sun. With this second calculated center of gravity, he then returned to calculate the future position of Jupiter. Reiterating this tedious process over and over and over, Laplace discovered that the orbits of Jupiter and Saturn were themselves on a cycle of 929 years of first moving toward each other and then away from each other.[18] Thus, Laplace mathematically demonstrated the stability of the solar system without the need for divine intervention.

Laplace's debunking of Newton's notion of a "fine-tuning" God deserves our praise. (We will say much more about the Enlightenment conception of God in chapter 4.) Additionally, had he reflected upon the laborious iterations involved in calculating his 929-year cycle, he might have realized that only *some* systems with three interacting gravitational bodies are stable. The orbit of a single planet around the sun is mathematically derivable; the orbit of two planets around the sun is *not* mathematically derivable, even though their orbits are wholly caused by gravitational forces. We can perfectly describe where they have been; but we cannot predict where they will be *with a single formula*.

Double pendulums exacerbate this mathematical limitation by introducing countless thresholds ("bifurcation points") where the second pendulum may or may not have sufficient energy to swing over the top. (If my verbal description is hard to follow, I suggest looking at one of the many videos of double pendulums on the Internet.) At each of these thresholds—like a tennis ball bouncing down a rocky road—the slightest miscalculation

18. Gribbin, *Deep Simplicity*, 13–16.

produces radically different results. So with sufficient energy the behavior of a double pendulum becomes chaotic and unpredictable, *but not because there are mystical or nonphysical forces involved*.

With a single planet orbiting the sun or a single pendulum, there is a single equation such that once the initial conditions are known, we can pick any time in the future, plug the data into the equation, and come out with the answer. However, when there are two planets in orbit or with a double pendulum, all we can do is to reiterate the equations. The further in the future our prediction, the more times we will have to iterate our calculations. So, as Joseph Ford said, "a chaotic orbit is its own briefest description and its own fastest computer: it is both determinate and random."[19]

A DEMON-SLAYING STAR

We have made two points thus far, either of which is lethal for Laplace's demon: 1) Quantum mechanics means that infinitely precise measurements are impossible, and the fact that our universe is riddled with thresholds means that little mistakes in the beginning will, at unpredictable points, have huge consequences in the end; and 2) there is no single formula for predicting the future location of three interacting bodies—so in these cases (like those involving double pendulums) all we can do is watch and wait.

We will now make a third point. Einstein's theory of relativity establishes that nothing can move faster than the speed of light. For example, if our sun exploded "right now,"[20] it would be about eight minutes before anyone on earth would know. Eight minutes doesn't sound like much, so let's think about a star a thousand light-years from earth—we will call it the "demon-slaying" star. To see why, let's transfer Laplace back in time to

19. Ford, "What is chaos," 354. See also Gribbin, *Deep Simplicity,* 49–50. Though here a confirmed Laplacian may object that "It is simply not true that the thing itself is its own fastest computer—after all, Laplace himself was able to calculate and predict, long in advance, when Jupiter and Saturn would repeat their cycles of expansion and contraction." True, but incalculable problems remain. Many paths taken by double pendulums are stable and regularly repeat themselves. So these, like the orbits of Jupiter and Saturn, *are* predictable. But other paths taken by double pendulums are not stable and do not regularly repeat themselves. It is in these cases that the thing itself is its own fastest computer. So strictly speaking, it is the point where chaotic systems like double pendulums become unpredictable that the thing itself is its own fastest computer. So again, while this transition point can always be *described* after the fact, it cannot be predicted or *explained*.

20. The scare quotes are necessary because "right now" only makes sense if we assume a Newtonian notion of absolute space and time, and this is precisely what Einstein will not allow.

ancient Rome and the Preacher of Ecclesiastes forward in time so that they can meet to discuss the "time and chance" thesis. Everything else we know about ancient Rome remains the same: in particular, it remains a time and place famous for both its legal, organizational, and military skills, *and* its superstitious fear of omens.

And to make clear the problem the finite speed of light creates for the determinist's thesis, we will ignore for the sake of the argument quantum mechanics and grant Laplace knowledge of the *precise* location and momentum of every electron in the observable universe. We will also ignore the three-body problem. Under these very generous conditions, what will Laplace be able to predict? More specifically, will he be able to predict on January 1 that three days later the Roman legions will still be at peace? The Preacher of course will say that he cannot since "time and chance happen to them all," and Laplace will disagree. So who's right—Laplace or the Preacher?

Twenty-first-century science (science with a small "s") gives the nod to the Preacher. Laplace's problem, even granting our incredibly generous assumptions, is that his database is incomplete. The observable universe does not and cannot include what happens outside Laplace's "light cone." Imagine that exactly 999 years 364 days before the fateful meeting we have described, our "demon-slaying" star (located exactly 1,000 light-years from earth) exploded in a supernova. On January 1, not even Laplace with his postulated superhuman knowledge could have known that on January 2, the light from the "demon-slaying" star would finally reach earth and be visible to *everyone*—including the Roman legions, who might well be spooked into war![21]

THE INCOHERENCE OF "SELF-PREDICTION"

Finally, there is a fourth source of unpredictability; it's the predictor.[22]

By definition a prediction involves three factors. First, every prediction by definition includes two events separated in time. It is not a prediction when a person describes what is happening *now*. Second, a prediction is public, that is, someone has to announce at t1 that some *specific event*[23]

21. For a more scholarly presentation, see Popper, *The Open Universe*, 57–61.

22. See MacIntyre, *After Virtue,* 95–97.

23. Closely connected to the conceptual problems involved in the idea of self-prediction is the idea of predicting future human inventions. To predict the invention of the wheel, someone would have had to *specify* what a wheel is. However, to specify what a wheel *is* is to ipso facto invent the wheel. Of course, one can, like Jules Verne, make

will happen at t2. Third, the predictor's prediction must be based on reason, evidence, and/or arguments. Simply making a lucky guess about the future does not count as a prediction.

Now we have already discussed the problem of getting up-to-date information about very small objects—any observation we make is going to affect the object so that we can only know where the object *was* and never where it *is*. But here, we will ignore that problem. We also discussed the problem caused by the finite speed of light. At t1 our prediction will, at best, be based on all that can be observed within the light cone at t1. So what is predicted to happen at t2 might always be falsified by events which, at the time of the prediction, were outside the light cone of the predictor. But once more, we will ignore this problem.

The final problem with mechanism concerns the predictor's *own* effect on the prediction. All human predictors are a part of the universe they are trying to explain, and as such, they necessarily interact with it. Without this interaction they could never obtain the evidence and data they need to make their prediction. Now in many cases, the interaction is nil. Bouncing photons off of planets to determine their mass and momentum has no significant effect on them. Thus, their orbits are as predictable as a good clock. That's why at least one of the planets—the earth—*was* the standard clock for millennia.

But the dream of mechanists is not that one day *some* parts of our universe will be predictable. That's not a dream; that's been true for ages. No, the dream is that one day *all* parts of our universe will become predictable—both those parts that presently exhibit clocklike behavior (such as the motion of the planets) and those parts that presently exhibit cloudlike behavior (such as the weather).[24] And it is a dream that is half fantasy and half nightmare. The fantasy is that one day those parts of the natural world to which we today can only submit—hurricanes, earthquakes, cancer cells, etc.—will have to submit to us! The nightmare is that "we" will turn into a "them"—that is, you and I will one day come under the complete control of a "them."

Mechanist philosophers will protest that their thesis is wholly philosophical, not political, so it cannot be refuted by the nightmarish scenarios of a "Big Brother." After all, why should we simply assume that humanity's

certain vague "predictions" about the invention of electric submarines or lunar modules. But then, I can, without any scientific training, "predict" the weather six months from today at my home in Northern California—it will be colder!

24. The contrast between clouds and clocks is an allusion to a famous essay by Karl Popper that first developed the argument which follows. Appropriately, his essay is entitled "Of Clouds and Clocks" and is now available online.

newfound power to control their own destiny will be put to nefarious use? Why not assume that in addition to controlling the forces of nature which bring us harm, we will also learn to control the "inner forces" that bring harm to both ourselves and others?

Fair enough. Our concern in this section is wholly philosophical, and the fact that power and control over "nature" is always a two-edged sword (since nature includes us!) is irrelevant. Even if the dream turns into a nightmare, we are here discussing the *truth* of mechanism, not evaluate the *desirability* of its consequence. Again, fair enough. So let us only consider the truthfulness of the claim that one day we might "learn to control our 'inner forces' that bring harm to both ourselves and others."

"Inner forces" can be understood in two distinct ways. First, they can be understood to refer to what Plato called the "leaden weights" of gluttony, sensual pleasures, and their more sophisticated refinements that drag people down so that they can only focus their attention on that which they can see or feel[25]—in short, what Christians call sin. But these are not the sorts of things that mechanists are referring to when they speak of "inner forces." For mechanists, the "inner forces" are processes in the brain that are themselves wholly determined by antecedent physical and chemical factors.

So let us test the thesis that one day these brain processes will themselves be predictable. And again, we are going to grant for the sake of the argument that (1) mechanists will one day be able to observe other people's brains with the same clarity and precision that physicists and chemists now observe our inanimate world *and* (2) they will be able to do so without significantly affecting what they are observing so as to make their data out-of-date. Even granting both of these scientifically dubious assumptions, there will always remain at least one set of brain processes that will remain *in principle* unpredictable, namely, the brain processes of the person making the prediction.

The problem, once again, is that no swimmer can catch his own waves. Suppose there is a neat and one-to-one correspondence between what a human thinks or says and particular states of that person's brain.[26] This means that when Fred, our super scientist, makes a prediction at t1, his brain is in some corresponding state that we will label BS1. And suppose further that his prediction is that at t3 Sally will uninhibitedly start singing "The

25. Plato, *Republic* VII.519.

26. We are deliberately being quite colloquial here. While there appears to be an intuitively obvious *meaning* to the idea of "neat and one-to-one correspondences," it hides a critical ambiguity. We discuss this ambiguity between type/type and token/token correspondences in chapter 7 of *Life, the Universe, and Everything*. But here we will grant the mechanist all his assumptions and metaphors.

Star-Spangled Banner" at the top of her voice. The problem is that as soon as Fred announces his prediction, Fred also knows that at t3 Sally will make a fool of herself, *unless he acts to prevent Sally's embarrassment*. But whether he will or will not act to save Sally from embarrassment is something that Fred doesn't (and cannot) know at the time he makes his announcement. Perhaps hearing his own announcement will remind him of one of his own embarrassing moments in the past and what it did to his self-esteem. So at t2, in a moment of pity, Fred warns Sally about what she is about to do, and hence, his original prediction is now out-of-date.

The problem with his first prediction is that he didn't factor in his own BS1, which included sympathetic thoughts toward Sally making a fool of herself. And the problem is insoluble. No one can observe the glasses they themselves are using to make observation. So too, the brain that Fred is himself using to make predictions cannot be observed while he is using it. The moment he announces his prediction concerning Sally's embarrassing behavior, his prediction is in danger of being falsified *by his own brain*.

Fred's self-reflection begins an escalating series of self-reflections that can never, so to speak, be "out-swum." If mechanism is true, Fred's moment of pity at t2 also has a cause, call it BS2. After warning Sally at t2 and having to make a second prediction, Fred will also *know* that he has been forced to make a new prediction. This in turn might cause Fred to worry about his own embarrassment. So once again, Fred will be forced to announce yet a third prediction saying that his t2 prediction is out-of-date because he forgot to factor in his own BS2. But if mechanism is true, Fred's third prediction at t2.5 also has a cause, call it BS3. Obviously, there is no end to the regression.

If this seems hopelessly convoluted, it is! The self-reflection of which all humans are capable is like standing between two mirrors and looking at the reflection of your reflection of your reflection of your reflection—it never ends. Likewise, self-prediction will always fall prey to the famous example from Gilbert Ryle.

> A singing-master might criticize the accents or notes of a pupil by mimicking with exaggeration each word that the pupil sang; and if the pupil sang slowly enough, the master could parody each word sung by the pupil before the next came to be uttered. But then, in a mood of humility, the singing-master tries to criticize his own singing in the same way, and more than that to mimic with exaggeration each word that he utters, including those that he utters in self-parody. It is at once clear . . . that at any given moment he has uttered one noise which has yet to be mimicked . . . and it makes no difference how rapidly he chases

> his notes with mimicries of them. He can, in principle, never catch more than the coat-tails of the object of his pursuit.[27]

The problem is that one's own behavior can never be *predicted*; it can only be *chosen*. The instant one tries to predict one's own behavior *on the basis of evidence*, an endless series of self-reflections begins. We become like the swimmer trying to catch his own wave or the singing-master parodying his own song. This means that not only is one's own behavior *in principle* unpredictable, but everything that happens inside of your own sphere of influence is also in principle unpredictable.

And somewhat ironically, as our power to control nature *increases*, the sphere of the predictable *decreases*. Right now it is quite possible for scientists to predict the future location of the planets years in advance because there is nothing humans can do to change their orbits. We can also predict the future location of many asteroids. But in the foreseeable future (or perhaps the time is already here) the orbits of small asteroids will come within the sphere of human influence. When that time arrives, the orbits of small asteroids will no longer be *predictable*; instead, they will be *chosen* and something that *could have been otherwise*.

Ancient wisdom and common sense both understood that our universe includes things whose behavior is as predictable as a finely made clock and things whose behavior is no more predictable than a tennis ball bouncing down a rocky dirt road. The growth of modern science in the seventeenth century[28] led people to begin questioning ancient wisdom and common sense. And toward the end of the nineteenth century, to many scientists it appeared that common sense had been vanquished. Contrary to our romantic sensibilities, it appeared that science had proven that the universe was one gigantic machine. However, as we have seen in this chapter, by the end of the twentieth century, science—more specifically, quantum

27. Ryle, *Concept of Mind*, 195–96.

28. We have deliberately focused on the physical sciences in this chapter since, if anywhere, it is there that Laplace's case is the strongest. But if we turn to the biological sciences, the case for universal predictability becomes even less plausible. Stephen Jay Gould, in his magnum opus, put it like this: "Finally, my general love of history in the broadest sense spilled over into my empirical work as I began to explore the role of history's great theoretical theme in my empirical work as well—contingency, or the tendency of complex systems with substantial stochastic components, and intricate nonlinear interactions among components, to be unpredictable in principle from full knowledge of antecedent conditions, but fully explainable after time's actual unfolding." *Structure of Evolutionary Theory,* 46.

mechanics, the three-body problem, and general relativity—had undercut the arguments for mechanistic philosophy.

Of course, what science gives, science can take away. It is minimally conceivable that one day quantum mechanics, the three-body problem, and general relativity will themselves be corrected and made deterministic just as these modern theories corrected and made indeterministic Newton's theory of gravity. Still, the incoherence of self-prediction remains. Valid predictions presuppose up-to-date data. But no one can observe their very act of observing. Thus, no humans will ever be able to predict either their own behavior or any other event they are capable of affecting.