But Then ... Who Designed God?

The PARADOX of EXISTENCE

by DON STONER

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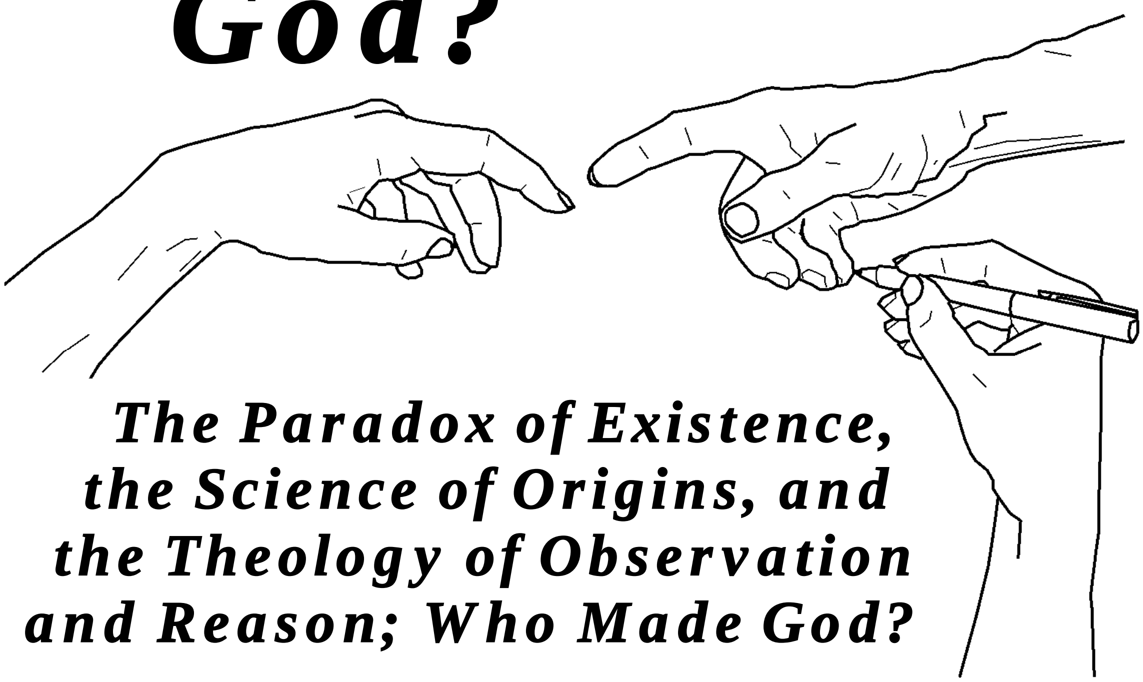

The Paradox of Existence, the Science of Origins, and the Theology of Observation and Reason; Who Made God?

by DONALD WAYNE STONER

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By Donald Wayne Stoner

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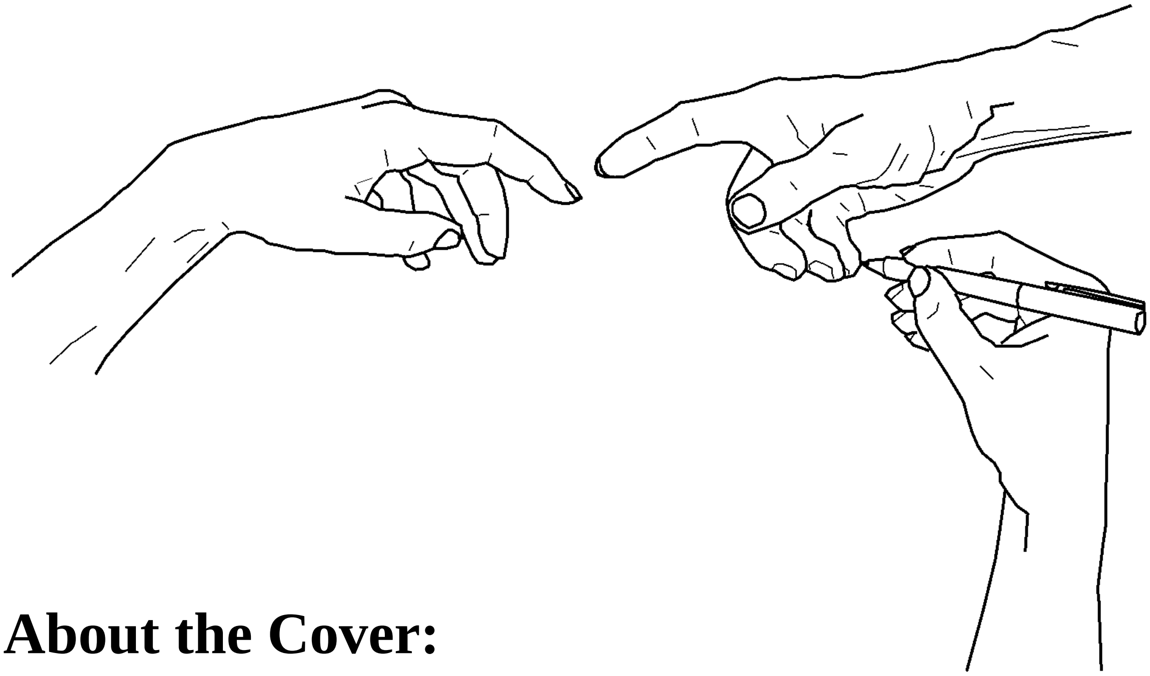

About the Cover:

Many readers will recognize Adam's hand on the left and God's at the upper right (borrowed from the ceiling of the Sistine Chapel), but whose hand is that drawing God’s? Perhaps it’s Michelangelo’s, doing a preliminary sketch (but using a modern rolling-ball pen). Or maybe it's Adam's right hand, figuratively reaching back through his descendants, re-creating his creator in his own image, in some paradoxical strange loop (and here we seem to be borrowing one of Escher's hands-drawing-hands to emphasize that point).

Or maybe the truth is stranger still: Maybe all three hands are digital representations of the author's own two hands, acting out the respective roles (holding the red pen he used to mark up early drafts of this book), captured in binary code by a digital camera, manipulated by various computer programs, until that digital information was finally printed onto paper by a digital printing press. Maybe this image was never really part of a physical picture at all – until the moment it first became part of this book – but instead, existed only as arrangements of binary numbers in computer files.

Or maybe all of those ideas are true in their own properly limited senses. – D.W.S.

The Paradox of Existence

Are logic and mathematics necessary and sufficient to explain space-time, matter, energy, relativity & quantum mechanics? What else might be necessary?

Are logic, math, and physics (space-time, matter, energy, relativity, and quantum mechanics) necessary and sufficient to explain chemistry?

Are logic, math, physics, and chemistry, necessary and sufficient to explain organic chemistry, biochemistry, molecular biology and all other biology?

Is biology (in conjunction with the above chain) necessary and sufficient to explain our brains?

Are our brains (and that chain) necessary and sufficient to explain minds?

Is logic merely a creation of the human mind?

Is logic necessary and sufficient to explain advanced mathematics?

Can we simply skip back to the first step above, and just keep looping?

Is epistemological mathematics (the kind which human scientists have invented) representative of ontological mathematics (the kind that call the shots in physics – e.g. at the quantum mechanical level)?

Are human logic and mathematics sufficiently robust (al least in theory) that humans could produce sentient electronic minds? – or even entire artificial worlds, like in the movies The Matrix and The 13th Floor?

How much might an artificial world be like our own? Can we skip back to the top and start down again – but in an artificial world?

How many such loops might we be able to make? Do recursively diminishing subsets of finite resources predict some kind of upper limit?

What happens if we work our way *backwards* around this same loop? Do we ever reach a beginning? At which step *could* any such beginning possibly occur?

I affirm that each of the above links in the seemingly endlessly spiraling causality “loop,” which I have just described, is absolutely valid – except, of course, for the one proverbial "weakest link." This loop contains at least one serious mistake; where do you suppose it might be? The consequences become fascinating *wherever* we might try to try to cut this strange loop.

(Back cover for book.) – D.W.S.

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Part One:

The Weird Behavior of Space, Time, and Matter

Chapter One:
"This Thing's Broken!"

The words comprising this chapter's title were angrily shouted by a young physics student who was about my age – maybe a year or two older. The year was probably 1971, and by now, my aging memory tells me he was only slightly more athletic than I was – but, of course, memory has a way of putting things in a better light than they really were. Accompanying his outburst, the student gave the optical instrument he had been using a violent shove.

I stared in disbelief as the collection of steel arms, mirrors, and other optical paraphernalia spun crazily around the instrument's carefully designed ball-bearing axis. I was instantly impressed by the man who had designed that instrument. It was as if he had somehow anticipated both this young man's frustration and the accompanying outburst; he had taken all of the necessary precautions to protect both instrument and student. The device was balanced perfectly and it had obviously been designed to take many times the abuse it was presently receiving.

Convinced that neither the instrument nor the student was in any immediate danger, I became curious about what had set the young man off. The spinning instrument was fitted with two right-angled arms, each with a front silvered mirror at its end, a monochromatic yellow sodium light source, and something that was probably an observation eyepiece. At the axis of rotation was a beam splitter. I began to suspect I had seen an instrument like this one once before. "Is that a Michelson interferometer?" I asked innocently.

The student turned quickly to face me with a touch of fear now mixed in with his anger. He stood as he turned. The laboratory became silent as a dozen or so upper-division physics students lost interest in their respective experiments and turned to see what the excitement was about.

I had just walked into this particular optics lab for the first time and didn't know anyone there; in fact, I was starting to feel a little bit nervous. I hadn't been looking for, or expecting, a fight; but my general cluelessness regarding human nature had often caused me to upset people before. Fortunately I had already figured out what had upset the student and knew how to solve his problem. I figured I was probably going to be safe enough.

The student studied me for a second before answering my question. "Yeah," he said, indicating that the instrument was, in fact, a Michelson interferometer. It sounded more like a question than an answer – maybe even a challenge. I think he was starting to suspect that I wasn't going to cause any trouble for him, but he wasn't quite sure yet. As I said, I was probably younger than he was, and I certainly didn't dress like one of the professors. Even so, I answered with the confidence of a professor, "It's not supposed to do anything."

He, of course, stared at me in disbelief. I definitely had his attention now, so I took the opportunity to explain how the same experiment had baffled the people who had originally performed it – just like it was presently baffling him. I also explained how a young man named Einstein, in his mid twenties, had figured out what had gone "wrong," and how this very experiment had forced the world to see clocks and distances in the radically new way which later became known as "The Theory of Relativity."

The atmosphere in the lab began to relax. There was a bit of scattered laughter among the students as the young man, now amused, sat back down and picked up his pencil. He was ready to get back to work with a newly acquired confidence. That student had just relived, in a very personal way, a little piece of the historic drama that had brought scientists, one step at a time, from the old world of classical physics, into the new one of relativity and quantum mechanics. He had just had a very real encounter with the strangeness of modern physics and could now see, using his own powers of observation and reason, how his universe was very different from what he had thought only minutes before.

Later that year, it was my turn to sit at the same instrument and measure the same missing velocity that A. A. Michelson had once measured. The only difference was that it was just a boring assignment when I did it. Unlike most of these young men who were working toward their degrees, I already knew what to expect.

I had been blessed with an exceptional mother (who had taught me algebra in the third grade), an exceptional father (who had showed me how to derive Einstein's equations many years earlier), an exceptional high-school physics teacher (who had prepared me to snag fifth place in a statewide physics competition), and an exceptional college professor (who had, by a masterful practical joke he played on me, turned a three-unit electronics class into the functional equivalent of an electrical-engineering degree). Together, those people (among many others) had given me an unusual head start. This may even have shaped my personality in many ways.

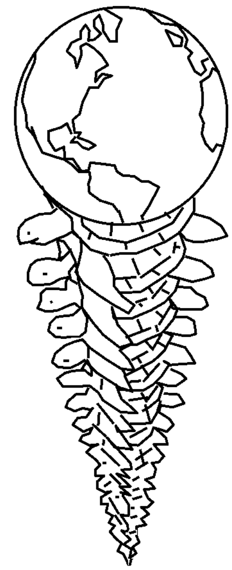
In case it isn't already obvious, I'm a total geek. Maybe, being a geek is just one of those nasty jobs that somebody has to do. Someone had to design each obscure piece of electronic equipment that sits in every aerospace research laboratory in Southern California. I just happened to be in junior high school the first time I designed one of them. Somebody had to take the laser disc, from an idea, to the CDs and DVDs we have scattered around our living rooms. Working as a member of that team was my first real job out of college.

How hopeless a geek am I? It's pretty serious. I have received more patents and academic awards than the number of times I have watched professional hockey, soccer, and basketball games combined. (If I include baseball and American football, I think it might be about a tie.)

Since I'm a technical geek and not a trained theologian, it is natural to wonder why I am trying to answer questions like, "Who Designed God?" – or the other half of that same question, "Who made God?" It's because those questions are every bit as much philosophical and scientific as they are theological. A theologian might claim that "God" created the universe; but a scientist (always a skeptic, if properly trained) must ask that theologian, "Who made God?" The mystery of existence has haunted men since the beginning of history – if not from yet earlier times. We can all *observe* that we exist, but we should also be prepared to explain how *existence itself* is even possible. All questions which address first causes can appear impossible at first glance. An old joke illustrates the problem:

The truth seeker asks, "What keeps the Earth from falling?"
The ancient sage replies, "It rests on the back of a giant turtle."
The truth seeker asks, "Then what keeps the turtle from falling?"
The ancient sage replies, "It rests on the back of a second giant turtle."
The truth seeker asks, "But what keeps that second turtle from falling?"
The sage replies, "I see where this is headed; it's turtles all the way down!"

– Adapted from a story told by Stephen Hawking (1988) and by others.

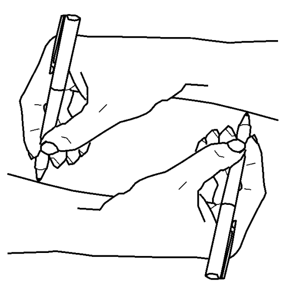


The modern explanation that “the earth rests on nothing” might not have satisfied an ancient truth seeker, but when enough of the missing scientific pieces (including universal gravitation and planetary orbital mechanics) were finally supplied, that very simple answer finally made sense.

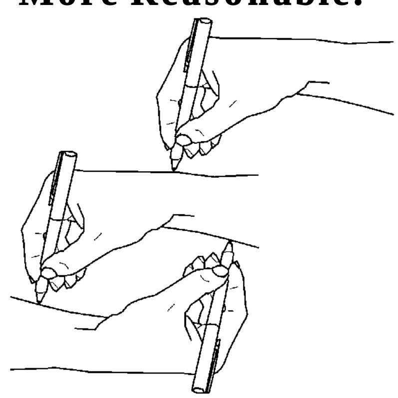
Sound reason demands *satisfying* explanations for everything. Invoking an infinite number of complex mechanisms to explain a finite situation is never a very satisfying answer. Even if it takes many steps to get there, there must be something sensible at the very bottom of “the stack.”

Strange causality loops (like those described on the back cover of this book) suffer from a similar problem. If “A” causes “B” to exist then “B” cannot also cause “A” to exist. Escher’s “Hands-Drawing-Hands” cannot draw each other; but it is no mystery that his real hand is able to draw both.

Disturbing:



More Reasonable:



Our search for the original cause of the universe and everything it contains (including our minds) should be no different. An oversimplified outline of the stack of causality supporting our minds is pictured on the opposite page. Every layer is supposed to be, at least in principle, completely constructed from, caused by, and explained by, the layers below it. This stack contains a few fairly serious errors (which we will examine later); however, the only *really obvious* problem is that bottom layer.

If we are told that the bottom cause is primordial matter, then we must ask how that primordial matter ever got there in the first place. If we are told that "God" put the matter there, then we must ask *who or what* put "God" there. In fact, *whatever* we decide to put at the bottom, we are still left wondering, "What supports that bottom turtle?"

A theologian might argue, from the appearance of intelligent design, that there must be a designer somewhere, but we still need to ask, "Who designed that designer?" Any entity with advanced design capabilities is obviously sufficiently elegant to require some kind of designer itself. Elegant designer or none, elegant design does exist, and it must come from somewhere. How can we comprehend that first cause? What explains that bottom turtle?

The situation may appear hopeless, but causality cannot evade its responsibility forever. There must be something reasonable at the very bottom of this "stack of turtles." The problem is to come up with enough pieces of the puzzle that the "bottom" explanation makes sense.

Our universe is a very complex collection of interrelated systems. Many of the systems are very difficult to understand; many of them seem to involve fascinating paradoxes. Sorting out initial causality may be an extremely difficult task, but it is also a very interesting one. This book's featured question, "Who designed God?" is certainly a tough one; but there are ways of approaching even the very most difficult questions.

Being a technical geek, I have had more than my fair share of experience studying how complex technical systems work. Among the things which I have learned how to design are computers. A computer is a very complex system – drawing on many diverse technologies including quantum mechanics; silicon device fabrication; electronic switching; logic gates; various increasingly complex arrays of those gates including logic sequencers, arithmetic logic units, and memory arrays; low level firmware; operating system code; and application software. The final result can overwhelm a beginning student; but each part can be studied, one small

Minds
/Psychology

Comprising /Caused by
/Explained by

Brains
/Neuropsychology

Comprising /Caused by
/Explained by

Nerves
/Neurology

Comprising /Caused by
/Explained by

Living Cells
/Biology

Comprising /Caused by
/Explained by

Organic Matter
/Biochemistry

Comprising /Caused by
/Explained by

Chemicals
/Chemistry

Comprising /Caused by
/Explained by

Atoms
/Atomic Physics

Comprising /Caused by
/Explained by

Space & Matter
/Modern Physics

Comprising /Caused by
/Explained by

God ???
/Theology ???

component or system at a time, building in complexity at a manageable pace, until the entire system becomes comprehensible.

Over the years, I've been involved with enough different design teams, and analyzed enough different kinds of designs that I have learned from experience how to "read" a designed item. The more machine parts I have studied in their proper contexts, the more quickly any new part "tells" me about itself, when I first encounter it in isolation.

There are many different kinds of clues which can be extracted from an isolated part: Is it supposed to pivot or rotate? Is it designed to be strong, lightweight, slippery? Was it designed to carry electric currents? hydraulic currents? Was it designed to be immersed in water? in oil? in acid? Is there evidence how it might connect to other pieces of the whole machine? Is it supposed to be adjustable? If it has been removed from a working machine, what patterns of wear, corrosion, or discoloration have occurred?

Likewise, studying the whole machine can tell more than just what it is supposed to do. It might explain what environment it was designed for, what size of production run it came from, and even who its intended customers are. I have often been handed various things and asked, "Have you ever seen anything like this before?" I often answer, "No; but I can tell you how it was made, what it does, and how it works." It's a skill that can be learned with enough exposure and practice.

One of the more interesting things that a machine can reveal is what its designer must have been like. Was it carefully designed? Carelessly? Did the designer care about mathematical optimization? Did he care how long the device would last? Was there a sense of functional aesthetics involved? An artistic sense? Which technologies did the designer draw from? What other skill sets did he possess? Might "he" have been a woman? Was a team of designers involved who had failed to unite their efforts?

I once drove a friend's van for a thousand country miles. I was only a few hundred miles into the drive before I was convinced that the man who had designed the cruise control must have been extremely frustrated with the man who had designed the transmission. I'm sure I felt that same frustration when I tried to think through different possible ways to improve the cruise control. Given the response function of the transmission, the designer of the cruise control faced an impossible task! I could imagine the blame-assignment meetings where that designer tried to defend his competence, and the probable flak he would have received from management. All of that seemed apparent merely from driving the completed machine.

It isn't really all that difficult to "read" the nature of a machine's designer. In nearly every piece of equipment I have studied, his style (which is virtually his signature) can be seen repeatedly throughout his work.

In addition to being a technical geek, I have also been a lifelong student of physics, biology, chemistry, cosmology, geology and a few other scientific disciplines bearing on the universe in which we live. Given the vast amount of available evidence detailing how the universe works, there ought to be a way to identify whatever sort of "creative agency" might have been involved in bringing us to where we presently are. There ought to be enough evidence to figure out how it is that this agency was able both to exist, and to cause us to exist. We really ought to be able to answer questions like "Who made God?" and "Who designed God? – one way or another.

Isaac Newton once said, "I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the sea-shore, and diverting myself in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me." There is certainly a lot left to wonder about, but perhaps if Newton had lived in our century, and if he had also acquired a Ph.D. in geology or oceanography, he might have been able to explain how each pebble or shell tied into the earth's entire set of systems, of which the world's oceans are only a relatively small part.

A single pebble selected from a beach holds clues which can be used to track its history through time. How long the waves have pounded against it might be read from its present degree of surface erosion. Whether it was broken off the local rocks, or carried down a river from a distant point of origin, might be read from its composition. Likewise the source for the "parent" rock might have been a volcanic eruption or it might have been a sedimentary composite of other rocks which, themselves, had once been ground to powder on the shore of some ancient and forgotten sea. Newton's pebble's composition and chemistry may answer all of these questions. We can even begin to understand where the very first pebble might originally have come from.

Our goal, of course, is to understand the first cause – the "creative agency" as I will call that "bottom turtle." As I have said, this will not be easy; but we can start by examining a few small pieces of the problem and then build from there.

If you are worried that this book might attempt to appeal to the authority of, say, the Bhagavad Gita, Bible, Dhammapada, or Qur'an, don't worry; it won't. Quoting ancient manuscripts is not likely to carry any weight with my targeted audience. The scientific environment teaches a man to live by his powers of observation and reason. It is by this authority that I have lived my professional life; and it is to this authority alone that I will appeal in the following chapters.

Some may want to challenge this claim – particularly those who have seen me in church (occasionally even addressing a congregation from behind the pulpit), or those who have watched me on the job, using prayer to help me through particularly difficult technical problems. I, however, don't see any contradiction. I hope that by the end of this book, we will all be able to see and understand at least this much from the same perspective.

Chapter Two:
Einstein's Special Theory of Relativity

OK, I can read the title of this chapter just like you can, and I can guess what you might be thinking. Don't panic; I won't torture you with complex mathematics. I'll even try to take the concepts very slowly. Relativity might be difficult to understand, but it is still an important first step in the journey we are taking here.

Our question is, "Who (or what) designed and manufactured God?" In order to figure this out, we first need to understand the universe; then we can work backwards to what must have been necessary to design and manufacture it. The universe is, in some very important ways, just like any other "piece of equipment." What we can understand about it will go a long ways toward showing us who or what was responsible for it. Then, once we have some kind of handle on the agency responsible for the creation of the universe, we can try to make some intelligent guesses about how that agency happens to exist.

Of course this means that we must first understand the universe. In particular, we must have real answers for all of those questions which curious children always seem to ask: How big is the universe? What's the edge like? What's just past the edge? Did it always exist? What was it like "before" the beginning?

These questions can be a real nightmare for the parents of any curious child. They are also the subject matter of the scientific study called "cosmology." The good news is that all of those "terrible" questions have answers which are becoming increasingly more certain and precise as scientists probe the stranger corners of our universe. The bad news is that these answers are not even close to what we are probably expecting them to be.

When the upset young physics student at the beginning of the first chapter retraced the footsteps of A. A. Michelson, he found himself face-to-face with one of the universe's very strange tricks. He had approached that experiment with a set of beliefs which he had collected over his young lifetime. He already had definite opinions about how time and space ought to behave. When he was confronted with the unexpected truth, he did what greater men than he had done before him: he decided that the instrument he was using was "broken."

The rest of us also have our own lifetimes' worth of collected opinions about what the universe ought to be like. Likewise, when we are confronted with the truth, we are likely to assume that it is the truth which is broken, and not our opinions. Of course the real universe "cares" very little about our opinions. If we are going to understand its design, then we may need to change our opinions about some very basic ideas concerning time and space.

It is a commonly held opinion that time and space ought to be easy to understand. We want to believe that simple concepts like "before," "after," "inside," and "outside," will apply to the universe, as a whole, the same way they apply to the simple clocks and boxes that we experience daily. Unfortunately, they don't. Time and space turn out to be very strange.

Perhaps what I am about to explain may sound completely wrong, but it is the truth anyway. Fortunately, the word is out. It is likely that most of us have heard this before. It shouldn't come as too great a shock: time and space are "curved." Not only that, but time and space are both made out of the same kind of stuff. The two even exchange roles to some extent when we change the direction and speed in which we happen to be moving (or not moving).

Although the following discourse will be something of a brain teaser, most readers will probably find it quite interesting. The ideas behind relativity are not really very complicated; they are just very strange.

According to Einstein's theory of relativity, there is "no preferred frame of reference." What that means is there is no place we can be, nor any speed at which we can be moving, that is more "true," or more "absolute," in any sense than any other place or speed would be. In particular, it is impossible to know if we are moving very rapidly or are completely stopped.

The laws of physics work just as well for a man in a high speed train as they do for one who is standing still. If the man in the train throws a ball straight up, it will come back down into his hand instead of hitting the back wall of the car in which he is riding. This is still true even if the man in the train thinks he is standing still. After all, the earth is a giant moving "spaceship" which is traveling very rapidly around the sun, yet all of the laws of physics work for us as we move, even though we regard ourselves as being stationary (ignoring Coriolis forces).

The moving-train example is an oversimplified one. It is easily explained, even without relativity. However, not all things can be explained without it. This is why the laws of relativity were needed. How Albert Einstein came to the conclusion that there is no preferred frame of reference is not only an interesting story, it may also help us understand relativity.

It all started back in the late 1800s with the same scientist (A. A. Michelson) that we encountered earlier. Michelson had invented a new instrument with which he had hoped to measure the velocity of the Earth through space. This attempt is known as the Michelson-Morley experiment – and the instrument he had invented to do this was essentially the same as the one the upset young student had assumed was broken.

It was known that the earth makes one rotation about its axis daily. Because the equatorial diameter of the earth is about 7926 miles, this means that a man standing at the equator is being carried along by the turning earth at a speed of about 1037 miles per hour (ignoring the sidereal correction). Furthermore, the earth goes around the sun (total circular distance about 584,000,000 miles) once in a year. This means that the earth is zipping around the sun at about 67,000 miles per hour. (That's roughly mach ninety – and you are riding on it!) But how fast might the sun be moving through the galaxy or the galaxy through the universe? This is what Michelson wanted to measure.

Loosely speaking, Michelson's apparatus measured the speed of light as it passed the earth in one direction and, very accurately, compared it to the speed of light passing the earth in another direction. Because the earth is moving, it seemed to him that light should appear to pass it at different speeds in different directions. As we have just seen, the earth is traveling at a pretty fast pace. The amazing result of the experiment was that, no matter which way Michelson (or the young student) turned his instrument, nor how carefully he made his measurement, he found that the apparent speed of passing light was always exactly the same – not almost the same; there was no observable difference at all!

Putting this into a common setting may reveal how absurd this measurement was. Assume we are in a slowly moving car and that we are watching faster cars on the same street which are passing us in both directions. Further, assume that all of those other cars are traveling at exactly the same speed, just like light does. We should expect that cars which are overtaking us from behind would pass us more slowly than those which are coming from the opposite direction. What Michelson discovered was like saying that the cars were all passing us at exactly the same rate in both directions – as if we were stopped. This seemed absurd; Michelson knew the earth was not stopped!

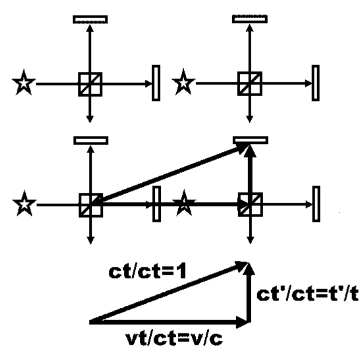
The scientific community (and the young student) had as hard a time accepting this as you might now be having. In fact, it was suggested that Michelson’s instrument (or even Michelson himself) might have been “broken.” Fortunately, Michelson was given the funds to construct much a bigger and better version of his apparatus. The experiment was repeated and, to the chagrin of the world, the result was exactly the same.

The earth did not appear to be moving at all! Either the earth was the stationary center of the universe and the sun and stars circled it, or new laws of physics were needed. Einstein was able to figure out what had gone wrong with Michelson's experiment; he also provided the necessary new laws to explain it.

Scientists found themselves in a position very much like the man on the train who could not tell from throwing his ball up into the air that he was moving. only their position was even worse; it was as if looking out the window wouldn't help either. According to the new laws of relativity, the speed of light was what was always constant, no matter how it was measured; other things, like the very rate of time itself, would change instead. When Einstein supplied this realization and the proper equations, Michelson's experiment made sense.

The rate at which time proceeds really does change; clocks actually “tick” faster under some conditions than they do under others. As incredible as this sounds, subsequent experiments confirmed it. Elapsed time for a very high speed particle can be shown to be quite different from that experienced by a stationary observer. Small effects can even be detected using extremely accurate clocks carried on supersonic aircraft. What time it is depends partly on where we are and how fast we are moving!

The way time’s rate changes can be calculated from three things: 1) The geometry of the Michelson interferometer., 2) A little algebra involving nothing more complex than the Pythagorean theorem, and 3) Einstein’s realization that the rate of time is not a constant. (A technical illustration, for “geeks” only, is to the right: just normalize all distances by “ct”) – Non-geeks may prefer the layman’s explanation which follows:



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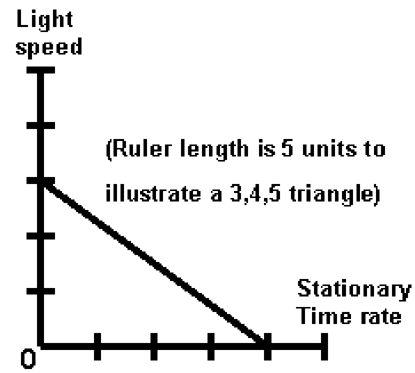
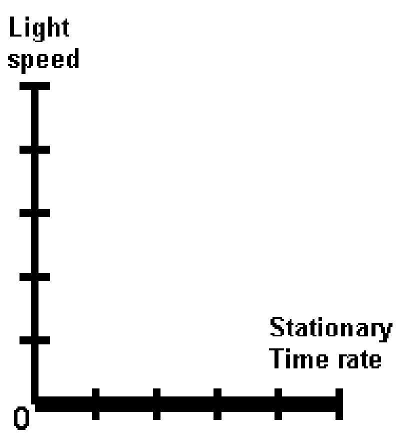


Without torturing anyone with the technical details, the results of Einstein's calculations can be visualized with the help of a simple 12-inch ruler (or a nice decimal meter stick, if you are lucky enough to have one handy). All we need to do is lean the ruler against a wall, with one end on the floor. If the velocity of a spaceship (as a fraction of the speed of light) is represented by the height of the top end of the ruler above the floor (as a fraction of the length of the ruler), then the rate of time in that spaceship (as a fraction of the rate of time for a stationary observer) is represented by the distance of the bottom end of the ruler away from the wall (as a fraction of the length of the ruler). The faster the spaceship, the more steeply the ruler will be tilted toward vertical. In the illustration (above right), the spaceship is traveling at three fifths the speed of light, so the top end of the ruler touches the wall three fifths of a foot (the length of the ruler) above the floor (that would be seven and one fifth inches). Since this makes a simple Pythagorean triangle ($3^2+4^2=5^2$), we can conclude that the rate of time in that spaceship is four fifths the rate of time for a stationary observer.

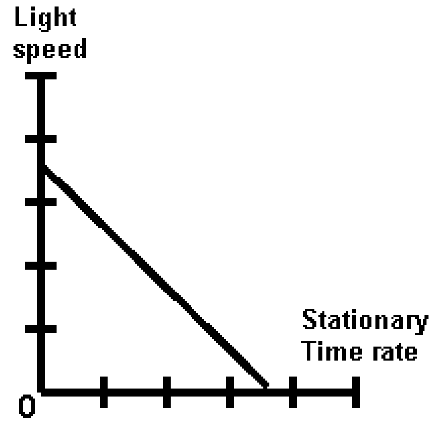
Velocity = 0:



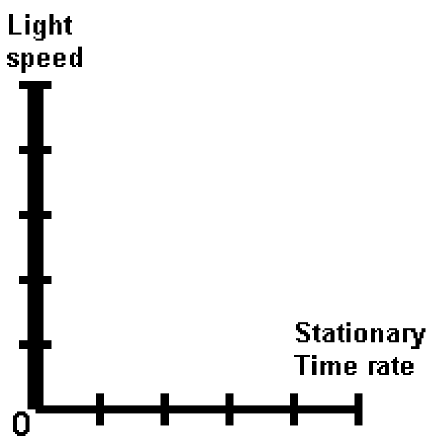
Trying out a few other specific examples will help explain this model: If we are moving relatively slowly (say a "mere" three thousand times the speed of sound), we would be moving with such a small fraction of the speed of light that it would be difficult to tell that the ruler wasn't sitting perfectly flat on the floor; the high end of the ruler would only be raised above the floor by about the thickness of a single sheet of paper. The low end of the ruler would still be almost exactly a full ruler's length away from the wall. We would need to measure time very carefully in order to see the difference at all; the spaceship's clock would only lose a couple of minutes in a year.

If we were to increase the spaceship's velocity to seventy-one percent of the speed of light (about 130,000 miles per second), this would be like tilting the ruler to about a forty-five-degree angle (putting the top end of a twelve-inch ruler about eight and a half inches above the floor). This would bring the bottom end of the ruler to within about seventy-one percent of its length away from the wall (also about eight and a half inches), The spaceship's clock would slow to seventy-one percent of the rate of a stationary clock – or to about seven seconds of spaceship time for every ten seconds of stationary time.

Velocity = 71%
Light speed:



Velocity = 100%
Light speed:



If we could make the spaceship travel at exactly the speed of light, the ruler in our model would have to stand vertically against the wall (illustration at left). The ruler's bottom end would have no separation at all from the wall. This means the clock in the spaceship would be completely stopped!

It has been shown by many different kinds of experiments that Einstein's theory really works; this stuff really happens to clocks which are moving very rapidly. We don't usually notice it because hardly anything ever moves fast enough to make a difference; however, some things do move this fast.

For one obvious example, light itself moves at exactly "the speed of light." This means that no time passes for a photon (a single "particle" of light) while it makes its journey across empty space from a distant star. This would seem to mean that photons can't change – since in order for something to change, time must pass. Yet photons can be created and destroyed by events which transpire within space and time, even though photons themselves experience no time at all.

From a photon's point of view, the instant of its creation is the same as the instant of its destruction – even when the two events are separated by many thousands of years (when measured with the clocks used by slower observers, such as ourselves). This might seem like a problem, since a single photon should not be able to exist in two different places *at the same time*; but it isn't a problem to a photon. As strange as this might seem, I hope to clear this up in the next chapter.

In the following chapters we will encounter many things which are even stranger than this! Among other things, we will encounter something that moves faster than the speed of light! In order to understand that, we will need to remember what we have learned here:

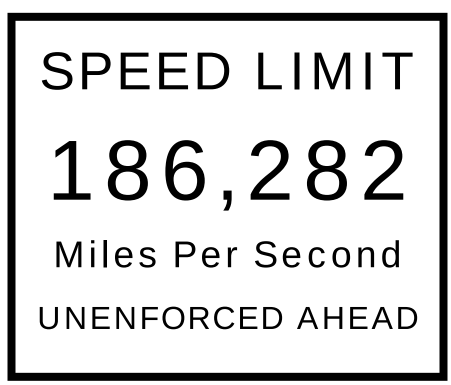
Summary:

1) Time passes at different rates for different observers.

2) The faster something is moving, the slower its clock runs.

3) Clocks stop completely at the speed of light.

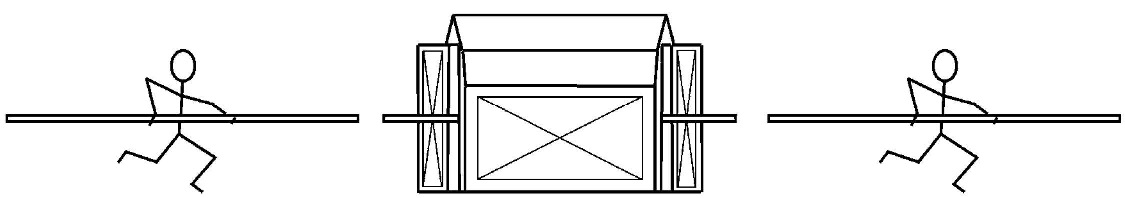
4) There is no way to tell who is moving and who isn't in any absolute sense.



Chapter Three:
Four Dimensions

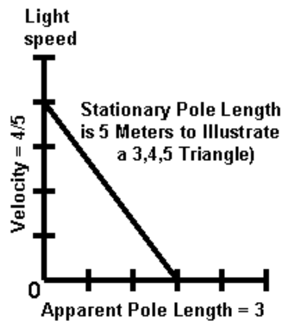
Before we try to understand traveling faster than light, we will need to get a better understanding of things that travel slower than light. The following illustration is silly enough to be interesting, while it is serious enough to accurately demonstrate some of the principles involved.

First, imagine a barn with two doors that open outward on opposite left and right walls. We will assume those two doors are three meters apart. Next, imagine a pole vaulter who is carrying a five-meter pole. If both doors are open, the vaulter can carry his pole through the barn – in from the left and out through the right. Of course there will be a period of time when his pole sticks out through both the left and right sides of the barn at the same time.

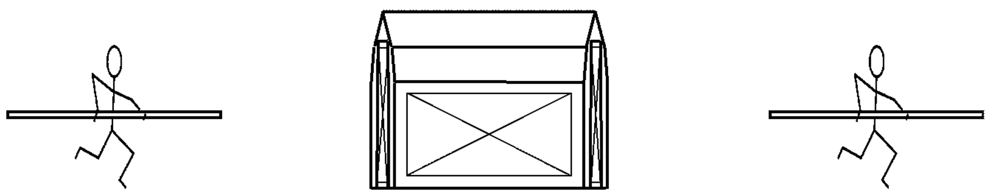


Next we will make our vaulter run very fast – four-fifths of light speed – and make him run through the barn again. This time the effects of special relativity will become apparent. His pole will now appear to us (if we stand next to the barn) to have shortened to a length of three meters. This is because, under

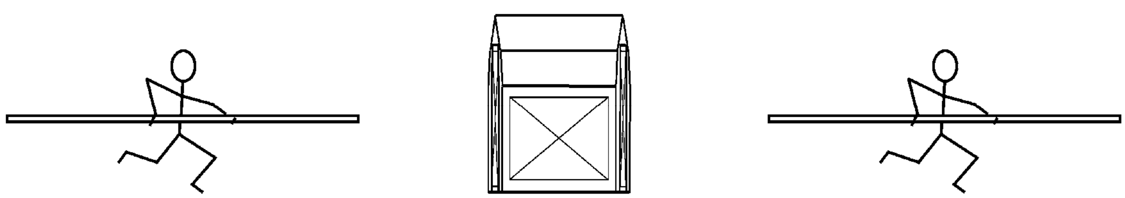
Einstein's laws, the length of a moving object (in the direction it is moving) will appear to shorten by the same percentage that a moving clock will slow down.



At this speed, the three-meter pole just fits into the three-meter barn! If we were quick enough, we could slam both doors shut *at the same time* and open them again before there was a real collision (just a gentle touch). With a fast enough camera, we could, in principle, even take a picture of the pole safely inside the barn with both doors closed.



But what would this look like if we were running along next to the pole vaulter? According to relativity, everything should be essentially symmetrical; we aren't supposed to be able to figure out who is moving and who is standing still. This means it ought to look to us (if we "stand" next to the pole) like the pole is stationary, and is still five meters long – but that the barn is moving, and is now only three-fifths of its original three-meter size (less than 2 meters)!



So what is going to happen when we go through the barn and both of its doors are closed *at the same time?* When we sit down to compare notes with those who "stood" by the barn, will we disagree about whether or not there was a collision? Will we have a splintered pole for evidence while they show a motion picture which proves that the pole was barely touched?

The answer is that we would observe that the barn's two doors weren't really closed *at the same time*. Instead, we would observe that the right door was closed first (just touching the pole), and that the left door wasn't closed until we were just barely out of its way. Any motion picture sequence which we might have filmed would confirm the absence of simultaneity as would any other recording instruments which we carried.

However, anyone who "stood by the barn" would observe that both doors were closed at the same time. Further, all of their recording instruments would confirm that "observable fact." What's wrong here?

It turns out that the phrase "*at the same time*" is completely without meaning when high speeds and different moving observers are involved. The problem is that when everyone's clock is running at a different rate, there is no way to figure out what "time" it really is. Only when we give up our notion that two separated events can happen *at the same time* – and that everyone will agree what this means – does the world really make sense!

Fortunately, there is still something that everyone can agree on; it's called "space-time distance." A person by the barn sees the two doors close with zero time separation, but with three meters of space separation; this is a space-time separation of three meters. The vaulter sees a full five meter space separation between the two ends of his pole (which each touched one of the doors); but he also sees a time separation of four "light-meters." (Here we are defining a "light-meter" as the *time* it takes for light to travel one meter – about 3 nanoseconds or .000000003 seconds; this unit will make the math easier to do.)

But how does five space-meters, plus four light-meters of time, add up to a space-time distance of three meters? The answer is a combination of the Pythagorean theorem and the realization that "time" is what mathematicians call an "imaginary" quantity; time has a value which is expressed in units of "i," where "i" is the square root of minus one. (Time isn't really "imaginary;" that's just the name that mathematicians chose to give to that particular kind of number.) Space is what mathematicians call a "real" quantity, so it's measured in normal units.

Let's work the numbers: 5 meters squared (25) plus 4 light-meters squared (-16, since time is "imaginary") equals 9 (which has a square root of 3). So both observers agree that the space-time separation is three meters!

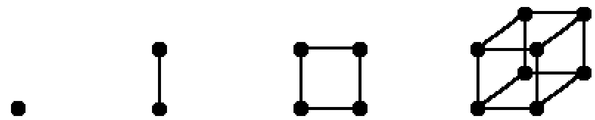
One "imaginary" dimension of time, and three "real" dimensions of space, (height, width, and depth) combine to make a space-time distance. Physicists sometimes call this a "four-vector." Similarly, one "imaginary" dimension of "energy" and three "real" dimensions of "momentum" combine to make a different kind of "four-vector."

We can picture these space-time "vectors" by thinking of either the ruler or the pole from the preceding examples. A ruler or a pole can be rotated (or pointed) in any direction within our three-dimensional space (right, left, front, back, up, and down); but a four-vector can also be rotated into *the direction of time*. This happens whenever we move it at very high speeds. We can visualize this rotation from the way we *tilted* the ruler against the wall, or how we *"rotated"* the pole (toward the "direction" of *time*) so that it was able to fit into the tiny *space* inside the barn. The dimensions of time and space are so much alike that real objects can actually be "rotated" between them.

Some time back, I had some friends over to discuss science, philosophy, and religion; and someone brought up the subject of Edwin Abbott's mathematical classic Flatland, A Romance in Many Dimensions. Abbott's book tells a story about an inhabitant of a two-dimensional world (specifically, a square) who was unable to understand the third dimension. There was simply no way that a visiting three-dimensional being (a sphere) could explain this third dimension to the square. The square saw the sphere as merely a circle which had the ability to change its diameter or even to disappear. Since the square could not see the third dimension, it had no way to understand the sphere's attempts at demonstrating its special kind of existence. It was completely blind to the greater reality which the sphere inhabited.

Naturally, the challenge was raised that *we* were probably incapable of understanding what a "real" fourth dimension of space might be like (not merely three dimensions of space, plus one of time).

Having had some training in mathematics, I decided to take the opposite position and tried to show the "unbelievers" that there was quite a lot about a fourth dimension that could easily be understood. Graph paper and a pen were handy, so I drew the figures which are pictured at the top of the opposite page:

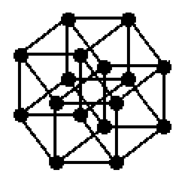


0 Dimensions 1 Dimension 2 Dimensions 3 Dimensions

Starting with a world having no dimensions, where all that could exist would be a single point, I separated that point into two points, which I moved an inch away from each other, then connected them with a line segment which could inhabit a 1-dimensional world. Next, I separated the line segment into two segments (each with two endpoints) and moved them an inch apart in a different direction, and connected the endpoints of the two line segments with two more segments to make a square. The next step was to separate the square into two squares (each with four corners, or endpoints), to move those squares an inch apart, and to connect the endpoints with four line segments to make a cube.

Since the cube was drawn on the flat piece of paper, it wasn't really a cube, but only a flattened drawing of a three dimensional cube. No one present even noticed that I had cheated. They were all accustomed to seeing 3-dimensional objects drawn on flat paper, so my 2-dimensional drawing of a cube was accepted.

But then I separated the cube into two cubes (each with eight corners), moved them one inch apart in yet another direction (still on the same flat piece of paper), and connected the endpoints with eight line segments to make a four-dimensional hyper-cube (illustration at right). If you study the picture carefully, you can see the original cube at the lower right and the duplicate at the upper left. There are also eight added diagonal lines that connect the corresponding eight points in each cube.



4 Dimensions

At this point one of my friends asked me to explain what I had just done, so I explained that I had repeated exactly the same steps I had done to get from zero to one dimensions, from one to two dimensions, and from two to three dimensions. He had one more objection; he couldn't understand the direction in which I had separated the two cubes. At this point, I explained that I had cheated when I drew the three-dimensional cube and hadn't really left the paper – and that this hadn't bothered him because he understood what I meant; we were both "seeing" the cube in three dimensions. Likewise, the four-dimensional cube was simply a flat, but otherwise correctly drawn, representation of what this structure would look like in four dimensions.

To make a slightly better model, we would have to use glue and toothpicks to construct a slightly more easily visualized (although still dimensionally "flattened") model in three dimensions.

For the next step, I demonstrated that we could easily use mathematics to understand the properties of these various constructions. I selected the length of the long diagonal for the example. First, the zero-dimensional construct had no "diagonal," so its length was zero. Next, the one-dimensional line had a length of one, which was also its longest "diagonal." The Pythagorean Theorem gave a diagonal length of "root two" for the square, and the extended version of the same theorem gave "root three" for the cube, like this:

Dimensions:	Diagonal:
0	0
1	1
2	1.4142136
3	1.7320508

Next, I pointed out that "zero" for the length of the zero-dimensional construct could also be written as "root zero" and that "one" could be written as "root one." In every case, the length of the diagonal was simply the root of the sum of the squares of the unit-length sides for each of the dimensions. This meant that we knew the length of the diagonal of the four-dimensional cube; it was "root four" or, more simply, two. Furthermore, we even knew the length of the long diagonal of a one-hundred-dimensional cube; it would be "root one hundred" or, more simply, ten.

Dimensions:	Diagonal:	Root of:
0	0	0
1	1	1
2	1.4142136	2
3	1.7320508	3
4	2	4
100	10	100

At this point, that first friend was impressed, and he was wishing he had paid more attention to mathematics many years ago – back when he was still young enough to learn it easily.

But a second friend was not so easily impressed. Earlier he had been trying to make the point that it might be impossible to understand things we had never experienced. Since he had followed the mathematics, he conceded my point, but he took his argument in a different direction. He suggested that maybe we could begin to understand multiple dimensions that we had never seen, but it was probably still impossible to make any definite statements about a world having "negative-one" for its number of dimensions.

I immediately agreed that he had proved his point, but then I looked down at the paper I had just been writing on. It showed me how to calculate the length of a diagonal for a cube with *any* number of dimensions! I said, “wait a minute,” and started filling in the table in the negative direction. The length of the "long diagonal" of a “cube” having negative-one dimensions turned out to be “root negative-one” – or that number which mathematicians call “i”.

Dimensions:	Diagonal:	Root of:
-2	1.4142136 i	-2
-1	i	-1
0	0	0
1	1	1
2	1.4142136	2
3	1.7320508	3
4	2	4
100	10	100

This was particularly interesting because, as we have just seen, there really are quantities that scientists encounter which behave as if they were square roots of negative numbers – “time” being one of these quantities (energy being another). The negative-one dimension turned out to be a perfect mathematical description of time! Not only could I calculate properties for this dimension, I could also “visualize” it in a familiar sense.

At this point, that second friend gave up and stopped trying to prove that we could not visualize things which we had never experienced. He may have given up too soon; although I can now calculate the “diagonal” of a “cube” having 3½i dimensions, I’m not at all sure I would be able to visualize the result correctly. (This is left as an exercise for the reader.)

My point in presenting this information is that mathematics seems to carry a whole lot more weight in the world of physics than it might seem like it ought to. I never would have guessed that there could be such a thing as a negative-one dimension, yet once I recognized that the mathematical possibility existed, it became obvious to me that “nature” had made that same “realization” before I had, and was even making practical use of this negative dimension. It was almost as if the mathematics came first, and the dimension of time stepped in to fill the space which the mathematics had already made for it.

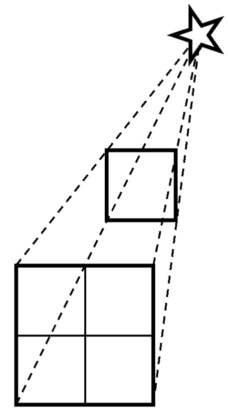
In future chapters, we will see how this fascinatingly tight relationship, between mathematics and physics will keep coming up again and again. Further, mathematics plays into other fields as well. In fact, it will come up frequently enough, that it may begin to look like an important piece of the puzzle we are attempting to solve here. In fact, it may begin to appear as if the sort of “God” we are seeking here might be linked very tightly to mathematics.

Chapter Four:
The Big Bang

In the early 1900s, an astronomer named Vesto Slipher discovered that most galaxies (still thought to be spiral nebulae back then) had "red shifts" – meaning that some very precisely defined colors (atomic spectral lines) emitted by those galaxies appeared to be slightly "redder" in color than they normally should have been. After testing the different theories which were presented to explain this, it was determined that the observed red shifts were a result of the Doppler effect.

The Doppler effect is what makes noisy vehicles make higher pitched sounds when they are approaching than when they are moving away. That same Doppler effect causes light from galaxies which are approaching us to be "bluer" in color (blue light has a higher frequency), and light from galaxies which are moving away to be "redder" than normal (a lower frequency). The fact that most galaxies were red shifted suggested that most of them were moving away from us.

Later, Edwin Hubble measured the distances to those galaxies, using the "apparent brightness" (brightness as seen from earth) of their Cepheid variable stars. Cepheid variables have luminance cycles; the brighter ones have slower cycle times, while the dimmer ones cycle more quickly. This means their "absolute brightness" (as it might be seen from a fixed distance) can be determined by simply timing the period of their cycles.



This gives us enough information to calculate the distance to these stars. If an object is twice as far away, the same amount of light must cover four times as much area. This area increases as the square of the distance. This means the square of the actual distance to a star is proportional to its absolute brightness divided by its apparent brightness.

What Hubble figured out was that the more distant galaxies had proportionally greater red shifts – and were therefore moving away from us more rapidly than the closer ones were. Later observations confirmed this correlation on the macrocosmic scale – but also revealed local regions which had their own lesser variations from the overall trend.

The overall trend implied something startling: When the known positions and velocities of all the galaxies were extrapolated backwards in time, the galaxies (generally speaking) appeared to have started moving away from the same place in space at the same time. This suggested that the present distribution of positions and velocities may have come about as the result of a very large explosion. It also implied that the universe must have experienced a "beginning."

The term "big bang" was coined in jest by a rebel astronomer named Fred Hoyle. Hoyle maintained that the universe had always existed. He was not particularly comfortable with the concept of a "beginning," or with the gnawing questions that would have to be answered about what might have caused that "beginning." Hoyle held out for many years, using his exceptional brilliance to explain away all arguments which favored the "big bang" explanation. But eventually, the radiation left over from this explosion was detected. When that happened, virtually all scientists agreed that the universe really did have an explosive beginning. (Even Hoyle finally stopped arguing against it.)

In spite of this, over the years many different attempts have been made to avoid coming to terms with the moment of creation. Some of these attempts involve assuming that the universe went through endless repeated "big bang" cycles. (Examples include big bang/crunch cycles, the budding off of new universes through wormholes, and quantum instability restarts.) Some of these theories even go as far as suggesting ways to deal with the problems presented by the various conservation laws, or the relentless increase in entropy.

Unfortunately, none of these attempts will help us much in our present quest to *explain* initial causality; they all propose essentially endless "stacks of turtles" in order to *avoid* the issue. Since we are actually looking for that "bottom turtle" here, and not simply trying to avoid it, we can simplify all of these theories into a single case by dealing with the present big bang as if it were either the first of the series – or as if it were the only one ever. Either way, the "bottom turtle" is the only one that really needs explaining here.

No matter what its position is in any possible "turtle" sequence, the "big bang" origin of this present universe has been very well confirmed. NASA's Cosmic Background Explorer (COBE) radiation-mapping probe even returned a detailed map of the structure of the background radiation left over from when this universe first became "transparent." (This is estimated to have happened about 377,000 years after the explosion – when the charged particles combined into neutrally charged atoms so that radiation, like light, could shine through between these particles, undisturbed). By observing this radiation, scientists confirmed both the reality and the details of the "big bang." The most recent NASA measurements place this explosion at about 13.7 billion years ago.

The good news is that we now know what happened; the bad news is Hoyle's fears have materialized, and we now have to explain a literal and explosive "beginning." This beginning turns out to be every bit as hard to picture as we might have expected (and as Hoyle had feared).

Our experience with explosions, and with the resulting spread of debris, might suggest that the universe's matter should be spreading out into empty space in all directions. As we will see, this would be an incorrect impression. The truth is a little bit difficult to explain; I think it might be easier if we take this in two chapters and I tell you a few "half truths" (a.k.a. lies) the first time through. In this chapter, we will keep the model relatively simple by pretending that the effects of Einstein's general theory of relativity simply don't exist. In the next chapter, we will try to "un-distort" this oversimplified picture to bring it closer to the horribly complicated truth.

To begin, the most distant galaxies we can see are traveling away from us, in all directions, at very nearly the speed of light!

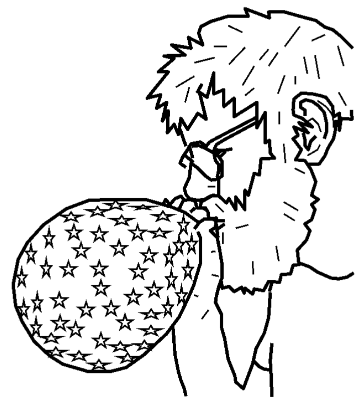
Furthermore, the radiation from the big bang is red shifted even farther (receding even faster) than the light from these most distant galaxies. The farthest edge of the universe appears to be moving away from us *at* the speed of light! (In fact it is receding even faster than the speed of light, but this will be much easier to explain if you try to pretend you didn't hear that.)

The implication is that the far edge of the universe is moving away from us so rapidly that the effects of Einstein's theory of relativity become very great. Assuming that we are stopped (not moving in space) in our present frame of reference (our own galaxy – the Milky Way), the rate of time at that far edge must be completely stopped (not moving in time)! This means the most distant "clocks" have ticked off no time at all! They are still "frozen" at the instant of the "big bang!" Since no time is passing there (as viewed from our frame of reference), not even a photon can escape from this edge. (Remember, we are still pretending you didn't hear that the farthest edge was actually moving *faster* than light.)

As interesting as that idea is, it implies something which is stranger yet: Since the farthest edge of our universe, whether north, south, east, west, up, or down, has had no time to move since the instant of the explosion, this means that it must all *still be at the exact location of the Big Bang*! And this location was *and is* a single point. The entire outer "surface" of the universe has lagged so far back in time that it is still at the beginning of time – back when there really was only one point of space in the entire universe. The entire far edge of space would fit inside a lunchbox. If you are thinking this is impossible, then you probably have the correct understanding of what I am saying. (And at least this part will not change when we examine general relativity in the next chapter.)

Although this is a strange idea, it is not completely foreign to people who live on (and are familiar with) spherical planets. Here on earth, no matter which direction we start traveling (north, south, east or west), if we continue in a "straight line," we will eventually arrive at the one point which is exactly opposite to where we start. Of course we are not really moving in a "straight" line, all directions curve back to that same point.

The same thing is true in space; no matter which direction we look (north, south, east, west, up, or down), our gaze will eventually take us to the place and time of the big bang! We may think that all directions in which we might look are straight paths; but somehow they all "curve" back toward the same point. "What shape does that make the universe?" "Round" is the answer most commonly given, but in what imaginable way? For a technical description, we might say that the universe is shaped something like the three-dimensional hyper-surface of a four-dimensional hyper-sphere; but if you understand what that means, you probably don't need to read anything I have written in this chapter.



To keep things “simple,” let’s pretend we live in a two-dimensional universe which occupies the surface of a sphere. This is easier to picture – since we do live on the locally-flat two-dimensional surface of the spherical earth. Since the universe is expanding, we are going to need to have the surface of our model getting bigger too – like a balloon which is being inflated.

Imagine that the universe’s galaxies are tiny spots drawn on the surface of this balloon. As the balloon inflates, its surface stretches, and all of the galaxies move away from each other. The farther apart they are on the balloon, the faster they will move away from each other. This expansion looks the same from any point on the surface. Hypothetical observers in every galaxy would see the same thing – the galaxies which are farther from them would be moving away from them at a faster rate.

We will imagine that our galaxy is at the point opposite to the balloon’s neck (or fill stem), and that the most distant galaxies are right next to the neck. The neck itself will be the most distant point in space from us. We will also pretend to inflate the balloon so rapidly that its opposite sides are moving away from each other at the speed of light. This will mean that the neck’s clock appears stopped (to us) and that it is, therefore, frozen in time at the instant of the big bang.

In this model, “time” would be the straight distance to the balloon’s surface, as measured from the neck – where the clock is stopped (holding that point’s time at zero – and also bending all directions back to that point). “Up,” or “outward,” represents the future, “down,” or “inward,” the past. Since we have no time travel, we are trapped on the balloon’s surface and can’t leave it to move inward. Instead, we are carried inexorably outward as time carries us into the future (as the balloon inflates).

No matter which direction we might look away from our location in space (or in any "flat direction" away from our location on the surface of the balloon), we are always looking straight toward the time and place of the big bang (or toward the balloon’s neck). However, to an “observer” at that “back side” of the universe, we would be the ones at the farthest edge of space, and we would be the ones with the stopped clock! (In fact, observers at all points think that the clock is stopped at the point which is "opposite" from wherever they happen to be!)

This may be more easily pictured by using a second balloon. The back-side observers are really on the surface of a different balloon which is being inflated in the opposite direction – away from the same point in space and time (same big bang or fill-stem location). Our position then becomes the neck (to them) and has its clock frozen at the moment of the big bang.

Since the balloon is expanding so rapidly, it is not really possible for us to move fast enough to get over to the other side and get a good look at it (staying on the same balloon). If we could move that far (which would require some kind of time travel and would put us on that other back-to-back balloon), by the "time" we got there, it would no longer look like the edge of space. Instead, it would look the same as any other point in space; the new "edge of space" would appear to be at the point opposite from where we would then be; our own Milky Way galaxy would mark the edge of space and the point of the big bang.

In this balloon model, the "two dimensions of space" are curved in the third dimension of "time." Instead of extending straight away from us in a plane, space curves back in the direction of "past" time – toward the neck. This is one way in which the "separate" roles of "space" and "time" begin to get confused with each other. This is also the way in which the big bang is unlike matter spreading into empty space; instead, space (carrying the matter it contains) spreads away from the time and place of the big bang.

As weird as this seems, this simplified model is not really all that far from the truth. If we could visualize that third dimension of space (the one we left out to simplify our model) we would have a much better picture. (Remember that all three dimensions of space are exactly the same – just like the legs on a symmetrical tripod. That other dimension must act exactly like the two that make up our model's surface.)

This is a step toward understanding the universe, but there are many other things which we must also try to understand – like the other complications which we have ignored up until now; one of these complications is the time it takes for light to reach us from different parts of space; another is the fact that gravitational mass and acceleration also bend the "fabric" of space. This additional bending is explained by Einstein's general theory of relativity; it is also what permits the far edge of space to move away from us at a speed faster than light. We will address general relativity in the next chapter.

The final answer to everything is still a ways beyond our grasp, but physicist Stephen Hawking has done a good job of summing up this ultimate problem with this haunting question:

> "Even if there is only one possible unified theory, it is just a set of rules and equations. What is it that breathes fire into the equations and makes a universe for them to describe? The usual approach of science of constructing a mathematical model cannot answer the questions of why there should be a universe for the model to describe. Why does the universe go to all the bother of existing?"
>
> – Stephen Hawking, from: A Brief History of Time, Chapter 12

So why does the universe go to all the bother of existing? Hawking's question is essentially the same question which we are dealing with here; he has used the metaphor "breathes fire" to describe whatever it is that makes reality happen – our "bottom turtle."

Hawking is, quite reasonably, biased against leaving anything hanging at the very beginning which might appear to require any kind of extra "turtle" that is causally supporting the universe. His model attempts to eliminate all boundaries which might require any kind of explanation – making the universe "self-existent" in the same sense that a theologian might claim that "God" *must be* self-existent. (So under Hawking's theory, the "God" we are seeking here might turn out to be the universe itself.)

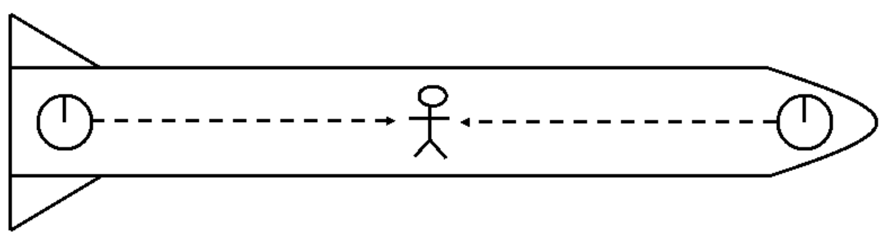
My own biases are quite similar to Hawking's; I don't want to leave anything hanging either. I even want to understand this thing which he describes as "fire;" and I want to understand how it interacts with the mathematics – and why the universe should go to all the "bother" of existing.

And while we're at it, we must also ask our friend the theologian what it is that "breathes fire" into God and causes Him to go to all the "bother of existing."

Chapter Five:
Einstein's General Theory of Relativity

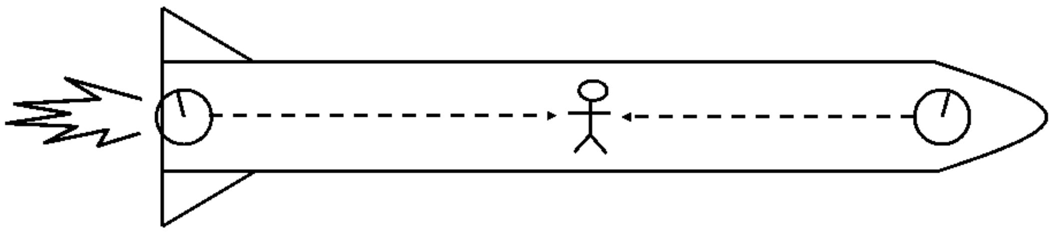
As strange as Einstein's special theory of relativity is, we aren't really quite done yet. Einstein had a general theory of relativity which is also important to understand - and which makes things even stranger.

Let's imagine that we are in a large spaceship which is parked somewhere out near the Gamma Quadrant, or if we're agoraphobic, maybe in the parking lot of the local Walmart (it doesn't really matter where). We will seat ourselves in the exact center of the spaceship. We will also imagine we have two perfectly synchronized clocks which are placed at the extreme front and back of this ship. Each clock will tell us its rate of passing time by sending us an evenly spaced sequence of light pulses.



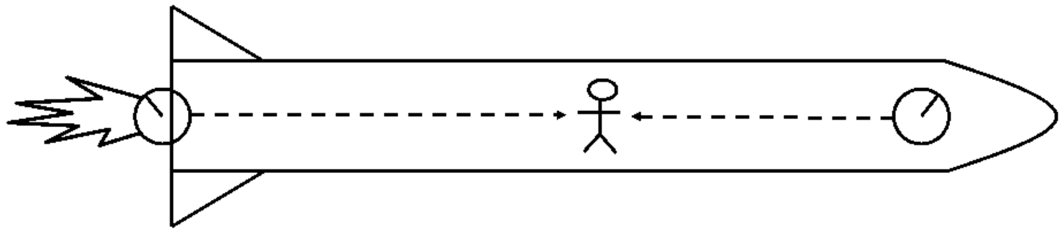
Let's also assume that the two clocks are far enough away from us, and are "ticking" rapidly enough, that it takes one full clock tick for each light pulse to reach us. Since the two synchronized clocks are the same distance from us, the two light pulses (one from each clock) will still be perfectly synchronized when they arrive at our eyes.

Now, let's start our spaceship accelerating at a constant rate and wait until we are moving at one tenth of the speed of light. We are now rushing toward the place where the front clock was (when it ticked) and away from where the back clock was. This means the pulse from the front clock doesn't have as far to travel as it did when we were stopped (since we meet it partway); likewise, the pulse from the back clock has farther to travel (since we are moving away from it). The effect of this is that the clocks no longer appear to be synchronized. We see the pulse from the front clock reach us first, followed by the pulse from the back clock.

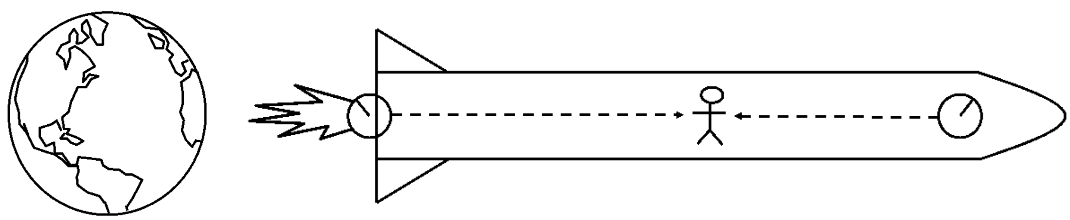


The clocks in this illustration are shown shifted to reflect the distance light has to travel to reach us. (They don't really slide out the back end of the spaceship.) Each clock is drawn where it actually was when it ticked, but by the time the tick reaches us, we have moved a little farther forward. The clocks themselves actually travel with the spaceship – but drawing them where they "are" instead of where they "were" would not illustrate the point I am trying to make as well. The "time" shown on the face of each clock shows us whether each clock appears to be gaining or losing time, as observed from our central location, as the spaceship accelerates.

If we keep accelerating at the same constant rate and wait until we are moving twice as fast (two tenths of light speed), the two clocks will appear to be twice as far out of synch as they were before (see the illustration at the top of the opposite page). If we keep accelerating, the clocks will continue to become even farther out of synch, the front clock appearing to be running faster and gaining time and the back clock running slower and losing it. In fact, as long as we can keep accelerating at the same constant rate, the front clock will appear to run faster – and the rear clock slower.



Now comes the really fun part; we are going to have a large planet quietly sneak up behind us (matching velocities with us). As this planet approaches us (see illustration below – not to scale), its gravitational pull begins to lessen our net acceleration. If the planet is large and close enough, it can exactly balance the thrust from our rocket engines until we have no net acceleration. Our engines will still be burning fuel and pushing us forward with the same force. We would even feel ourselves being forced back into our seats as if we were still accelerating at the same rate (although the pull would now be from the planet's gravity instead of from our ship's acceleration), but we would no longer be accelerating.



What would the two clocks now be telling us? According to Einstein, the front clock would still be ticking faster than the one in the rear. This is because, according to his general theory of relativity, clocks which are "higher" in a gravitational field run faster than those which are lower. Subsequent experiments have verified that Einstein was correct; this is what really happens. Gravity and acceleration turn out to behave in exactly the same way. This means gravity will bend time and space in the same way that a smoothly changing velocity (constant acceleration) would.

So, knowing this, we must now take another look at our model of the universe: When we look toward the balloon's fill stem from our point of observation in the Milky Way Galaxy, we are looking straight up from the surface of a planet (probably Earth) whose gravity is pulling us down. According to general relativity, this means a series of clocks, placed higher and higher above our heads, would appear to be ticking faster and faster the higher they were placed. But, according to special relativity, since the galaxies "above" us are receding progressively faster with increased "elevation," their clocks are running slower and slower, the higher they are.

Fortunately this is not a paradox; it is merely a subtraction problem. The increase in clock speed (due to general relativity and the earth's gravity) is very small when compared to the decrease (due to special relativity and the expansion of the universe).

However, the increase isn't zero. If the edge of space were really receding at exactly the speed of light, its clock would not be exactly stopped; it would be progressing at a rate which would be greater than zero by the contribution made by general relativity and the gravity of the earth. In addition to the earth's gravity is the gravity of our sun, that of every other star in our galaxy, and of every star in every nearby galaxy. This still isn't that big a deal, but it is starting to add up.

The bottom line is that the edge of space can actually be moving away from us at a little bit faster than the speed of light without reversing the direction of time or becoming infinitely massive (another effect of special relativity).

There is a tongue-in-cheek principle called Murphy’s Law which (loosely) states, “Anything that can happen, will happen.” This seems to have been true for the expansion of space; since it actually can move faster than light, and since the big bang gave it a *really* hard push, the far edge really is moving away from us faster than the speed of light! Unfortunately, this means we can't see it at all.

The situation is actually even worse: Shortly after the big bang, all of the mass in the universe was packed together into a very small space. This means that gravitational forces were once extremely strong and time distortion resulting from general relativity was very large. This means that, early on in the universe's history, space was able to expand at many times the speed of light without reversing the direction of time, or causing anything else really bad to happen. Since the big bang gave all of this matter such a hard push, the initial expansion of the universe was *really* fast.

This makes the edge of space a little harder to picture. The beginning of space, time, and the big bang still occupies a single point, but space starts having several different kinds of edges -- like, for example, the farthest thing from which light can ever reach us. That particular "shell" doesn't fit into any lunchbox.

We might ask ourselves "why" the universe expanded this fast; the answer is probably that the mathematics (which Einstein discovered) permitted it to. How hard a push was our universe originally given at the moment of the big bang? When we were assuming that the speed of light was as fast as anything could move, it made sense to us that the universe had been pushed hard enough to get it going that fast, but no faster. With general relativity repealing that speed limit, the same push seems able to achieve even faster speeds. How much faster? We don't really know. Some studies of this early "inflationary" period of the universe's history suggest original speeds of perhaps thirty times the speed of light. What kind of force can deliver that kind of push? I'll leave it as an exercise for the reader to try to imagine it.

I'll also have to leave it as an exercise for the reader to try to twist the balloon model from the previous chapter into the correct shape to model the universe which I have just described. I have tried, and haven't come up with anything that I would want to try to describe here using words and simple pictures.

Even so, at this point, we are finally ready to try to answer some of those difficult questions which inquiring children like to ask:

Q. How big is the universe?

A. It is actually much bigger than the distance which light could travel in 13.7 billion years (moving at 186,282 miles per second – which works out to be about 80,000,000,000,000,000,000,000 (or $8x10^{22}$) miles – in all directions. We don't really know how much larger than this it might be; assuming the estimated factor of thirty times light speed, this could be about $2.4x10^{23}$ miles (in all directions). But we can't ever see anything out past the first $8x10^{22}$ miles – the farthest distance from which light will ever be able to reach us. These are two of many possible ways to define the "farthest edge" of the universe.

Q. What is the edge of space like?

A. Which edge? The farthest edge is the single point (in space and time) of the big bang (the balloon's "neck" in our simplified model from Chapter Four). It's extremely hot and very dense; and any direction we might point will always be right toward that single point. Hypothetically allowing time travel, we could approach this point from any direction – it's just a point when viewed from all sides, there really is no "beyond." Think of that silly peppermint-striped "North Pole" next to Santa's house. There is no way to get "beyond" it if we always walk straight north (we just bump into it). What we can do, instead, is simply walk around it and view it from every direction. The whole far edge of space would fit inside a lunchbox. But a word of warning: Since that "edge" is also the beginning of time – if we did this, we would be "staring down the bore" at the very nasty "big bang" (if we could really get that close).

There is also a much closer "edge" which is expanding away from us at the speed of light, and beyond which we can never see. All clocks on this surface are presently stopped (at least approximately – when viewed from our frame of reference); but they haven't always been. We can point to different places on the surface of this "edge," but the farthest edge of space is the single point, far behind this surface, in every direction.

An even closer "edge" is the surface from the time when the universe first became transparent; we can't actually see past this surface either.

Q. What is beyond the edge of space?

A. Which edge? Beyond the closer edges is more space – filled with more galaxies. Anyone who lived at any of those edges would think they lived in the middle of the universe and that *we* lived at the corresponding closer edge. What is beyond the farthest edge? Same answer as before: it fits inside a lunchbox. Since (allowing for time travel) we could approach this point from any direction, and since it's just a point when seen from every angle, there is no "beyond" (like the North Pole). This farthest "edge" of space is also the beginning of time – and therefore it is the time and place of the big bang; there is no "beyond" that edge.

Q. Did the universe always exist?

A. No. It has only existed for about 13.7 billion years.

Q: What was it like "before" the Beginning?

A. There was no "before" this event. In our oversimplified special-relativity-only model of the universe, time would have been the distance from the neck or fill stem. Since this is like a "radius" it can not assume a negative value –

assuming, that we are dealing with the actual "beginning" (instead of a previous "inside out" universe on some kind of infinite "turtle stack"). It follows that there was no "before" it in any meaningful sense. As Einstein explained, "time" itself started at the "beginning." So did "space." The universe began as a point and expanded with the spreading matter of the universe.

While our minds are all bent into pretzels, and we're thinking about strange mathematical distortions, this might be a good time to reflect on our pole vaulter: In Chapter Three, we made the five-meter pole "shorten" to a three-meter length when we stood by the barn. When we stood by the pole vaulter, we saw the barn's doors close four "light-meter" time units apart (each unit being the time it takes light to travel one meter). Using our graphic model (the tilted ruler leaning against a wall) we can get a picture of what really happened. Instead of a twelve-inch ruler, we simply lean the five-meter pole up against the wall. Instead of velocity, we mark the vertical axis with "light-meter" time units, and the horizontal axis with meters (marking how long the pole appears in the barn's frame of reference).

To an "omniscient" observer (one who fully comprehends all frames of reference) the pole doesn't really change size. It just gets "rotated" into the direction of time – so that each end exists at a different point in time (as seen when the pole vaulter observed the barn's supposedly "synchronized" clocks), and the apparent length (the "horizontal shadow") of the pole (as seen using the barn's supposedly "horizontal" ruler).

Notice that this perspective makes the three-meter "space-time distance," which we calculated, appear to be a somewhat artificial construction; the real constant is the length of the five-meter pole, and the two components of this length are its apparent physical length (its three-meter "shadow" length) and the difference in time between its two ends (four "light-meter" units). So, one effect of velocity is to rotate the two ends of a pole into two separate times; this is very similar to the kind of rotation which bends the universe into its strangely curved shape.

Our powers of observation and reason seem to have brought us a long way. Of course this is because we have received a "free ride" from the powers of observation and reason of the many great philosophers and scientists who have preceded us – and because we have probably exercised our minds harder than we are normally accustomed to doing. But we are not finished; these powers will take us further yet!

Chapter Six:
Quantum Mechanics

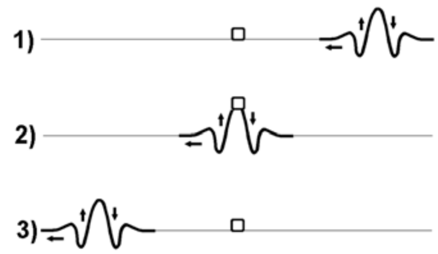
Relativity is not the only really weird thing that has been discovered about our universe. Equally strange is the discovery that all elementary particles exhibit an unpredictable wave nature. What this means may take a little bit of explaining:

An early version of "atomic" theory can be traced back to the fifth century BC. The ancient Greeks believed that everything was composed of invisibly small particles which they called "atoms" (the Greek word for “indivisible”). Complex materials were thought to be composed of combinations of these fundamental elements, which were originally presumed to be earth, water, wind, and fire.

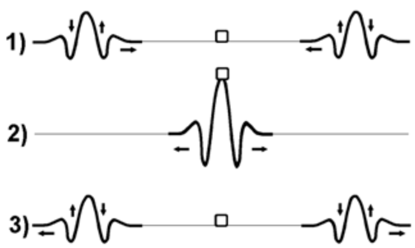
At the turn of the eighteenth century, Isaac Newton, and many of his contemporaries, still thought that light was composed of particles, much like the ancient Greeks envisioned. Mirror reflections were thought to be explained in the same manner as billiard balls bouncing off of a straight edge, and refraction (the bending of light as it passes at an angle through a denser transparent material, such as glass or water) was thought to be caused by the *speeding up* of these particles, as they entered the denser material.

By the nineteenth century, it was understood that light had a wave nature, and that refraction was better explained by light waves *slowing down* as they entered glass. James Maxwell produced a series of equations which explained electrical and magnetic fields; these equations reduced electro-magnetic light waves to a precise mathematical science, predicting how light would behave in every different medium.

Of particular interest, the wave theory of light predicted a phenomenon called diffraction. To understand diffraction, first consider a single ripple moving along on the surface of a pond (see the illustration to the right). If we float a cork on the pond's surface (illustrated by the little square), that cork will bob up and down as the ripples pass by it.

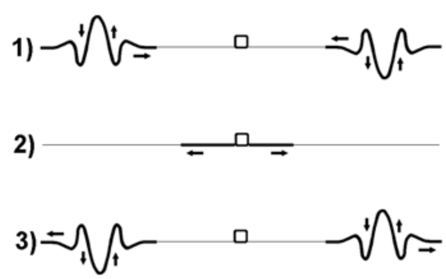


Next, consider two ripples approaching that cork from two different directions at the same time (illustrated to the left below.) Unlike particles, such as billiard balls, water waves (at least non-breaking water waves) do not collide with each other; they pass right through each other without any interaction or change in direction.



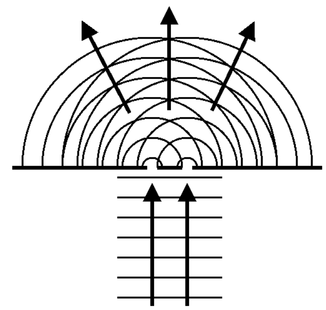
A cork floating on the pond's surface where the two ripples pass through each other, would get jostled by both ripples at the same time. If the two ripples were perfectly timed, the cork might experience twice the displacement as it would with a single ripple.

But what would happen if the two ripples were upside-down mirror images of each other? (Illustrated to the right) If one ripple pushed the cork up at exactly the same time as the other ripple pulled it down, then the two inverted actions, when added together, could, in principle, cancel each other out (at least at the exact center of the cork). The cork might hardly move at all.



Diffraction is the collection of all of the different effects which are caused by waves reinforcing and canceling each other (normally as a result of encountering various kinds of obstacles). The rainbow patterns that can be seen on music and data CDs, for example, are caused by diffraction. This is because the reflective surface of a CD is covered by a series of narrowly-spaced information tracks which reflect light differently than the spaces between those tracks do. Light waves of different colors have different wavelengths – which means they will get diffracted at different angles. You can experiment with this effect by reflecting a laser pointer off of a CD onto the ceiling (or any white screen); you should see spots from three or more different diffracted beams. This is because the light which is reflected from the different individual tracks either reinforces or cancels, depending on the angle of reflection.

Here is how it works: When a neatly lined up series of waves (like the light from a laser pointer) passes through two narrowly-spaced holes (or reflects off two narrowly-spaced CD tracks), the light may head away from each hole (or track) in any direction (see illustration to right). There are a few directions where the geometry allows the waves from both holes to combine constructively, and other directions where they cancel each other out. Different wave lengths (different colors of light) head off at different angles. The more holes (or tracks) that are reinforcing each direction, the more sharply focused the resulting beams will become. (A little laser spot is big enough to cover hundreds of tracks on a normal CD.)



A two-point interference pattern, showing how light from a single source will head off in different directions when it encounters an obstacle with two holes in it.

As weird as diffraction is, quantum mechanics (QM) is weirder still. According to QM, light has both a wave and a particle nature at the same time. Although Albert Einstein discovered this property of light, he never quite became comfortable with the consequences of his own realization.

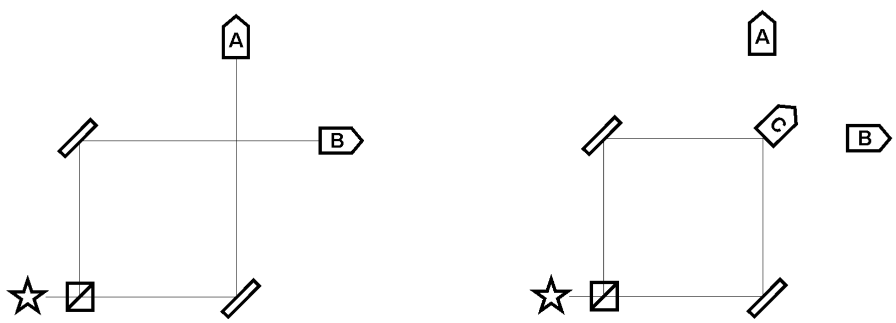
As Einstein explained in his 1905 paper, light waves come in little packets which he called “quanta” (and which we call “photons” today). Each photon is an indivisible unit (like an ancient Greek’s “atom”) and each carries an amount of energy which is proportional to its frequency (or color). Blue photons (higher frequency, shorter wavelength) have more energy than red ones (lower frequency, longer wavelength); but all photons of the same color will always carry exactly the same energy. A brighter light source simply gives off more photons than a dimmer source does.

Scientists have designed light sources which produce a single photon at a time so they can study how these little “particles” of “waves” behave. As it turns out, individual photons act just like they would in large groups. In particular, all of the phenomena involving “diffraction” work exactly the same way with each individual photon as they do with many photons. The problem with this is trying to understand how one single photon can “reinforce” or “cancel” its own light.

Imagine a laser pointer which is so dim that it only emits a single photon at a time and also a very sensitive photon detector which can detect each individual photon. (If we connected this detector to a speaker, it might tick like a Geiger counter.) If we then “bounced” this very dim beam off a CD onto a screen, a much fainter, but identically shaped, pattern of spots would be produced, as with the full-powered laser. If we put our detector next to the screen, it would "tick" when it was held where the spots would normally be, but it would never tick if placed anywhere between those spots. Furthermore, those "ticks" could never be observed at more than one of the spots at the same time. Each photon would only diffract into one of the normal directions (demonstrating that each photon does not seem to be able to split into multiple fractional parts).

This suggests a way to measure how large a photon is. Since each photon seems to be reflecting off of many of the tracks of a CD at the same time, how far apart can we place those tracks and still get diffraction effects? The answer to this question turned out to be the stuff from which scientist's nightmares are made:

In 1978 John Wheeler designed an experiment to test this; in his experiment, each single photon was sent through a beam splitter, which sent it off in two different directions (or maybe one of two different directions) – each path being redirected back to a common target area by a mirror, so that experiments could be performed on the two returning beams. What was discovered was that if two detectors are placed such that one detector observes the photons from each beam, then one (**A**) or the other (**B**) detector will "tick" – but not both. But if we test for diffraction between the two paths at the point where they passed through each other (**C**), we see a diffraction pattern in the hits at that point suggesting that the photon always took both paths. If either path is blocked, or if the diffraction test is done at **A** or **B**, then the diffraction effects completely disappear.



Wheeler's experiment is known as the "delayed choice experiment" because every photon seemed to *wait until* it got to the end of the experiment (where it could "see" how the experimenter was going to try to measure it) *before* it *chose* which path (or paths) to take through the beam splitter at the *beginning* of the experiment. This suggested that photons might be *very* large – so large that they could be everywhere at once within the experiment. To test this, the size of the experiment was increased until the beam splitter was fifty meters (164 ft.) away from the detection area. The experiment still produced exactly the same results. But at this distance, it was inconceivable that even light's speed could be sufficient to supply information from the end of the experiment back to the beginning – never mind that the light was traveling in the wrong direction.

What is really happening here? There are many theories, but no one really knows for sure. Most scientists believe that the photon's mathematical "wave function" occupies every part of every possible path – and that anything that happens to any part of the wave function affects what can or cannot happen to any other part of the wave function; they just don't understand how this can be possible. This is exactly the sort of "extraordinary evidence" which people (rightly) claim must be produced in support of "extraordinary claims," and extraordinary claims are certainly being made to explain it. (It is also another piece of our puzzle – which I promise to put together into a coherent picture before I'm finished with this book. But don't try to skip ahead; you'll never believe the solution if you haven't seen all of the puzzle's weird pieces first.)

The quantum mechanical world has produced a host of oddities: weird kinds of particles like positrons (positively charged anti-matter electrons) which turned out to be mathematically opposite to normal electrons (or, weirder yet, they could be thought of as being exactly identical to normal electrons, but traveling *backwards in time*). Similarly, photons (light particles) turned out to be mathematically identical whether they were presumed to be traveling backwards or forward in time (remember no time passes for the photon itself – it doesn't care which direction time travels). To illustrate this, consider an electron and a positron which collide, and destroy each other – giving off a photon. This turns out to be the same thing as a photon moving backwards in time which hits an electron and sends it recoiling backwards into time. These are just two very different descriptions for the same event; the mathematics is satisfied either way.

Maybe the weirdest behavior of all is that some particles seem to be constantly popping in and out of existence. For example, the electrical repulsive force between two electrons turns out to be the result of the constant emission and absorption of photons which are simply popping in and out of existence, flying between electrons, and seemingly violating the conservation laws of momentum, matter, and energy. However, all of these "violations" are within very small and mathematically predictable limits.

In case you are thinking that at least the "solid" particles (like electrons and protons) are behaving themselves properly, the *really* bad news is that they have a wave nature too – just like photons. Wheeler's experiment can be performed with a series of individual electrons, with the same result – they exhibit exactly the same weird behavior. Each electron seems to occupy a "cloud" which fills the whole experiment; yet each electron can only be detected in a single place. As with photons, actual cancellation and reinforcement patterns will occur wherever any possible paths cross.

In short, the *entire* subatomic world turns out to be a very strange and lawless place. In each case, the attendant mathematics predicts general aspects of particle behavior while leaving specific aspects unconstrained. On the average, all of the laws of physics are faithfully obeyed, but individual events appear to be somehow "above the law." Even those outcomes which are consistent with every physical conservation law seem to find ways of individual expression which are not covered by any physical law. Nature seems to be allowed to make some kind of arbitrary "choice" every time any kind of subatomic encounter occurs!

It begins to become clear that strict physical causality "leaks." Nature seems to have left a "back door" open. The question is "what" kind of phenomenon is making all of these myriad choices? They all appear to be completely random; but it still leaves researchers wondering exactly what is going on. Einstein, in particular, could not accept this random behavior; his famous and poetic reaction was, "God does not play dice."

As the evidence kept confirming the "rogue" behavior of elementary particles, physicists began to question whether "matter" had any substance at all, beyond the pure statistical mathematics of how "waves" and "particles" interact with each other. Since the behavior of particles (as much as it can be predicted at all) appears to be dependent upon mathematics alone, *there seems to be no reason to assume that there is anything present except mathematics.* Table tops still "feel" solid when physicists bang their fists on them, but those physicists are beginning to suspect that "solidity" is exclusively a mathematical effect.

It is as if "mathematical law," and not "matter," is the primordial substance from which all other things are made. It is far from certain that mathematics completely replaces "matter" at the lowest levels, but it is, at least, certain that mathematics plays some kind of dominant foundational role (in both the predictable parts, and in those stranger parts which only "obey" the statistical aspects of mathematics). *If anything else is involved at all, it is at least true that no one has any idea what it might be like.*

Of course more work is always in progress in the ongoing attempt to explain the underlying mystery. One attempt to make sense out of all the strange kinds of subatomic particles is called "string theory." String theory involves modeling all elementary particles as mathematical vibrations on ten-dimensional "strings." (One variation of the theory uses eleven-dimensional strings.) Although this attempt shows some promise of reducing the overall complexity of modeling the different kinds of bizarre particle behavior, it is not going to make any of that behavior go away.

If any version of string theory proves to be successful, it will add another six dimensions to the overall scope of "reality." String theory may provide the first peek into an "extra-dimensional" reality beyond space and time. (These "new" dimensions do not appear to be expanding like the four dimensions of time and space are.) Although it is really too early to be doing much of this sort of speculation, these new dimensions *may* turn out to be foundational to QM.

Returning to our causality diagram (at right), we probably need to replace "matter" (and its interchangeable equivalent "energy") with "quantum mechanics," which is founded, at least in part (if not purely) on mathematics. Mathematics also seems to be the underlying basis of "space" and "time" – since they also behave according to mathematical laws, and since they even comprise the very framework in which *mathematical* "particles" and "waves" must exist. We don't know exactly where to squeeze mathematics in – except that it belongs somewhere below QM and space-time. For the moment, we'll squeeze it in next to our extra-natural "creative agency" with the understanding that this may require some adjusting later.

Since mathematics seems to be the underlying basis of space time as well as QM, this raises a few interesting questions. Mathematics allows for interactions between subatomic particles to be explained as easily in reversed time as in normal forward-moving time. Does this mean time is really able to run in reverse? The same question might be asked about the universe as a whole. What if our universe were contracting instead expanding? In our simple balloon model, time was the radius of the balloon. If gravity was pulling the galaxies together, and if this radius was getting smaller, would this mean that time would be

Minds
/Psychology

Comprising /Caused by
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Brains
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Comprising /Caused by
/Explained by

Nerves
/Neurology

Comprising /Caused by
/Explained by

Living Cells
/Biology

Comprising /Caused by
/Explained by

Organic Matter
/Biochemistry

Comprising /Caused by
/Explained by

Chemicals
/Chemistry

Comprising /Caused by
/Explained by

Atoms
/Atomic Physics

Comprising /Caused by
/Explained by

Space-time and
Quantum Mechanics

Comprising /Caused by
/Explained by

Mathematics – God?
/Math? – Theology?

going backwards? Or maybe time progresses in a reversed direction in those "reversed balloons" which expand in the opposite direction from the "fill stem." We don't really have any way to test this to find out.

For another example of a strange question raised by QM, consider this: If "anything" might happen in the world of QM, then how can we be sure that only one of the many possibilities actually does happen? How do we know that reality isn't branching out into ever-multiplying paths? Is there really any way to answer this question either? This possibility is seriously suggested in Chapter Eleven of In Search of Schrödinger's Cat (Gribbin, 1984).

Fortunately, we have selected *observation* as well as reason to guide us in the present search. Whatever mysteries might underlie the seemingly reversible mathematics of time, we can still *observe* that "time" (at least in our local "balloon") simply seems to proceed from past to future. Likewise, those who might choose to argue for a wildly branching future can only do so at the cost of abandoning what we can simply *observe* to be true: it at least appears to us that "reality" only follows the single path which we observe that it follows. Those who argue against this must, at the very least, abandon the "observation" part of their dual foundation; by invoking observational authority, we are taking the scientifically "higher ground."

After all, our goal here is not to speculate about things which we cannot, even in principle, observe (imagined flying spaghetti monsters and giant pink bunnies come to mind here) – instead, we are trying to make the best sense we can out of what we actually do see. Even so, observation (much less reason) does not always protect us from the stranger elements of our universe: We are still stuck with a highly-curved space-time fabric; and now we are also stuck with a seething mass of somewhat random and purely mathematical events where we had hoped to find solid and law-abiding material particles.

Quantum mechanics is a scientific truth, but like relativity, it is something of an embarrassment to normal people. It doesn't seem to be quite what reality is "supposed" to be like. Unfortunately, ignoring it may set us up for making some otherwise avoidable mistakes. This turns out to be particularly important to us here, since we are trying to understand the bottom layer of causality. It is particularly important that we do not permit ourselves to slip into sloppy thinking concerning the layers which border the ones in which we are primarily interested (even if, in normal life, it complicates things unnecessarily to drag out the horrifying details which are present in the world of modern physics).

Chapter Seven:
What Must "God" be Like

At this point we may have enough information about the universe that we can begin to think about what might have caused it: We know that the "creation" of matter, space, and time was accomplished before any time had passed; however, the universe grew quickly as space and time stretched outward from nothing – growing as all of the matter and energy rapidly spread.

This tells us that the creative agency must be able to operate either infinitely quickly or from "outside" of time! For the same reason, we know that it must also be able to operate from "zero volume of space" or from "outside" of space. If we restrict the definition of "nature" to "all that occupies space and time" (including space and time themselves), then we must identify this agency as being, in some sense, "unnatural" or perhaps "extra-natural."

If we were sufficiently careless, we might even use the traditional term "supernatural," to describe this agency; it describes what we mean here almost perfectly. Unfortunately, that term carries a load of emotional and historical baggage which we would do well to avoid. Similarly, we should probably avoid the term "God" for the same reason. Even though it is a nearly perfect term for the creative agency, it is tainted with images of old bearded men painted on cathedral ceilings.

Both positive and negative preconceptions are crouched and ready to pounce into this argument; but we must hold them back if we are going to make our decisions using observation and reason alone. All of the traditional gods (including Allah, Krishna, Zeus, and perhaps even an imagined giant, pink, floppy-eared bunny or two) will be waiting in the wings, trying to claim credit; but unless their credentials pass a very rigorous inspection, we cannot give them serious consideration.

At the present point in our investigation, our knowledge is limited to what we have already extracted from the observations of astronomy and physics and from human reason. What this does tell us about the creative agency is that it has some kind of "extra-natural" existence – somehow it can exist and operate independently of (or using "zero" amounts of) both space and time.

This alone may be enough to eliminate some of the candidates who might like to be given credit for creating the universe: We can, at least, eliminate all giant, pink, floppy-eared bunnies – if we study their credentials with sufficient care. First, they are "giant" and therefore must exist and operate from within space – not outside of space like the real creative agency. Second, they are "pink" and therefore must reflect a particular spectrum of light. (Light, being a wave, requires both space and time.) Third, their ears "flop" and therefore change their position with time – again, requiring both space and time. At this point, we can safely declare that the creative agency is not "giant," "pink," or "floppy"; but that still doesn't tell us much about what the creative agency *is* like.

What we are looking for metaphorically "breathed fire" into the particular equations which describe this extremely weird universe, and somehow made it "go to all the bother" of existing. How much "bother" that might have been can be calculated in terms of the energy which would have been required. For example, we know that this "creative agency" had sufficient energy to bring all of the mass and energy in the entire universe into existence. Further, we know that all of this energy must have been produced in an instant! The total amount of energy involved turns out to be quite substantial.

Our sun is one of a great many stars in the universe. It alone releases an amazing amount of energy; in fact, every second it releases trillions of times as much energy as the Hiroshima bomb – and that single bomb released enough energy to power and heat a normal middle-class home for about two thousand years!

Multiply a few trillion Hiroshima bombs by 32 million (the approximate number of seconds in a year), and again by quite a few billion (for the number of years the sun is able to keep doing this), and we will get the total amount of energy which our sun is able to put out. Multiply again by the roughly 100 billion stars in our galaxy; and again by the 100 billion or so galaxies in the universe, and we begin to get an idea of how much energy might have been required to "fuel up" the universe. (All of this, taken together, works out to be roughly: 10^{42} or 1,000,000,000,000,000,000,000,000,000,000,000,000,000,000 times as much energy as one atom bomb – and remember that each one of those zeros makes the number ten times larger than the previous one did.) This is the amount of energy the creative agency had to come up with (much of it quickly took the form of unburned hydrogen) to keep all of the stars burning for billions of years – sort of like filling the gasoline tank before a very long trip. *And every bit of this energy had to be produced at the very first instant.* This is quite a significant amount of “bother.”

The size of this number can be difficult to grasp, so I will spend a little bit of time trying to explain it: Instead of using one of those atom bombs to power and heat our home for two thousand years, let’s trade the energy for its equivalent buying power. This would be enough to buy ourselves a nice home, nice cars, and have enough money left over to pay our bills for life! That’s what just one of those atom bombs would be worth in terms of its energy content. If we could control the buying power of just 10,000,000,000 of those atom bombs (ten zeros), we could grant the same favor to every man, woman, and child on the earth! With just ten of those forty-two zeros, we have already taken care of everything anyone might need on the entire earth. This involves just about as much power as any man is able to comprehend. But remember, we still have thirty-two of those zeros left, and each one of them is good for ten times as much power as the one before it was. Ten more of those zeros and every single human possesses the same level of wealth as the entire planet might have possessed with the first ten.

Forty-two zeros worth is a whole lot of energy! It also constitutes a great deal of *bother!* Even so, this is really much less energy than what was required to “wind up” the universe. We have left out all of the energy released by stars that burned out long ago and energy which will eventually be released by stars which have not yet formed. We have also left out the energy which was released by the big-bang explosion itself, and by many other processes which have used huge fractions of the universe’s total energy budget. And this was just what it would take to power our local “balloon” in our visible corner of the universe.

The bottom line is the creative agency needed to have a whole lot of energy available. It obviously had access to more energy than we can imagine! So, we know that this creative agency must be incomprehensively powerful.

Since it appears to have access to so much power, we might as well ask if it can “make a rock so big that it can't lift it.” Although this isn’t normally considered to be a “straight” question, examining it may help us get a better understanding of what kind of limitations this agency might actually have.

The simple answer would be that this agency, although extremely powerful, is not infinitely powerful. Unfortunately, at this point, we have no way of knowing whether or not the simple answer is the correct one. In fact, as we have just seen, this agency’s power reserves are difficult to comprehend! Can we really be sure there is any limit to them at all?

Before we take on a question involving numbers approaching our concept of infinity, it might be a good idea to warm up with a simple practice problem. Let's consider the ultimate glue. Here are the properties of that glue:

1) It bonds anything to anything else.
2) It forms an unbreakable bond.
3) It sets under even the most adverse conditions.
4) Unfortunately, the lid is stuck to the jar.

We can see the problem. When we try to extend all virtues to their absolute limits, we are likely to discover a problem or two which we didn't expect at first. If we really want to design the ultimate glue, we need to add a few limitations:

1) It will not bond the lid to the jar.
2) It will not bond the applicator to the target surface.

Keeping it from gluing our skin to itself, or to the jar, might also be a desirable feature – especially for those of us who are particularly clumsy – or for those of us whose noses might occasionally happen to itch.

By adding these limitations to our “perfect" glue, we have really made it better. We don't need to damage the effectiveness of the glue; we just need to prevent potential disasters from happening. So, if our agency’s powers happen to be potentially infinite, what difficulties might need to be considered? (We are assuming this agency does not want to trap itself inside the jar, so to speak.) What kind of limitations might logic impose upon it, in order to avoid possible problems?

The question of having sufficient power (the required infinite force) to lift an immovable rock hinges on the exact definitions of the terms involved. These terms have very precise definitions:

1) An irresistible force is a force which no object can resist.
2) An immovable object is an object which no force can move.

By their very definitions, these two items contradict each other. They simply cannot exist at the same time in the same universe. Obviously it is a simple contradiction to create both simultaneously. Can this agency contradict itself? Maybe not, if it happens to be bound by logic, but is it logically bound?

How might a logically unbound entity contradict itself? One way would be to "lie." Truth cannot contradict itself. Another way would be to change its position (not necessarily a "lie" – at least not until the two positions are brought into oppositional contact).

Since we already know that our agency is able to operate without any passage of time, then it is at least able to exist in an environment where change (requiring time) is impossible. Whether or not this creative agency is, metaphorically speaking, "logical," "truthful," or can be "trusted," is yet another matter; we will return to that sort of question later.

If we simply work the question backwards, and assume that this agency cannot move an immovable object, then we must conclude that it is either not infinitely powerful, or that it is, in some way, beyond "nonsense" or "deceit." Either way, this would be a limitation rather than a power.

And if we make the contrary assumption, then this agency might be logically-lawless and beyond reason. This would leave two remaining possible conclusions: physical constraint or no constraint. In later chapters, we will collect more information and will find an interesting way to narrow this down.

Next, let's examine where this creative agency might be located. It does not require any stretch of imagination to assert that this agency must have been "on location" (at least in some sense) in order to cause the universe to "pop" into existence. Since this location (containing the entire universe as it existed at that time) filled a very small (point-like) space, we can also safely assume that this agency was able to reach every "part" of this tiny space.

Further, as we have seen, any randomly selected direction we might point our finger is always aimed straight toward this event's location in space and time. This means that, wherever else this agency might also be located, it at least completely surrounds us in a shell which has a greater-than-13.7-billion-light-year (8×10^{22} mile) radius! And since this also was-and-is a single point, it would be fair to say (in poetic terms) that this agency "spans" the universe with whatever kind of "hand" it used to create it. Strangely, it is able to do this while avoiding "disqualification" from consideration by requiring "space" for existence (like a giant pink bunny would have).

One last thing: We may not be quite ready to answer the question, “Who designed God?” But, we can, at least, give a partial answer to the question “Who made God?” To be created, a thing must first not exist, then, it must exist. This requires “change” – and “change” requires time (e.g., even a photon requires time outside of its own frame of reference). Since we already know that the creative agency must be able to exist completely independently of time, we can conclude that it cannot be created – or destroyed either, for that matter (both requiring time). Its existence cannot depend upon time. It must depend exclusively on lower-level causes than time and space. This makes this agency self-existent in a sense similar to how Fred Hoyle hoped the universe might not require being created (p.38); this creative agency itself simply cannot be created.

Observation and reason force us to accept this much. Yet somehow the concept of an “uncaused creator” or of “uncaused design” still haunts us; getting any kind of “entity” or “design” at all from “nowhere” still doesn’t really feel possible (even if it had been nothing more than the universe itself which had been self-existent). How is it possible for anything to be self existent? It doesn’t do any good to produce a logical-sounding argument for an answer if that answer doesn’t really make any sense to us! We will try to get a better handle on how “self existence” works in future chapters. We will also try to address what sort of constraints (physical or logical), if any, might limit this agency.

So far, we know we have an uncreated, creative agency whose existence is independent of both space and time – in addition to being able to produce space, time, matter, and an unimaginably large amount of energy. We also know that, in some sense, it completely surrounds us at an astronomical distance – if not from more closely as well – reasonably assuming that it did not cease to exist, (problematically requiring temporal existence) at some time “after” the big bang happened.

Here we will review some of the really weird things about this universe which we have encountered in the chapters of this first section:

Chapter 1: The universe is different from what we may have expected. There really has to be some kind of “bottom turtle.” Furthermore, it really should make sense to us at some level.

Chapter 2: Time and space are not as simple as we may have supposed. Time changes its rate under different conditions.

Chapter 3: Real objects can be rotated between time and space. Time and space behave surprisingly mathematically. Time behaves as if it has “minus one” dimensions.

Chapter 4: The entire farthest edge of space would fit into a lunchbox. As we approach that far edge, space curves back into past time. Time is completely stopped (at the beginning) at that far edge (as seen from our frame of reference). The rest of space and time is “expanding” away from that point in all directions (including three dimensions of space and one of time). Since the creative agency must have been present at that time and place (a single point), and since that time and place is also presently the far edge of space, the creative agency surrounds us. *Something* metaphorically “breathes fire” into the equations and *causes* a universe for them to describe.

Chapter 5: General relativity bends time and space even more, and makes them both even harder to understand – breaking the universe into many separated pieces. The universe is huge and it has several edges, the farthest being a single point with nothing past it. The universe also had a beginning – with nothing before that time.

Chapter 6: We learn from quantum mechanics that individual particles behave in very strange ways. Their individual behaviors cannot be predicted by physical laws, and some of this behavior is simply impossible to explain physically, yet it happens – somehow. On the submicroscopic scale, it appears that individual particles may have no *physical* nature whatsoever, – but instead, may be purely mathematical constructs. On the macroscopic scale, however, all behavior is statistically predictable.

Chapter 7: Whatever agency created this universe requires no time or space in which to operate, yet it surrounds us at the farthest edge of the universe. It has access to virtually unlimited resources. We don’t know what limitations (if any) it might have.

Part Two:

The Weird Behavior of Biology, Brain, and Mind

Chapter Eight:

Machines and Minds

When I was very young, my favorite toys were always the ones that had mechanical parts that would display complex behavior. In the crib, these were originally the most complex combinations of colored beads sliding on moving sticks. When those were mastered, the next challenge became the mechanical latches that were *supposed* to keep me inside the crib. I think it took me less than a minute to disassemble the latch on the left (stage left) and disconnect that end of the front side of the crib. Then I made a surprising discovery; I had no need to repeat the routine for the latch on the right – the front of the crib swung away like a gate. It immediately occurred to me that I could climb out onto this "gate" and swing on it. Unfortunately, I soon toppled my crib and cried for my mother – not realizing she might try to put me back inside.

For the next challenge, it turned out that the playpen's weakest link was that its floor hinged upwards in two parts, so half of it could be opened up from inside, and the pen could be exited through its bottom. By this time, my mother was wise to me and was secretly watching the process from around a corner. This arms race ensued for a while, but the reward that kept me going was always a much larger world to explore.

There was a whole lot out there to investigate: I soon discovered the kitchen drawer that contained the coolest stuff. My favorite was the hand-cranked mixer with counter-rotating blades; it had a system of beveled gears that allowed it to shift between low and high speeds. Later, I remember being fascinated by the sliding-switching device on a stamped-metal, wind-up, Swiss railway toy; each car would drag the mechanism as it passed, switching the track, so that the next car to pass would always follow a different path. Later still, I was spellbound by a working take-apart clock with colored plastic gears, a pendulum, and an escapement (that's the part that connects the gears to the pendulum and makes the tick-tock sound). Yet later, it was the little hooked "propeller" that “chained” the thread in my sisters’ toy loop-stitch sewing machines.

Some devices were harder to understand than others. Some required destructive dissection under the screwdriver of the budding young scientist, but one way or another, every mechanical thing that could be explored would eventually give up its secrets. I now cringe at the memory of the horrible fates of my mother's and sisters’ sewing machines; these remained in pieces until many years later, when my skills had improved sufficiently to reassemble them. (My mother actually saved all of the little pieces for me – anticipating that day.)

But the very most fascinating thing I ever encountered was well beyond the reach of my exploratory capabilities, and it was not mechanical at all. I remember, at about the age of two or three, staring out through my own eyes, at nothing in particular, and thinking how very strange it was that I could perceive the world around me, and how strange it was that I was aware of my own existence. In this case, there was something very different about the "device" involved; it wasn't just more complex; it seemed to operate on a completely different principle.

My generation was the first to be raised on television, so, for better or worse, I spent a great deal of time glued to the couch-potato-side of a primitive, round, cathode-ray-tube display device which, if I had realized it at the time, would not have stood a chance against my screwdriver – nor I against its high voltages. (It gave up its secrets shortly *after* I learned how to control its dangers).

Eventually this electronic "window" introduced me to Walter Disney and a group of children, who were about my age, called the Mouseketeers. Among this group was a little girl named Annette, who had somehow learned the trick of flirting with the TV camera. All that I (and nearly every other little boy in the United States) understood was that she was looking right at me when she flashed that "secret" smile.

The quite-predictable result was that I was hooked, and faithfully sat in front of that old TV every time there was a chance to see Annette smile at me. This meant I also sat through numerous presentations by "honorary Mouseke-teers" who could do, or had done, something deemed sufficiently interesting to attract viewers and sell Mattel toys.

One of these "guest stars" (as they called them) was a young lad who had built a life-sized "robot." What I remember seeing was a rather primitive electromechanical toy. It looked like it was made out of painted cardboard boxes fastened together, and was controlled by a bunch of switches, but what the narrator told us was that things called "electronics" (which apparently powered that robot) had the ability to "move," "see," "hear," "feel," and even to "think."

This completely stole Annette's thunder that day. Back then, I had no concept of what a "metaphor" was; so I was certain that if I could understand what an "electronic" was, and how it worked, I could finally understand how I could look out through my eyes and see the world; maybe I could even understand why I was aware of my own existence! My life was never quite the same after that; I was on a quest.

This search led me to start collecting electronics textbooks, motors, switches, electromagnets, mechanical relays, microphones, "electric eyes" and every other kind of surplus junk that could be hooked together to perform some kind of useful function. By junior high school, my designs were starting to employ some primitive logical sequencing; my Dad noticed this and started letting me design some automated test and production devices for his engineering company. As I mentioned in Chapter One, (p.15), one of these devices went into service in a local aerospace laboratory.

By high school, I was designing very primitive electromechanical computers. These differed from the earlier designs I had used in that they could be programmed by merely loading instructions into their memory, instead of by rewiring the entire machine. This change was precipitated by an exceptional math teacher who took his class on a field trip to the local city college, where we were taught to write binary programs for a very early electronic computer. The target computer used a mechanical, rotating, magnetic drum for its main program memory (this was an early, and very expensive, substitute for the RAM used in present-day computers).

By college, I finally understood every part of the newer transistor-driven electronic computers which I was then using to do my engineering and physics assignments. I soon acquired a thousand transistors and started building one for myself. As a result of this exercise, I made the disappointing discovery that there was no soul of any kind, anywhere in those machines. As I reduced the electronic "mind" to its component parts, the imagined "ghost” inside the machine fled; there was nowhere left for it to hide – nothing left but a completely lifeless, programmed, logically-sequencing machine.

My observation wasn’t by any means unique: back in 1714, Gottfried Leibniz observed that “perception” had to be inexplicable in terms of “mechanical” processes. Leibniz invited us to imagine an enormous 1700s-styled mill designed to mimic a human brain; this mill would be fitted with various mechanisms performing the necessary complex functions. He then invited us to imagine ourselves walking through this machine, watching its parts push on each other, hunting for anything that might be responsible for “perception.” (Koch, 2012, p.26.) I merely observed that Leibniz’s observation also applied to electrical charges rapidly pushing on each other in complex ways. Once they are completely understood, electronic computers are no more mysterious than wooden gears and levers. Silicon gates and latches alone are not enough to explain sentience.

The fact that these newer, and rapidly-improving, electronic machines would eventually beat me at chess was little consolation. It became obvious that the Mickey Mouse Club robot could never be "brought to life" by mere electronics. Fortunately, understanding computers was a marketable skill, and I made my living designing embedded computer systems into many products ranging from some of the earliest optical disk players, and a high-end “imaging” sonar system, to some very low-cost computer-assisted toys for Mattel.

But returning to my childhood, when I was in about the third grade, my parents started a local science club. This meant we always had plenty of interesting scientific equipment scattered around the house. This, coupled with a remarkable collection of readily available science books and other reference materials, got me started on many unsupervised projects of questionable safety. Mixing this kind of activity in with toy trucks and Monopoly games kept science a very real part of my early world.

Part of the art of teaching science is keeping it down-to-earth and real. It looks cool to see phenolphthalein or litmus paper “magically” change color in some fancy scientific-looking glassware when a mysterious chemical called “ammonium hydroxide” is added to something containing “acetic acid,” but it becomes "real" when common household ammonia (very diluted ammonium hydroxide) and kitchen vinegar (diluted acetic acid) change the color of what my wife calls "red" cabbage (it's really purple) back and forth between pink and a bluish-green. An old mayonnaise jar works just as well as a fancy glass flask.

Similarly, a simple battery connected to a couple of old nails in a jar of water will break the water molecules apart into little bubbles of oxygen and hydrogen gas. Collecting the bubbles can be even more fun, since hydrogen is explosive. This was my introduction to chemistry. Eventually, I put together a little chemistry lab in the family workshop, but I spent most of my time messing around in the well-equipped electronics lab that was rapidly taking over my bedroom.

At that time, I still had hopes that electronics could answer my deepest questions, but I took a few chemistry classes during my first two years of college anyway – just to cover the bases. After those first two years, I dropped chemistry from my collection of "majors" to focus on physics, mathematics, electronics, and computers.

Unfortunately, this meant that I dropped chemistry before I discovered how much fun molecular biology could be. I remained blissfully ignorant of this fascinating field (involving technical complexity which left computers in the dust) until later in life – when I taught an eight-week class on the first chapter of the book of Genesis.

I had decided to turn that class into a real science class, so I was motivated to work my way through the first half of the 500 section of the local county library – to fill in some of the gaps in my understanding of science. That's when I realized I had made a mistake. It turned out there was a whole lot more to chemistry than just designing better plastics or blowing things up.

The "Holy Grail" of computer robotics is to build a machine that can make a working copy of itself. Of course I already knew that living cells had done that – and on a microscopic scale that computer engineers could only dream about. Likewise, computer designers have been talking about the day when computers would rival the human brain in creativity and problem-solving ability. Again, I already knew that human brains had been doing exactly that since long before the invention of the first bead-counting abacus. What I hadn't realized, was that *enough progress had finally been made in that field that it might actually be possible to start to figure out how it all worked!*

If there is a field of study where a person might eventually hope to understand what makes a human soul "tick," molecular biology would have to be that field. As soon as I realized what could potentially be done with biochemistry, I made a point of getting myself more familiar with that field; and after working my way through a few molecular biology textbooks, I came to the realization that scientists might be getting closer than I had expected to answering some of these difficult questions.

However (not too surprisingly, considering what we have already seen regarding relativity, cosmology, and QM), there are a few things that are just plain weird about the chemistry of life. By this time in my life, I was actually sort of expecting something like this. We will examine some of these oddities in the following chapters.

Minds

Comprising /Caused by /Explained by

Brains

Comprising /Caused by /Explained by

Nerves

Comprising /Caused by /Explained by

Living Cells

Comprising /Caused by /Explained by

Organic Matter

Comprising /Caused by /Explained by

Chemicals

Comprising /Caused by /Explained by

Atoms

Comprising /Caused by /Explained by

Space-time and Quantum Mechanics

Comprising /Caused by /Explained by

Mathematics – God?

In the first part of this book, we looked at different things that might help us get some kind of handle on what makes *existence* possible – what it is that supports that bottom turtle of our causality stack (see left column). Before we are finished with this book, we will evaluate one plausible answer to that question. My intent here is to bring together all of the strange pieces, which we have encountered in these chapters, and to assemble them into a consistent picture. The hope is that we will not only make sense out of all of those paradoxical oddities, *but that some of them will even begin to seem obvious.*

In this second part, we will examine many other strange pieces of this puzzle; *paradoxically, most of these pieces will come from the top end of the stack ("mind") instead of the bottom;* why shouldn't we understand something which is made completely from things which we now appear to understand very well? This paradoxical oddity may be yet another piece of our puzzle.

Human "minds" are sufficiently difficult to understand that it often seems like it would be easier to say that they are really just an illusion. Do we really have the ability to make freewill choices? One experiment seems to suggest that maybe we don't.

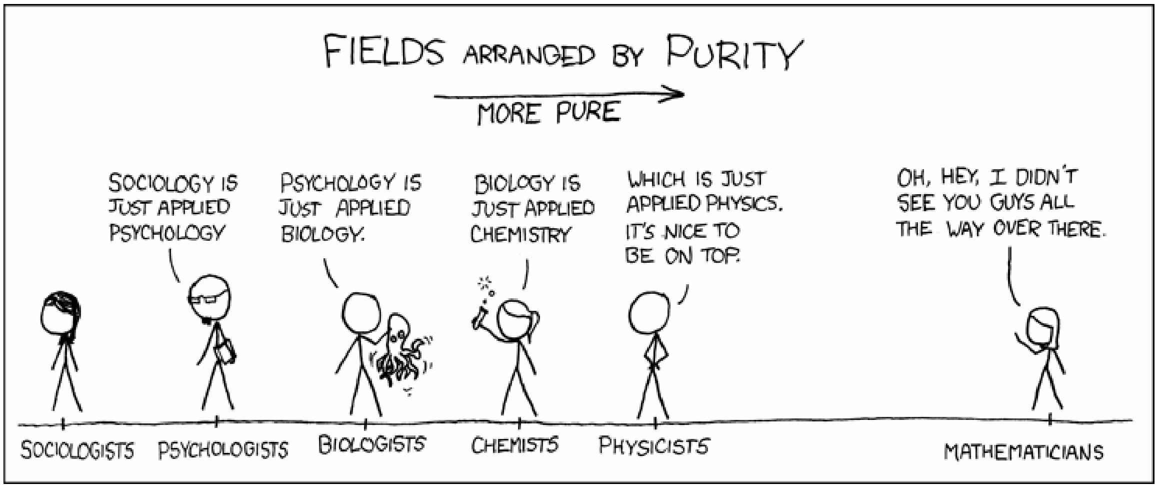
In the 1980s, neuropsychologist Benjamin Libet at the University of California in San Francisco measured activity in the brains of humans as they made decisions. What he found was that he could tell, from watching this activity, which decision his test subjects would make, a full half second or more *before* those subjects believed they actually made each decision. (The subjects would note the exact moment when they made each decision and then record that decision by pressing one of two buttons or by some similar method). Libet observed that the decision had already been made in unconscious parts of the subject's brain before the subjects reported having consciously made those decisions. He concluded that the "conscious choice" which followed the unconscious selection was illusionary. (Koch, 2012, pp.105 ff)

I was not alone in being surprised at this observation; my initial reaction was to wonder, "What would happen if the test subject was shown the same information that the tester had? (biofeedback) Would the subject be surprised to see his decision before he made it? Would he then be unable to change his mind at this point? Would his choice require more than half a second to reverse? I really wanted to try this experiment for myself.

Later I encountered a report on exactly the experiment I wanted to try. This experiment was performed by Christof Koch, and reported in his book Consciousness, Confessions of a Romantic Reductionist, c.2012, p.67. In this experiment, the subject would think about one of two images – choosing freely between the two. In this case the subject's brain's activity was detected and whichever of two images the subject had selected would be immediately displayed. As we might have expected, the test subject loved the experience; she felt that she could control the displayed picture directly with her own thoughts. No mention was made of the picture changing *before* she decided to change it, nor of anything seeming unnatural about the experiment. Further, Koch reported Libet's experiment on p.105 ff of the same book in which he reported his own experiment (Koch, 2012, p.67), without appearing to notice any inconsistency between the results of the two experiments.

There seems to be some kind of mistake being made here which isn't being noticed for some reason. I have my own opinions about what might be happening in these experiments, but for now, it is enough that we be aware of this interesting problem. Whatever turns out to be the truth about "mind," we are living in an exciting time. Discoveries are being made at an amazing rate, and the information is quickly being made available to everyone. "Mind" is presently an enigma to those who are trying to understand it, but the necessary tools are becoming available to probe its secrets. The trick is to be ready to see the truth as soon as it emerges, and to be ready for *whatever* that truth happens to be. As we have seen, again and again, the truth might not be what we were originally expecting.

There is something else here which is probably worth pointing out: With two exceptions, these causality layers are organized with the "harder" sciences (the best understood, and the least tolerant of variation from the rules) toward the bottom of the stack, and the "softer" sciences (the least understood, and the most tolerant of variation) toward the top. The two exceptions are "the creative agency" at the very bottom (which we don't understand at all), and "quantum mechanics" on the next layer up from it. QM is a strange mixture of being both very well understood (being almost like pure mathematics) and very poorly understood (also being unpredictable). For some reason (perhaps ironically), this is a curious reflection of the two entries which we have tentatively placed on the supporting layer immediately below it (*mathematics* and our *creative agency). In some ways, particle physics acts like hybrid of that pair.*



This cartoon (xkcd.com/435/ by Randall Munroe) illustrates the relative "purity" of some of the disciplines which are sequentially ordered on our causality stack (except that Munroe has chosen to put "most pure" at the "top" of his stack while we are putting it at the "bottom" of ours). This cartoon captures the weird disconnect between particle physics and pure mathematics. It also illustrates why each layer becomes less well understood as it becomes more removed from its foundation, suggesting a reason why human "minds" might be difficult to explain. However, as we will see, the weirdness of the human mind actually far exceeds what can be explained by this relatively small amount of disconnection alone.

Before we try tackling the mysterious top and bottom extremes of our causality stack, it may be helpful to take a closer look at the rest of the stack between them. Remember, the requirement is that each step in the sequence must provide enough foundational information that the next step up can, at least in principle, be fully understood. Our confidence may have taken a bit of a jolt in the previous section, but it should be smoother sailing for awhile. The next few steps harbor fewer surprises, and those remaining surprises will be less strange than those which we have already encountered before.

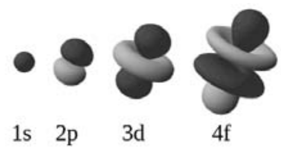
Chapter Nine:

From Quantum Mechanics to Brains

In this chapter, we will quickly survey all of the causality links between quantum mechanics and the human brain. This is a whole lot of information, so we will take it rather quickly. Fortunately, there will be very few surprises here. Almost everything in these layers will behave itself exactly as it ought to – given the weird supporting layer (QM) from which we are starting. Even the very strangest steps will not be actual violations of the basic principles of causality, although some of them might be pressing that envelope a bit – at least when viewed with some of the philosophical systems which we might be using.

As explained back in Chapter Six (quantum mechanics), a photon or an electron can be spread out over an extremely large area. Any part of that area always seems to know what happens in any other part of that area. Physicists have a few different names to describe this area; one of those names is a "probability wave cloud." The idea is that the single particle or photon exists somewhere (and everywhere) within that "cloud," but when it interacts with a different "wave cloud," that interaction will appear to happen at a single point. Different points in these wave clouds have different probabilities of being the place where this interaction might occur; hence the name: "*probability* wave cloud."

A free electron's probability wave cloud can be *many* times greater than the spacing between atoms; however, when an electron binds itself to one particular atom, its "wave function" (the mathematical name for a "probability



Brains

Comprising/Caused by /Explained by

Nerve Cells

Comprising /Caused by /Explained by

Living Cells

Comprising /Caused by /Explained by

DNA/RNA/Enzymes /Ribosomes/Etc.

Comprising /Caused by /Explained by

Sugars/Amino Acids /Nucleotides/Etc.

Comprising /Caused by /Explained by

Chemical Compounds

Comprising /Caused by /Explained by

Chemical Elements

Comprising /Caused by /Explained by

Orbital Mechanics

Comprising /Caused by /Explained by

Quantum Mechanics

wave cloud”) collapses into a much more compact configuration. While "collapsed," the electron does not abandon its wave nature; it merely "wraps" it tightly around a particular atomic nucleus.

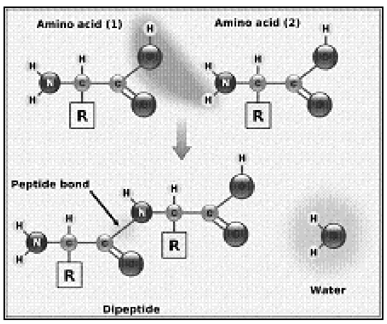
Instead of simply “orbiting” the nucleus of an atom, each electron occupies one of many oddly-shaped, but mathematically defined, probability “clouds” which surrounded the nucleus at different distances (illustrated on upper left). These differently shaped clouds are named “orbitals.” They are assigned different letters (s, p, d, and f) to identify their specific shapes. The “s” orbitals, for example, assume “spherical” configurations surrounding the nucleus at different radii; the “p” orbitals look sort of like figure eights (or maybe two tear drops with their pointed tails touching back-to-back at the nucleus). The “p” orbitals are arranged in groups which are oriented in the x, y, and z “polar” directions. The “d” and “f” orbitals have more complex shapes. There are overlapping series of each of these types of orbitals at different distances from the atomic nucleus.

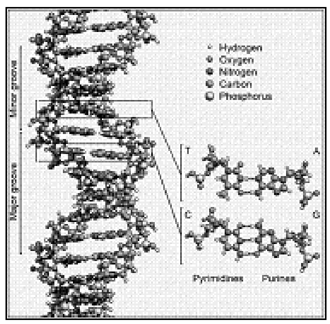
Each orbital holds a maximum of two electrons (in stable, mathematically-canceling, and non-radiating configurations); as more electrons are added to an atom, these orbitals are filled in a sequence starting closest to the nucleus (lowest potential energy first) and working outwards (to sequentially higher energies).

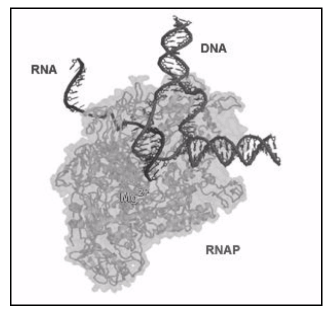
A chemical bond results from two atoms which each have a partly-filled outer orbital (each containing only one electron). When the atoms are close enough to each other, the two partly-filled orbitals combine into one single filled configuration surrounding both of the atoms – forming a bond. The strange arrangement of atoms found in the Periodic Table of the Elements (which predicts how different atoms will combine chemically) is a result of the particular mathematical configurations of these s, p, d, and f orbitals – which, in turn, are a result of the mathematics underlying particle behavior (QM).

This means that the foundation for chemistry can be understood from the principles of quantum mechanics. (See the causality diagram on the opposite page.) Likewise, chemistry and biology can be explained through a sequence of smoothly connecting steps which might look something like what this diagram shows. Carbon is the element which exhibits the most complex chemical behavior. It is the smallest atom which has four half-filled orbitals in its outer shell, allowing it to combine with other atoms in the most complex different kinds of ways. This makes it the basis of organic chemistry and the foundational element underlying life. (Second place goes to the silicon atom, which is the basis of semiconductor electronics, which, in turn, is foundational to computers.)

Carbon atoms can be joined to other carbon atoms or to different kinds of atoms to form molecules (the smallest indivisible piece of a chemical compound). These molecules can be joined together into larger molecules, which can, in turn, be joined into still larger molecules.

1. 

2. 

3. 

We start with relatively simple chemical compounds including sugars, different kinds of amino acids (top of figure 1), and nucleotides (A T G & C – lower right of figure 2). These particular compounds vary in complexity, beginning with about a dozen atoms each, and ranging up to several dozen atoms. Amino acids are little molecules that have part of an ammonia molecule at one end (NH_2 – left end in figure 1) and part of a vinegar molecule at the other end (COOH – right end in figure 1 – these three images are from Wikipedia articles).

The next level up is composed of larger combinations of these building blocks, such as DNA molecules (2. left), RNA molecules like transfer RNA (t-RNA) and messenger RNA (m-RNA), and chains of amino acids (proteins including enzymes – bottom of figure 1). Some of these amino-acid chains are extremely complex, like the enzyme RNA-polymerase (RNAP – figure 3), which acts more like a tiny CNC (computer numerical control) machine than like a mere molecule. RNAP constructs RNA, following the pattern which it reads from DNA.

There are also combinations of proteins and RNA such as ribosomes (r-RNA). A ribosome is another tiny CNC machine. Ribosomes take various amino acids, (identifying them by reading the “bar codes” on the t-RNA molecules which deliver them), and chain them together following the instructions programmed on a segment of m-RNA (the r-RNA, t-RNA, and m-RNA molecules all having been constructed by that other tiny CNC machine – the RNAP enzyme, by following instructions found in segments of the DNA molecule).

Of particular interest, ribosomes construct enzymes (including RNAP) and RNAP constructs r-RNA (the major component of the ribosomes). These two machines make parts for each other! Fortunately, they don’t have to be building each other at the same time; first one makes the other, then the other makes parts for a *copy* of the first. Once the cycle gets started, there is no causality loop. But it does leave a weird and interesting “chicken and egg” question concerning how the whole cycle originally got started. Both machines also construct other pieces of biochemical machinery, which together handle many other functions of every living cell (ATP production, DNA replication, cell structure manufacture, recycling of damaged molecular chains, photosynthesis, and a whole bunch of other complicated and important stuff).

Continuing up the chain, we can build smoothly upwards through the construction of self-replicating living cells; increasingly complex nerve cells, and combinations of nerve cells; all the way up to higher-level structures including human brains. As mentioned in the previous chapter, both the bottom and top ends of this stack are far from being well understood. At least this middle portion of it seems to flow together seamlessly – or at least with only a few relatively minor glitches and gaps in our understanding.

It may be worth emphasizing that each higher step, in this stack, rests on more than just its immediate predecessor. “Living cells” depend directly on physics as well as on chemistry. This is no problem for causality – as long as each step is completely above its supporting steps, and as long as there are no missing steps, no “loops,” no unexplained beginnings, and no infinite stacks of “turtles.”

As it is with relativity and quantum mechanics, there is still something here which seems to be a little bit weird! In this case, it’s the chicken and egg question with ribosomes and RNAP. Both make each other, but how did this originally get started? What we appear to have started with must have been something like two extremely complex Escher turtles constructing each other while they, figuratively, stood on each other’s backs. Furthermore, we also need mRNA, t-RNA, and DNA – none of which is (nor can it theoretically be) particularly simple. (I think of my mother's sewing machine when I watch a computer simulation of a "running" ribosome – except that my mom's machine was actually much simpler; it had no CNC capability). Even the DNA, which is basically inert (it does not need to *do* anything itself), must contain all of the instructions required to produce each of the other machines; in its own way, this makes it as complicated as all of the other machines put together!

The improbability of enough of this just happening to fall together in one time and place, somewhere in the universe, bothers quite a few scientists. In fact, after doing the mathematics, astronomer Fred Hoyle (the same rebel scientist whom we encountered back in Chapter Four, p.38), suggested that the probability of a random assortment of atoms falling together into the first living cell was about the same as the likelihood of a tornado passing through a junkyard producing a Boeing 747 (See NATURE, 294, 1981, 10. for the quotation). Another high-profile scientist, Nobel Prize winner Francis Crick, has seriously proposed that some of earth's life forms might have originated elsewhere in the galaxy – and were then introduced into earth's ecosystem by some alien form of "intelligent life." (Hoyle, himself, proposed some kind of silicon-based alien life.)

If anyone is interested in pursuing the question of probabilities, as they relate to the assembly of the first living cell, I recommend Robert Shapiro's book, <u>Origins, a Skeptic's Guide to the Creation of Life on Earth</u>. Although this book is probably a bit out of date by now, it does a good job of explaining the problem.

It might seem as if we have just encountered a small "herd" of causality turtles, all struggling to climb upon each other's backs. Maybe so, but life does exist, so there must be a way to get them all started together. Our goal here is not to deny that we exist, but to understand how existence is possible. Even an extremely improbable event *might* have happened once. And maybe this is another piece of the puzzle we are trying to assemble here.

At least causality itself is in no greater danger from this relatively minor problem than it already was from all of the previous problems we have explored. Original causality is greatly more difficult to explain than how preexisting atoms might have been organized into the earth's first life forms. For this relatively minor step, causality would be equally well served by any of the different possibilities which have been suggested by one scientist or another. Here are three possibilities:

1) Although the suggestion that space aliens introduced life forms into our ecosystem may sound as silly as adding another "turtle" to our stack, the idea does have something going for it: Maybe that alien life form had a simpler kind of chemistry than Earth life does; maybe it comprises exactly the right sort of

"stepping stone" to bridge the gap between "no life" and "life." (Hoyle, for example, suggested a silicon-based life form.)

2) Likewise, although the random-accident suggestion would require an extremely improbable event, perhaps a way could be suggested where a series of less-improbable stepping-stone-styled accidents could accomplish the task. Then the problem of causality could be properly answered. Shapiro, for example, has made this suggestion, and his position is a commonly held one.

3) Or, the required causality link could even be closed by a creative agency that chose to meddle with the various chemical elements. In this case, we would still need to answer the question, "Who designed God?" but that is already the question on the table – so at least this would not set us back any farther than we already are. This is also a commonly held position – in one form or another. Some suggest extremely high levels of meddling; others suggest a very small level of intervention.

In any case, one way or another, most of us are satisfied that the first living cell was able to come into existence. This is good enough for us here. All we need is 1) all of the cellular machinery necessary to replicate a cell; and 2) all of the instructions, coded on the DNA molecules, that specify how these machines are to replicate themselves. Once we are given the first living cell, we can resume working our way up the chain of causality on the way to the level of our "brains."

From this point on, the steps become relatively easy: Very small changes in the pattern of atoms in the DNA molecule can make the same cellular machinery produce different kinds of cells – or even different kinds of creatures. Nothing more than a long sequence of these steps is required to produce any kind of creature – including those having human brains.

Unfortunately, the mere mention of the term "evolution" is virtually guaranteed to alienate one half or the other of the English speaking world. (And now I have used that word!) But as with the first cell, it doesn't really matter here which side of the issue we choose to support. We might believe that space aliens engineered different types of retroviruses which caused deliberately engineered mutations (e.g. Hoyle), that random mutations, guided by survival fitness alone, provided the design (e.g. Shapiro), or even that a "creative agency" manipulated the DNA of selected creatures – modifying their descent (e.g. yours truly). But, as before, whatever we believe, we are all agreed that the task was possible. One way or another, all of life's kinds can be causally explained.

Since evolution is presently considered to be the "standard model," we will give it a little bit of time here: Evolution sketches out a plausible path whereby causality might be able to proceed, from the first living cell, to creatures as complex as humans: Given that replication is not always perfect and that "nature" itself has a ruthless way of removing "mistakes" and even inefficiencies from the gene pool (and also of favoring any accidental improvements – however rare they might be), it is not too difficult to imagine how the first living cell might, over many steps and a great deal of time, have been able to produce any creature we might happen to find alive today (or dead in the fossil record).

This explanation certainly appears to be adequate to serve whatever need causality requires – even if it is a bit oversimplified. Like relativity, quantum mechanics, and the first living cell, "evolution" involves a few strange and paradoxical elements which are often avoided in public conversation. However, they are sufficiently interesting that they are worth examining briefly. Here is the complication:

1) The mathematics of population genetics accurately predicts when, and at what rate, evolutionary change will happen. Among the important parameters is population size: It can be shown that, other things being equal, survivability improvement (the normally-featured type of evolutionary change) will happen more rapidly within larger populations than within smaller ones. We can have no argument with this; it is the result of careful reasoning and it has been tested by both laboratory-based and field-based scientific observation. (See <u>An Introduction to Population Genetics</u>, 1970, by James Crow and Motoo Kimura,)

2) The fossil record (including a huge database of myriad marine creatures) proves that "evolution" has followed the course of "punctuated equilibria" as spelled out by Stephen J. Gould: Change appears to have happened relatively rapidly, but only within very small populations, and only when one species breaks away from another. We can have no argument with this either; it is the result of careful scientific observation of the fossil record. (See <u>Evolutionary Dynamics</u>, 2003, edited by James Crutchfield and Peter Schuster, pp.66ff.)

If you are thinking that these two truths seem to contradict each other, then you probably understand what I am saying correctly. One might use this pair of facts to conclude that "descent with modification" could not possibly have been what has actually happened during the course of life's history, but that would just be a different kind of error. There is a great deal of other evidence which plays into the problem. For example, fossil taxonomy (comparative anatomy) and biochemical taxonomy (comparative biochemistry) both verify that all of life's kinds are connected by a chain of causality (normally called the "tree" of life's kinds). This confirms Darwin's "descent with modification" for the coarse structure – even if the fossil evidence simply falsifies some of the finer-grained features of that theory.

Perhaps this paradox will be resolved by future research, or perhaps it is another piece of the puzzle we are attempting to solve here. Either way, this is the evidence as we observe it; how we decide to reason this paradox out might take different forms. Like other strange things we will encounter in future chapters, this is, at least, no more perplexing than what we have already encountered in our brief studies of relativity or quantum mechanics.

Before we leave evolution, one final comment is in order: As Richard Dawkins has rightly pointed out, any "God" we might try to "invoke" would need to be at least as plausible as any series of accidents which might be required to bring evolution about naturally – or, as Hoyle or Crick might have added, as plausible as any race of intelligent and meddling space aliens might be.

Dawkins has proposed that "complexity" is the metric by which improbability is best evaluated; according to his model, any "intelligent designer" must be "simpler" than the first living cell in order to make that kind of argument plausible. Although Hoyle and Crick might have taken exception to this, here we will concede something that is effectively more than what Dawkins is requesting: We assert that any bottom "turtle" (on whatever causality stack we might propose here) must not require any kind of causal supporting infrastructure at all – and that *all* subsequent "turtles" must be *fully explained* by those below them. This is, obviously, an even more constrained criterion than the one Dawkins has proposed.

In this chapter, we have carefully avoided taking the last step from "brain" to "mind." The human mind is sufficiently complicated that it will require a few chapters, all by itself, just to survey a few of its pertinent nuances.

Chapter Ten: **The Paradox of Human Minds**

Although scientists are far from being able to understand human minds, our powers of observation and reason do fill in some fascinating details. Probably one of the most fascinating things which we are able to *observe* is that we are actually able to make “observations.” We *obviously see* that we have this ability; we can *verify* that our minds have what we call “awareness.” And we are not only aware of our surroundings, we are also self-aware (since we can *observe* our own ability to make these observations). But whether we are observing “self” or something else other than “self,” *awareness* is still a very strange phenomenon.

This *observable* fact is so amazing that many people have chosen to assert that awareness is merely “an illusion.” (We are reminded of the two contradicting experiments testing our perception of “choice” in Chapter Eight, pp.76-77.) It is so hard to understand how “perception” can arise from mere chemistry and physics that denying the phenomenon might look like the easiest path to take.

However, taking that path presents a very serious problem for us here. Since we are using *observation* and *reason* as our guides, we simply cannot deny *observation* itself. Either we must accept the fact that we are able to make valid “observations,” or we are denying one of the two pillars upon which our ability to understand anything is supported. Facing the fact that “observation” exists is more likely to lead us to the answers than “closing our eyes” will. Instead of closing our eyes, we must see where our powers of observation and reason will take us.

For that matter, reason itself is a surprising property. Why should our minds be able to distinguish truth from error? If a computer makes a mistake (other than an easily testable copying error) it will probably report that mistake as if it were the truth. Why is a human mind able to tell the difference between its own mistakes and the other conclusions it produces?

Those who study human minds often divide the mind's functionality into two separate parts: The *Conscious Mind* and the *Subconscious Mind*. Many of the subconscious functions are quite well understood; their functionality has been accurately mapped out in the human brain. In some cases, this has been done by studying people who have had local areas in their brains disabled by injury; in other cases it has been done by observing properly working brains using various kinds of electronic equipment. For anyone who is interested in more detail, I recommend <u>Neuroscience for Dummies</u>, (Amthor, 2012).

The conscious parts are still very poorly understood. For a layman's book about the attempt to understand the conscious parts of the mind, I recommend <u>Consciousness, Confessions of a Romantic Reductionist</u>, (Koch, 2012).

Here we will perform a few simple experiments to examine this division between these two parts of our minds: If we cover our *left* eye and look at the "L" below, while moving the page closer to or farther from our eye, at some distance the "R" just seems to *disappear*. (We could also cover our right eye and look at the "R.") This is because there is an area in the light-sensing area of our eye (the retina) where we don't have any light sensors (cones). Our optic nerve connects at that point. All people have "blind spots" in about the same place.

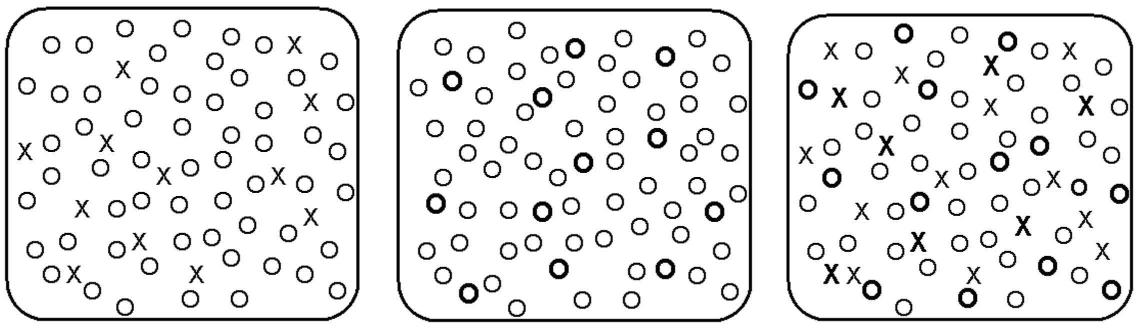
L R

If we are trying this experiment for the first time, the result is likely to surprise or even startle us. We are unaccustomed to having obvious things simply disappear from right before our eyes. Yet this is what happens.

Now, if we cover that same eye and look at different kinds of things around us, we will notice that there is usually no obvious missing spot in our vision. This is because our subconscious mind tends to fill in the missing information for us. When we look at the two large letters on this white page, our mind fills it in with white; if the page had been blue, it would have filled it in with blue. We might try looking at a brick wall or some repeating floral-patterned wallpaper to test the limits of what our subconscious is able to fill in. For example, try it with the highlighted **(L)** characters in this line; though the highlighting **(R)** disappears, we somehow get the impression that the text is still all there (although it may appear to be too indistinct to be sure).

This experiment gives our conscious mind a chance to catch (or observe) our subconscious mind in the act of performing one of its many routine tasks. Notice that this is a sharp division. No matter how hard our conscious minds might try to fill in our blind spots differently, our subconscious will always fill it the same way. It is a trivial matter for us to separate, mentally, the two parts of our minds; there is no question which part is doing which things.

The next experiment will illustrate another automatic function which our subconscious mind is always busy doing. Look at the random patterns below. How difficult is it to locate the "X"s in the left frame, or the bold "**O**"s in the middle frame? It should be pretty easy. This is because our subconscious mind locates them for us.



But how difficult is it to locate characters which are both bold and "**X**" in the frame to the right? This time, our subconscious mind will not be helping us out as much; it hasn't been "wired" (or trained, in this case) to identify these two characteristics at the same time. It's as if our conscious mind has to check each character, one at a time, in order to find them all!

Again, we are easily able to tell that our subconscious is messing around with what we might otherwise think we are simply observing. Although we cannot make our subconscious mind fill in our blind spots differently, with practice, we can actually "train" it to locate patterns or easily solve problems which it wouldn't normally be able to do – at least not without conscious help.

A beginner at chess will struggle to remember how each piece may or may not move. Finding legal moves might resemble finding the bold "**X**" characters in the right frame above; to a practiced player, legal moves might be as easy to see as the "X" characters in the left frame; but to a chess master, moves which are both legal and potentially strategic can be as obvious as those "X" characters in the left frame.

As I type this paragraph, my fingers transfer the words from my conscious mind onto the computer's screen without my having to think about which finger should press which key, or even how I should spell the words. Years ago, typing was a painful chore for me. Finding each character on the keyboard took a great deal of mental effort. Spelling was the same way. When I was a "novice" I used my conscious mind to perform every part of every task. Now that I am more like an "expert" at many of those same tasks, I can usually perform them with hardly any conscious effort at all. *(Unfortunately, because of the content of this paragraph, I really was thinking about what I was doing while I tried to write it; as a result, I very nearly forgot how to type and spell!)*

There are many experiments which we could perform to help us identify the differences between these two parts of our minds, but we are sufficiently familiar with our own minds that more evidence probably won't be necessary. Here is a guess at of how some of the functionality might be sorted:

Subconscious Features (Id):	**Conscious Features (Ego):**
Fills in blind spot	Sees filled blind spot
Fast simultaneous processing	Slow sequential processing
Expert – simply "sees" solutions	Novice – hunts for solutions
Pulls our own name out of noise	Must listen to every word
Remembers facts and conclusions	*Observes and Reasons*
Recalls memorized logical theorems	Feels axiomatic truth
Suggests alternatives	Chooses from alternatives
Provides information	Requests information
Fast learned reflex motor control	Slow conscious motor control
Rote or routine processes	Creative processes
Slave mode operation	***Master*** mode operation

Notice that, in some ways, the items in the two columns are very much like opposites! But there are other things which are *even more different than neatly-paired opposites should be*: for example, the human ego, found in the conscious functions, seems to be the first to express itself in very young children – and also the last thing to go in old age (long after memory and other automatic functions are well on there way to deterioration); it can appear to be fully functional in people who are, otherwise, extremely mentally disabled. It would seem, from this observation, that these two parts of our mind might be generated *very* differently.

There also appears to be a huge difference in how we relate to the entries in the two opposite columns. In particular, we regard parts of the left column to be mere tools, while we feel as if we live in parts of the right. If by some drug or surgical operation we could improve our capacity to remember, or increase our ability to learn, most of us would consider the treatment to be quite worthwhile – or even extremely valuable; but if a similar drug or operation were to be made available which promised to improve our ability to “make choices,” most of us would be horrified by the prospect; it crosses some non-negotiable and universally understood boundary line; it seems to threaten our very “souls” (whatever we might mean by that religious-sounding term).

This *observation*, about how we view our conscious minds, was originally made by people who lived centuries ago. The first two sentences of René Descartes’ Discourse on Method read: “Good sense is the most evenly shared thing in the world, for each of us thinks he is so well endowed with it that even those who are hardest to please in all other respects are not in the habit of wanting more. It is unlikely that everyone is mistaken in this.”

This quotation would have to be one of the silliest things ever written – if it didn’t brilliantly capture the surprising and somewhat paradoxical way in which we all perceive our own conscious minds as well as each other’s. We all seem to believe that we can reason correctly, and we all seem to attribute the same ability to others. In fact, the truth goes way past what Descartes claimed; we don’t merely believe our reasoning is adequate, many of us would be willing to use lethal force against a government surgeon who insisted that he be permitted to perform an operation on us which would “improve” our good sense! For some reason, we perceive that action to be on par with murder.

On the next page, we will modify our causality hierarchy diagram to reflect this important division, by splitting “mind” into its two *very different* conscious and subconscious components. We will also add “Logical Reasoning” to the top.

Possibly the most interesting aspect of this new “Conscious Mind” layer is the obvious paradoxical *causality* reversal between it and all of the layers below it. The small lettering (left column on the next page), which identifies the connections between all of the causality levels, reminds us that the higher layers *must always be* “caused by” the lower layers; but here we have placed the “conscious” or *“master”* functional layer of the mind *above* the “subconscious” or “slave” layer – as well as above all of the lower layers which describe muscle action, and also above those yet-lower layers which describe the effects that our chosen actions have on the physical world.

Mathematics
Logical Reasoning

Comprising /Caused by /Explained by

Conscious Mind

Comprising /Caused by /Explained by

Subconscious Mind

Comprising /Caused by /Explained by

Brains

Comprising /Caused by /Explained by

Nerves

Comprising /Caused by /Explained by

Living Cells

Comprising /Caused by /Explained by

Organic Matter

Comprising /Caused by /Explained by

Carbon Chemistry

Comprising /Caused by /Explained by

Atoms

Comprising /Caused by /Explained by

Space-time
/Quantum Mechanics

Comprising /Caused by /Explained by

Mathematics/God?

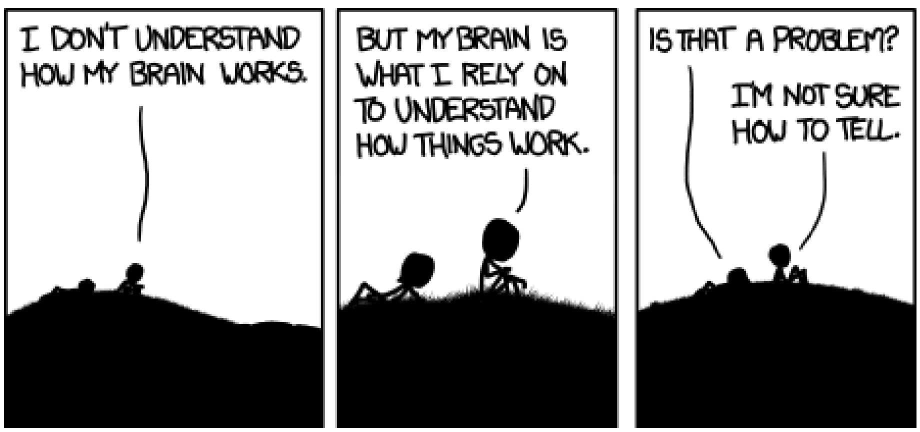
Although few people doubt that conscious mind is caused by the brain (as our causality diagram affirms), it is also true that few people doubt that conscious mind controls (causes) the actions of the rest of the body (in contradiction to what our causality diagram asserts). By choosing to swing a hammer, the conscious mind can even drive a physical nail in the physical world. By choosing not to feed the body, the conscious mind can starve and destroy itself. So, does the mind control the body or the body the mind? Or is this some kind of strange causality loop (like Escher's Hands-Drawing-Hands)?

If you are thinking that all of this is completely absurd – that there has to be some kind of mistake here – then you probably understand what I am saying. This apparent reversal of causality is enough to make some people conclude that *human choice* has to be an illusion – meaning that it is *untrue* in spite of the fact that we can *observe it for ourselves.* In fact, according to our causality diagram, *we appear to have made a valid, logical argument that our ability to choose must be an illusion!* We are reminded again of the time delay between when a human test subject's *unconscious mind* is detected making a "choice" (by the experimenter's instruments) and when that same test subject consciously "observes" that he had makes that same choice (Chapter Eight, p.76).

But if our choices are illusions, then how do we know that our conclusions are not also illusions (for similar reasons)? This is a direct challenge to our ability to reason (the sister pillar to observation – upon which pair we are jointly basing our search for truth). If an engineer uses *logical reasoning or mathematics* (presumably constructs of his mind – see the top of our causality column to the left) to design a bridge, is it also an illusion that the engineer's *reasoned choices caused* the bridge to stand – instead of collapsing? Or did something more primordial cause the engineer's choices to conform to whatever might cause the bridge to stand? If our "choices" are illusions, then why should their substance and consequences be sound and factually based? What makes that happen?

At the beginning of this chapter, we asked whether "observation" might be an illusion. We decided to presume otherwise to avoid abandoning our foundation. Here we are challenging the sister pillar. The same argument (or meta-argument) tells us we must presume that our reasoning is, in fact, valid – lest we abandon that other half of our foundation.

If we choose not to deny our only basis for sorting truth from error, then we must accept the apparent fact that we can *observe* that our choices can be converted into subsequent actions. We are also reminded of that other contradicting experiment (p.77) which seemed to suggest that perceived "choice" does, in fact, determine brain activity (in apparent violation of our causality diagram). But can we really trust our own minds? How could we ever decide? We will take a closer look at this question in Chapter Twelve; but for now we will simply stick with our reasoning as it is – for better or worse.



This cartoon xkcd.com/1163/ illustrates the paradox we have encountered.

One interesting attempt to understand how our minds work is found in Roger Penrose's book, Shadows of the Mind, (1994). Penrose has suggested that a causal foundation for some of the stranger features of "mind" might be found in a direct link to the QM causality layer; he has even gone as far as to identify neural structures which he believes may provide this link (see Penrose, 1994, pp.357-371). However, it is still fair to ask why we should expect *random-appearing* quantum behavior to be any more likely to produce the phenomena of awareness or reason than normal predictable causes might be.

Penrose and others have also attempted to understand our minds through the study of artificial intelligence (AI). Complex computer programs, attempting to simulate human thought, can give us a chance to experiment with different ways to model how human minds might work.

As we will see in the next chapter, the causality-reversal problem which we have encountered appears to be present in artificial simulations of intelligence as well as in biological minds; it turns out that it is very difficult to make a "machine" work in a way that might be considered an acceptable simulation of this weird "master" sort of property. It would seem that this little quirk has "substance" which is independent of the specific physical embodiment used – since it appears to occur in both human carbon chemistry (where we are unable to understand or explain it) and in AI silicon chemistry (where we seem to be unable to duplicate it, or even to simulate it convincingly).

Aside from this exception, and the two other *very* strange exceptions which we identified earlier (in addition to many additional very-weird oddities), causality seems to be behaving itself (mostly) as it ought. The first serious exception which we encountered was, of course, that haunting first step – from nothing to something. (In a later chapter, we will try to make some kind of sense out of this first step.) The second was the submicroscopic world of quantum mechanics where causality appeared to become a completely lost cause (except that statistical mathematical properties were still faithfully followed). And now, in this chapter, we have encountered a third serious exception – that "little" step to conscious mind (maybe just half of a step, since it involves only the "top half" of "mind"). *This mystery, surrounding human consciousness and freedom of choice, appears to represent a significant* ***gap*** *in our understanding.*

We will examine this little snag in more depth in the following chapters. This snag occurs only within a tightly localized part of our causality stack (conscious mind). It is also very near to the top of it (so it almost missed being on the stack at all). Given this, maybe it wouldn't matter if we simply ignored it for the present. We are encouraged to be patient and wait; *maybe we should have* ***faith*** *that the experts will eventually solve the remaining mystery and close this little gap* as they have closed nearly all of the others. Haven't all "gods of the gaps" eventually fallen before the advance of science and technology? It has happened many times before, and it will certainly happen yet again – and again. Or maybe this little gap is yet another important clue to solving the puzzle which we are trying to tackle here.

Chapter Eleven: **Artificial Intelligence**

From very humble beginnings, like electro-mechanical Tic Tac Toe machines, AI has made some amazing progress. This includes chess programs which are able to beat human grand masters (see Penrose, 1989, p.13), and control systems which perform tasks which are every bit as amazing as stage magic. Practical applications are seen in such diverse fields as engineering, management, production, music, art, accounting, and transportation. But in spite of all the progress which has been made, some of the expected goals are yet to be achieved. While some types of AI systems are able outdo the very best human competition, other kinds of tasks have left the AI experts completely baffled.

In the previous chapter we examined the weird nature of human minds. In that chapter, we examined the two very different major divisions of our minds: the *conscious* and *subconscious* parts.

AI experts use a slightly different division. They perceive their task to involve two major hurdles, separating it into two main parts: The first step, which they call “weak AI,” is the attempt merely to *simulate* a working human mind. This first step does not try to achieve *awareness*; it was expected to be relatively straightforward. The second step, which they call “strong AI,” is the attempt to produce a machine which is actually aware of its own existence and is able to make conscious choices. Although this too was generally expected to be achievable, at least in principle, there has been some lively debate about this – including some interesting arguments raised by both sides.

Here we will compare the division used by AI researchers to the one used to separate the conscious and subconscious functions in the human mind. From the previous chapter, we have:

Subconscious Features (Id):	**Conscious Features (Ego):**
Fills in blind spot	Sees filled blind spot
Fast simultaneous processing	Slow sequential processing
Expert – simply "sees" solutions	Novice – hunts for solutions
Pulls our own name out of noise	Must listen to every word
Remembers facts and conclusions	*Observes and Reasons*
Recalls memorized logical theorems	Feels axiomatic truth
Suggests alternatives	Chooses from alternatives
Provides information	Requests information
Fast learned reflex motor control	Slow conscious motor control
Rote or routine processes	Creative processes
Slave mode operation	***Master*** mode operation

As a first guess, it might seem that the task of "weak AI" would be to simulate the subconscious functionality; and "strong AI" would also attempt to include the conscious functionality. However, because of the slightly-different way these two terms have been defined, this is not quite how it works. In order *even to simulate* a human mind, *both columns* must be handled in a convincing manner. Even "weak AI" must somehow simulate consciousness. Many, if not all, of the *conscious* functions are presenting stubborn obstacles – even to the "weak AI" part of the project. Terms like "observes," "reasons," "feels," "chooses," and "requests" (in the "conscious" column) all imply some kind of "initiative" or "will." This is what has been so very difficult to simulate. The terms "slave" and "master" also seem to do a pretty good job of separating the areas of AI functionality into the correct "amazing success" or "abysmal failure" category.

The entire left-hand column can be simulated in ways that outdo the best humans; commercial applications have essentially granted computer users virtual superpowers. A computer-savvy grade-school child can quickly answer questions that would have stumped a pre-Internet Ph.D. The problem has been simulating the right-had column; there none of the experts have even been able to get to first base. The problem is that weird reversed-causality direction which we encountered in the previous chapter. How do you "cause" computer circuitry to "cause" right back at you (like two Escher hands) – instead of just responding?

This strange reversal keeps showing up in different ways: it seems completely backwards that “expert” level functionality (see left column, p.96) should already have been achieved, while “novice” level functionality (right column, p.96) is among the things which present unexpected problems, making it difficult for the experts even to simulate it convincingly. Why should AI experts have to fake (unnaturally) a few mathematical errors or add a few misspellings into their attempts to simulate real human behavior? It seems obvious that normal learning proceeds in the opposite direction. Mistakes come naturally; mechanical precision requires diligent practice. *Somehow the order of difficulty of those two tasks is reversed the same way causality is in humans.*

The foundational structure behind artificial intelligence may be organized something like what is shown in the column to the right. All of the steps from the mathematics and quantum mechanics of semiconductor junctions, clear up to excellent chess programs, are sufficiently-well understood, that they have become parts of low-cost consumer products.

However, to achieve even the goal of “weak AI,” the experts must find a way to deal with the “reversed-causality” problem. Originally, it was presumed that the most difficult goals of AI might turn out to be “emergent phenomena.” It was expected that if enough logic, mathematics, language, and other “slave-level” problem-solving procedures were joined together, that “master” level functionality would begin to manifest itself. Experience suggests that this might not be the case after all.

This problem might have been anticipated by studying any very young or mentally-challenged child. In these cases, all of the “master” functionality seems to be in place (children seldom seem to be particularly “challenged” in the area of “will”) – even when there is insufficient “slave” functionality present to cobble together a trivial counting mechanism.

Strong AI

Comprising /Caused by /Explained by

Weak AI

Comprising /Caused by /Explained by

Computer Software

Comprising /Caused by /Explained by

Machine States

Comprising /Caused by /Explained by

Computer Hardware

Comprising /Caused by /Explained by

CPUs/FPUs/RAM/etc.

Comprising /Caused by /Explained by

Latches/Counters/ Sequencers/etc.

Comprising /Caused by /Explained by

Logic Gates/etc.

Comprising /Caused by /Explained by

Transistors/Traces

Comprising /Caused by /Explained by

Solid State Junctions

Comprising /Caused by /Explained by

Silicon Chemistry/ (Human Designers)

For an example which is very close to me, my son Joshua was born with a third copy of his twenty-first chromosome (Down syndrome). It has always been very difficult for him to learn anything; and when he finally picks up a new skill, he always has his own style. New research is beginning to open some doors for him, but for the first decade of his life we watched him struggle with challenges which his siblings had all picked up quickly and effortlessly.

Even so, at no time did Josh ever give us any reason to suspect that he might be at all deficient in the area of awareness; in fact, he was so keenly aware of friction between his siblings that they all had to learn to get along with each other to keep him from crying. They couldn't fake it either; he would immediately see through it if they were just acting. (One of the priceless gifts that Joshua has given my family is the ability to resolve problems quickly, enabling us to concentrate on loving each other.) If conscious awareness was simply an emergent phenomenon, this level of sensitivity would have been extremely improbable; instead, it appears to function completely independently of any operational complex logical processing.

Furthermore, although many major parts of properly working human brains process large amounts of complex information, most of those areas seem to have absolutely nothing to do with awareness. For example, the cerebellum handles all of the processing required to coordinate complex motor-muscle control. Highly skilled classical pianists, coordinated visual artists, ballet dancers, and unicycle-riding jugglers, all depend on it for their abilities. If such a performer's cerebellum becomes injured, those skills will be replaced with the jerky and uncoordinated movements of a complete novice, who must think each motion through – one step at a time. But an injury which only affects the cerebellum will not affect that person's conscious abilities – not even slightly.

Back in Chapter Eight, we saw how Leibniz invited us to imagine ourselves walking through a complex 1700s-era machine, watching its parts push on each other, and hunting for anything that might be responsible for "perception." Here we will take a similar imaginary walk through a modern digital computer. We will begin with some basics about the sort of language which programmers use.

Although the world of computer logic has much in common with the kind of logic and mathematics that humans use to construct proofs, there is one very important difference: When a student of algebra studies the sequence of characters: "N = N + 1," he sees an "equation" which expresses a contradiction; (there can be no finite number "N" such that it is the same as a number which is greater than it by "one.") But a student of computer science doesn't see an "equation" at all; instead, he sees an "assignment statement" which takes whatever number has previously been assigned to "N" and assigns it a new value by adding "one" to it.

The important difference here is "time." Computer-based arithmetic and logic happen sequentially within time. But normal human symbolic logic and algebra are composed of symbols which "sit still" on the paper. To the student of algebra, both sides of the "equation" (to the right and left of the "equal" sign) have simultaneous meaning; the value of the "N" on the left must always be the same as the "N" on the right. But the student of computer science regards the "N" to the left of the equal sign to be assigned the "result" after the expression to the right is "executed." The letter "N" is used to identify the location in which to store this result. If the memory location identified by "N" had contained a "2" before execution of "N = N + 1", it would contain a "3" afterwards.

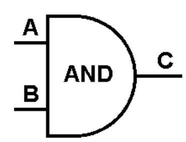
Symbolic logic and algebra seem to personify conscious human reason, but executing computer programs seem to personify the subconscious functions of the human mind. Although a stream of human consciousness occurs as a sequence of temporal events, in some ways the thoughts which human minds form are truths about a world which has no use for time. In algebra, what is true now, has always been true, and will always be true.

On the other hand, the electrical states within a computer may be identified as having "true" and "false" values, but there is never anything timeless about those states; they flip rapidly back and forth between the "true" and "false" values as the program proceeds. A variable named "C" will become "true" or "false" depending only on the nature of the last statement that happened to assign a value to it.

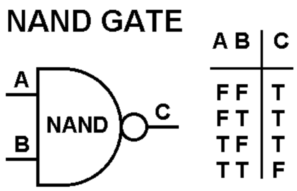
When a student of symbolic logic says that "A AND B" is "TRUE," he means that "A" is "True" and that "B" also is "True." A student of computer circuitry represents the analogous function quite differently. He uses a digital logic AND gate to represent the function. (see illustration below and right)

A digital logic gate is a simple electronic circuit which accepts one or more inputs ("A" and "B" in this case) and, shortly afterwards (maybe a billionth of a second later), generates an output ("C"). The AND gate (symbol on near right) performs the logical function: "C IF AND ONLY IF A AND B." The "truth table (see far right) shows the different states "C" will assume for all four possible combinations of "A" and "B." Output "C" has no permanent value; it changes whenever inputs "A" or "B" change states.

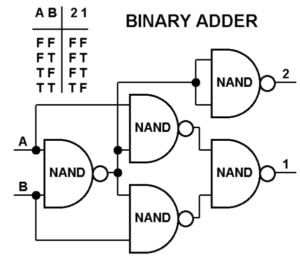
AND GATE



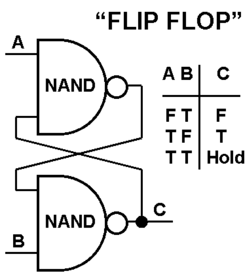
A B	C
F F	F
F T	F
T F	F
T T	T



For various reasons, a NAND gate (left) is more commonly used than an AND gate in computer design. A NAND gate simply outputs the opposite, or "inverted," state from what an AND gate outputs.



Inside a computer, digital logic gates can be connected together in different configurations to perform various functions. Pictured (right) is a simple circuit which "adds" two binary "bits" together. All of the logic in a large and complex computer system could, in principle, be constructed entirely of two-input NAND gates.



Because computer logic happens within time, "memory" circuits become necessary to hold patterns of information. A simple memory circuit, called a "flip flop" or "latch," can be constructed with two NAND gates as shown (left). Applying a "False" signal to input "A" causes output "C" to become "False;" applying a "False" to input "B" will cause "C" to become "True." If both "A" and "B" are true, then "C" will hold (or remember) its previous status.

Incidentally, a "latch" actually involves a causality loop. The output of the top gate controls one of the inputs to the bottom gate – and vise versa. When power is first applied, something called a "race condition" occurs. The two gates "race" to turn on, with the winner determining whether the output will be "true" or "false" ("1" or "0" respectively). This means that the contents of a computer's memory (often made of many latches) cannot be trusted when the computer is first turned on. Although this effect can generate indeterminate conditions in electronic devices, it does not present any kind of philosophical causality paradox (like Escher hands) because the status of each gate is completely determined by the electrical charges applied to its inputs - which are foundational to the operation of the gates; *a "gate" is really just an abstraction for what the electrons were already going to do anyway (by following the laws of physics).*

A computer can (in principle) perform any mathematical operation, and anything a computer can do can (in principle) be done with combinations of gates – so *logical operations are foundational to mathematics*. And since computers can do anything mathematical they ought to be able to simulate anything physical that happens (since physics is ultimately based on mathematics).

If our minds are also based on logical principles, then all of those principles ought to work in a computer simulation. No matter how difficult the AI problem is, it would seem that it must be theoretically possible: if necessary we should be able to simulate every single atom in a human brain (at least in principle), and from that starting point, there should be nothing left to prevent that AI model from "operating" (within the simulation) exactly like a real human brain does.

And why stop with that? Since we can use a computer to simulate any physical system, and since we can even simulate entire worlds (as we do for computer games), there should be nothing to stop us from building an entire world for these AI minds to inhabit. Furthermore, those minds ought to be able to design their own computers (within their worlds) and create other AI minds (within those simulated computers) – which, in turn, ought to be able to build their own computers, and so forth – at least until all of the available resources within the original computer (the one we supplied) are exhausted (see right column).

But what happens if we try to work our way backwards down this upward cycling causality spiral? If we were, ourselves, one of these simulated minds, we would, probably, presume we were at the very bottom of the stack; we are reminded of the movies "Matrix" and "Thirteenth Floor," where the inhabitants of this sort of artificial world were unaware of the true nature of their existence. Let's try placing ourselves in this fictional situation so we can investigate the consequences.

Since our computer's resources are finite, there cannot be infinitely many of these worlds simulated "above" us. Further, the computer immediately below us must have sufficient resources to simulate our universe (including all of the universes which we ourselves may have simulated). Likewise, the computer below that computer would have to be larger still – and so on, for as many levels as there are. If we don't want

Thrice Simulated
Atoms & World – Etc.

Comprising /Caused by
/Explained by

Twice Simulated AI
Engineers' Computer

Comprising /Caused by
/Explained by

Twice Simulated
AI Mind / Engineers

Comprising /Caused by
/Explained by

Twice Simulated
Atoms & World

Comprising /Caused by
/Explained by

Simulated AI
Engineers' Computer

Comprising /Caused by
/Explained by

Simulated AI
Mind / Engineers

Comprising /Caused by
/Explained by

Computer-Simulated
Atoms & World

Comprising /Caused by
/Explained by

Computer

Comprising /Caused by
/Explained by

Human Engineers & ...

Comprising /Caused by
/Explained by

"Real" Atoms & World

to presume that the bottom computer is infinitely large and complex, we must conclude that there are a finite number of levels below us as well as above us (we're still trying to avoid infinite "turtle stacks" here).

But how is it even possible that any such spiral could be finite? If there is going to be a beginning, at what point around this "loop" could we place it? Doesn't each turtle in our simulated world require the support of the turtle below it? Shouldn't "minds" always require "worlds" which, in turn, should always require "computers" which, in turn, should always require "minds" ... ? It would seem that somewhere around this loop there must be a turtle which is quite able to stand on something other than that next turtle down around the loop. One of those turtles must be *pretending* to need that particular kind of support.

We also need to deal with the reverse-causality problem. If a computer can be constructed entirely of gates, and if each gate's output is entirely determined by its inputs, then that computer's actions must be entirely causally determined. This would suggest that the operation of a computer program would be completely controlled by the gates within that computer; yet we consider the operations performed by that computer to be under the *control* of whatever *software* it is running (kind of like the causality-reversal problem for the mind).

If we are to believe our causality diagram, then we must conclude that it is an "illusion" that the *program* is controlling the *computer*. In actual fact, a *human programmer* designed the program, loaded the electrical pattern of logical states (1's and 0's) into the computer's memory, and caused the computer to run that pattern. The "program" itself did none of this; it is really nothing more than an abstraction. Inside the machine, it exists only as a complex pattern of logical states. Nothing happens with those logical states other than combinations of them being fed through combinations of logic gates, with the results being stored as other logical states. The gates and logical states control the machines; the term "program" is merely an abstraction detailing this fact. Ultimately, the programmer's actions supplied the control (see the causality stack, p.97).

When Leibniz walked us through his 1700's-era clockwork machine, we saw no hint of "perception" in it anywhere – just levers and gears pushing on each other. We find essentially the same thing in a computer, but with gates and latches instead of levers and gears. We might not even notice the stored program.

What might we expect to find in a real human brain? We will certainly find an extremely complex array of nerve cells "pushing" on each other, but *we should also find perception*. This seems obvious to us; we can simply *observe (perceive)* that we do. The only remaining problem is that we also have a valid *reason* to conclude that we simply can't. *So what's really happening here?*

Chapter Twelve:
Can Logic be Trusted?

It seems that we may have made a mistake somewhere; so now we must recheck our assumptions. In particular, we must take a hard look at everything which we have accepted without proof. Our powers of observation and reason certainly fit into this category. What proof do we have that they are valid tools? What happens if we turn them against themselves? Can “reason” be tested by “reason” itself? This exercise turns out to be quite interesting; it even provides another missing piece of the puzzle which we are trying to solve here.

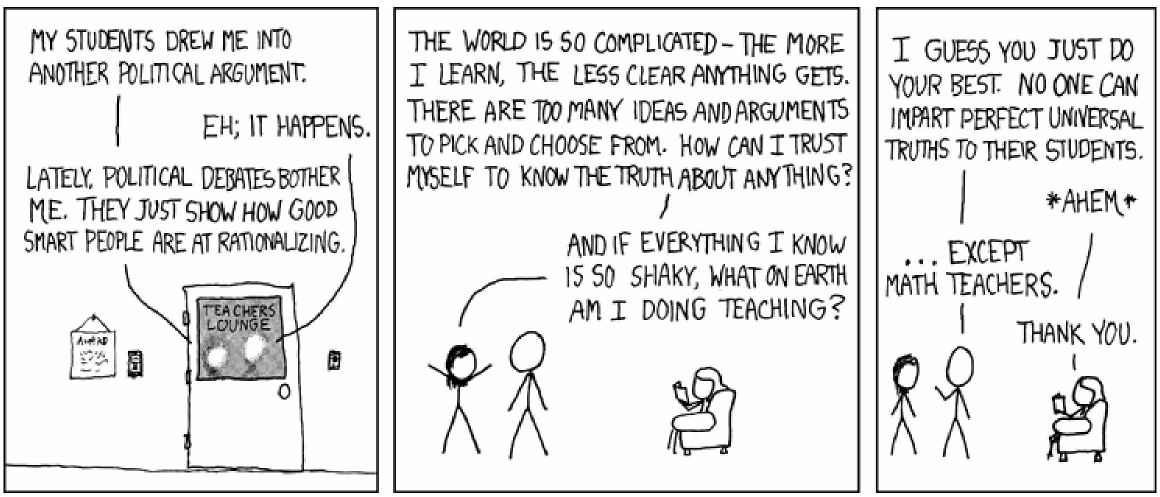
The prospect of “proving” the validity of logic itself is problematic. If we were to construct a “logical” proof, it would have to be a “circular” proof – since it would depend on the methodology of “logic” being correct in the first place. If we attempt any other kind of argument, it would have to be an “illogical” argument (or at the very best, an “a-logical” argument). If you are thinking this can’t possibly be true, then you probably understand what I am saying. Logic itself cannot, even in principle, have a valid non-circular logical foundation.

As “flimsy” as logic’s foundation may appear to be, logic still has a lot going for it. For one thing, most of us seem to understand the rules of logic in exactly the same way. For another thing, it enables us to do great things – like to design sophisticated (and very useful) computer systems, or to design bridges that don’t collapse.

When we chose “observation and reason” to guide our search, it was understood that we were taking the “high road” (reason being virtually synonymous with logic), and that we can expect to have as good a chance of finding the truth as anyone can. In fact, most people seem to feel that logic has an almost primordial existence; we seem to be convinced that somehow logic would remain – even if our minds and the rest of the universe were to be removed. *Logic seems to be "self-existent" in this sense.*

Since we are looking for a bottom turtle here, we should probably pay close attention to anything that feels like it might be able to stand all by itself. *This suggests that logic, itself, is likely to become a very important part of the causality puzzle we are trying to put together here.*

In the previous chapter, we saw how computer logic was foundational to all mathematical operations which could be performed on a computer (p.100). It has also been formally demonstrated how the human form of mathematics can be derived from a small collection of logical rules and axioms. (See Principia Mathematica P.M., by Bertrand Russell and Alfred North Whitehead, 1910-1913). They specifically derived addition and multiplication for natural numbers, but the remainder of arithmetic follows logically from this start.



When we argue, we may all be coming from different positions and assuming different truths as being axiomatic; yet we all seem to appeal to the same sense of logic to make our case. What is it about logic and mathematics that makes them so convincing? (The above xkcd.com/263/ cartoon by Randall Munroe illustrates how very differently mathematical arguments are regarded.) Why do we all regard reasoning itself to be so completely reliable? (We are reminded of Descartes' comment on how evenly shared good sense is – page 91).

Although we are still a long way from understanding how the conscious part of a human mind works, logic seems to be an inseparable part of it. The “minds” of sharks, turkeys, and spiders don’t appear to have much use for logic; instead they all appear to be hardwired to do what they do – running on something more often described as “instinct.” Humans, on the other hand, all seem to embrace logic – even when we cannot be made to agree on anything else.

Testing *reason* itself might turn out to be a difficult task. As George Orwell illustrated in his 1949 book, titled "1984," the way words are defined can play tricks with our thoughts – and even reshape them to some extent. In particular, a single word with two similar, but significantly different, definitions can present considerable confusion. This can even cause us to muddle our logical distinctions. As C. S. Lewis explained in his book, Miracles (1947), one such word is our English word "because" which plays a key role in our concept of how logic itself works. This is an important word for us to understand, because it bears heavily on two of the main ideas we are trying to sort out here: *causality* and *reason*.

As Lewis explained, the word "because" has two distinct meanings which are sufficiently similar that we often forget that they are different at all. The first meaning of the word "because" (hereafter "because$_{[CAUSE]}$") is the "cause and effect" sense of the word. When I say, "I am healthy because$_{[CAUSE]}$ the food I eat is nutritious," I mean that the nutritious food which I eat is a cause which produces the effect that I am healthy. If I had eaten poison instead, it would have caused me to be unhealthy. *We use this definition to describe the order of levels on our causality stack.*

The second meaning of "because" (hereafter "because$_{[GROUNDS]}$") is the "grounds to conclude" sense of the word. When I say, "I know the food I eat is nutritious because$_{[GROUNDS]}$ I am healthy," I mean that the fact that I am healthy after eating that food, provides the grounds for me to conclude that the food must have been good for me and not poisonous. If I were now suffering severe gastric pains, it might provide grounds to assume otherwise. *We use this definition to describe our use of observation and reason.*

Notice that my good health does not cause (because$_{[CAUSE]}$) the food I have eaten to be nutritious; nor is the fact that I am now eating nutritious food necessarily grounds for concluding (because$_{[GROUNDS]}$) that I am now (or even ever will become) healthy. The two ideas are quite different. In fact, as will be shown, there is one critical sense in which these two meanings are essentially opposites (like "give" and "take"); yet they are tangled together in our minds under the single word "because" (this time I mean the English word "because" – hereafter "because$_{[WORD]}$").

If the concepts "give" and "take" had been combined under the single word "transfer," moral ideas like "donating" and "stealing" might have required lengthy explanations to sort out. The following lengthy explanation is necessary because$_{[CAUSE]}$ because$_{[WORD]}$ has two easily confused meanings.

Let us assume that a man named Sam has told us that high-fiber food is good for us. Our task is to decide whether or not to believe him. If we are gullible we might decide to believe Sam simply because$_{[CAUSE]}$ he told us high-fiber food is good. If Sam is a respected friend we might believe him even if we aren't particularly gullible because$_{[GROUNDS]}$ he had earned our trust by his actions in the past. If Sam is also an expert in nutrition, he might earn more credibility in our minds because$_{[GROUNDS]}$ of this.

Next, let us assume that a chain of events happens which erodes our trust in Sam: First we learn that his brother Joe sells high-fiber food. We realize that this might influence Sam. He might support high-fiber food because$_{[CAUSE]}$ his family loyalty tends to influence him. We should be less trusting in Sam's advice because$_{[GROUNDS]}$ of this.

Next we learn that Sam's brother pays him to tell us high-fiber food is good. Sam only says it because$_{[CAUSE]}$ he is getting paid to. Now we know that Sam is influenced and we should be even less trusting because$_{[GROUNDS]}$ of this. Or maybe we learn that Sam is just a robot constructed by Joe. Sam tells us high fiber food is good because$_{[CAUSE]}$ that is how Joe built him. Now we cannot trust Sam *at all* because$_{[GROUNDS]}$ Sam's advice is *completely* mechanically caused (in the because$_{[CAUSE]}$ sense). Instead we would have to decide whether or not to trust Joe; or, better yet, we could do our own research and come to our own conclusions.

But there is one last twist to this story: We go in for our regular weekly checkup at our neurologist who shows us an x-ray of our brains. There, to our chagrin, where we expected to see our brains, we behold the image of a small computer designed by Joe. At this point we cannot even trust our own thoughts. Why? Because$_{[GROUNDS]}$ they are caused (because$_{[CAUSE]}$) by a source which we have not logically evaluated; our thoughts are what they are simply because$_{[CAUSE]}$ that's how Joe programmed them. Can we ever trust Joe? There is no way we could ever decide; our own thoughts could not be trusted. We could not even perform our own research on high-fiber food; there would be no way we could properly trust our own evaluation of our own research (we are reminded of Munroe's xkcd.com/1163/ cartoon on p.93).

In this story, the more causality (because$_{[CAUSE]}$) encroached upon the process of our logic and reasoning, the less reason we had to trust the basis for that reasoning (because$_{[GROUNDS]}$). When causality finally became *absolute*, our grounds for believing our conclusions *disappeared completely*. This is the sense in which because$_{[CAUSE]}$ and because$_{[GROUNDS]}$ are opposites. They are mutually exclusive in our thought processes. When a person has a mechanical reason to say something (for example, because$_{[CAUSE]}$ they are prejudiced, or because$_{[CAUSE]}$ they are drunk, etc.) we believe we are justified in disregarding any "authority" their opinions might otherwise have carried.

Although this story about Sam and Joe was fictional, it still raises an important question about our own brains. How much do we know about how they were "designed”? Whether it was by evolution, intelligent design, or perhaps by some combination of both, the question is still somewhat disturbing; how much can we "know" about our own "knowledge”? If our brains are defective in some critical sense, will that defect protect itself from our ever discovering it?

What is particularly frightening here is where “*Logical Reasoning*” fits on our causality stack: On page 92 we put it on the top of our stack, right underneath “*Mathematics*,” because they were both obviously products of (caused by) our conscious minds; and since our conscious minds are also products of a chain of other causes, we appear to have no way to assure ourselves that our ability to reason has any value.

We are reminded of our failed attempt to construct a logical proof that logic itself is valid, but this time we have examined the problem from a different perspective and have gathered a few more details: In particular, the source for the design of our minds has become a pivotal issue. At this point we could make a somewhat arbitrary decision:

A) We can choose to trust our own thoughts.

OR

B) We can choose *not* to trust our own thoughts.

Or, we could use a meta-argument and work the problem backwards – like we did in Chapter Ten (p.93). That time we just pushed ahead and pragmatically presumed that our powers of observation were working correctly – since the opposite conclusion would mean we would be leaving the logical high road.

But at this point, we seem to have been knocked off of that high road in any case. We can no longer merely presume that our reasoning faculties are intact, because$_{[GROUNDS]}$ we have just used those faculties to expose a reason to doubt them. We can still look at the consequences of the two choices and use those consequences to help us decide, but this time there may be some serious consequences attached to our choice; it may require us to reorganize our causality diagram in a very strange and unexpected manner.

If we were to select the "B" option, then we might just as well stop right here. Under that choice, there can be no rational approach to this problem – or to any other problem. That would be the end of this book and the end of all other logical arguments as well; in fact, it would have to be the end of putting our trust in our powers of *observation* and *reason*, particularly in reason. In fact, there would be no remaining alternative other than complete *nihilism*.

But if we continue with the argument, as we presently seem to be doing, it is because we have opted to choose "A," at least provisionally. At any time, we may switch back to "B" and be done with this entire discussion (and with all others as well). However, as long as we proceed, we are doing so on the provisional assumption that our thoughts have meaning – and that we actually have the ability to evaluate the grounds upon which we base our conclusions.

There are a few very interesting, and seemingly paradoxical, consequences of this choice which we will need to deal with later; first, we will merely follow the argument to wherever it takes us: One consequence is that our *ability to choose must be completely free-will*. If our “choice” is merely the end result of a chain of causes ($\text{because}_{[\text{CAUSE}]}$), then we can’t trust it any more than we would be able to trust any other "caused" decision. As long as we choose to follow path "A," we must accept the implied consequence that real “choice” must exist at some level (as we seem to *observe* that it does). *We* ***must*** *conclude that the apparent “causality reversal” we encountered in Chapter Ten (page 91) is actually real.* Somehow, we will need to figure out how this can be possible.

The question of the existence of “free will” is certainly a very controversial one. Oddly, most of those who consider “free will” to be merely an illusion also base their conclusions on their powers of observation and reason. But as we have just seen, denying “uncaused” human choices carries the consequence of also denying the grounds for belief in the validity of human *reason* – it’s just like selecting the “B” path. (As promised, we will return to these paradoxical elements. The result of this “paradox” has elements which are very strange; in fact, this time they might turn out to be every bit as strange as some of the concepts we encountered with relativity or quantum mechanics.)

None of this would bother us if choosing logic hadn’t also forced us to abandon strict causality. But it did. Causality simply cannot be the basis for human reason. Human reasoning must, in some way, transcend that chain – and break free. Unfortunately, breaking free from our foundation of causality appears to destroy everything we have been trying to put together regarding our causality stack. Maybe there is still some way that valid grounds for belief can be achieved, even in a world driven by causality.

Some of the more productive avenues which have been explored by AI researchers involve random numbers. Normally these AI programs use “pseudo-random sequences” instead of real “random numbers.” These sequences appear to be completely random, but they will eventually repeat in a loop (which may take centuries). Since everything a properly working computer does is ultimately “caused,” this is the easiest (and cheapest) way to simulate randomness.

These AI programs first make many “random” choices (based on “random” numbers), then they carefully evaluate each choice, using some logical test to see how suitable each possibility really is. The program finally goes with whichever possibility did best on whatever test it used. In this way, computer programs can be made to come up with some creative-appearing solutions to various problems. If enough random choices are evaluated, these “creative” solutions can approach a quality level which is nearly as good as the logical test by which they are sorted.

This sounds very much like biological “evolution” where randomly generated mutations modify the DNA in different individuals; then survival and reproductive fitness evaluates each individual. Only those who pass that test remain to repopulate the next generation. This certainly sounds as if it might have great potential to produce various “creatively selected” designs for different creatures which are still well optimized.

Unfortunately, in that particular case, the selection criterion is not logical validity but survival and reproductive fitness. When we examine our world, we see that it is populated with myriads of different creatures which all appear to be very well adapted for survival and reproduction. These creatures include: cockroaches, lobsters, dandelions, molds, cold viruses, mushrooms, pine trees, hippopotamuses, sparrows, snakes, snails, puppy dogs, scorpions, sea urchins, lions, tigers, and bears. All of these are “miracles of design.” But, as we might have expected, none of them have much use for logical validity.

In fact, if we were to tally all of the living species on the earth, “ability to evaluate logical validity” would make an extremely poor showing. It would be generous to allow that one species in a thousand has *any* significant philosophical capability. Apart from humans, it doesn’t get any better than chimpanzees or dolphins, and most of us aren't ready to let either of those groups start making our decisions for us. For example, we might not trust them to weigh the difference between our life’s savings and a banana or a mackerel correctly. Even among humans, most of us seem to do at least as well (in regard to survival fitness and attracting of spouses) with physical exercise, grooming, or even basic hygiene as we do with a Ph.D. in philosophy or symbolic logic.

Yet, for some reason, humans do have logical reasoning capabilities. It is tempting to use this as "evidence" that evolution was able "to deliver the goods" in this one case (even if in this one case alone) and then use this to justify our belief in our own reasoning having a solid foundation. This is, of course, a circular argument. It starts with the assumption that our logical reasoning capabilities do have some kind of valid foundation (justifying the argument); then it pretends to reach that as a conclusion. Mushrooms would be equally justified in concluding the same about their own reasoning powers.

Evolution does not appear to have much, if any, interest in making us logical. At the very best, we must conclude that the odds are heavily stacked against it. It is more likely to have made us believe that anything we might say to save our lives is "right" than making us believe that "the truth" might be, in some way, more important than our own lives – or even than the survival of our entire species – or of biological life itself.

Contrarily, evolution has a clear vested interest in encouraging us to be good liars. Whenever we must choose between the lie that might save our lives, and the truth which might end it, survival fitness has no interest whatsoever in reminding us about any logical or moral errors; instead, it would be better served by hiding that information from us. Yet we all know what our minds actually do.

Evolution has no obvious incentive to encourage either logical or mathematical understanding, yet somehow, both exist in human minds. If evolution did produce our logical minds, it was, at least, not in any way an inevitable result; at best it would have been an accident. More probably, logic is simply contrary to evolution's goals. Evolution does not appear to be a very safe place to ground our trust.

So, unfortunately, we still seem to be stuck with the need to break free from our foundation of causality – or even to reverse its direction somehow. Unfortunately, this leaves us with a whole chain of unanswered questions: How can we logically build from what merely "is" to what "ought to be?" How can we construct "awareness" or "free will" from mere atoms? Who or what designed our brains, our minds, or even "logic" itself? And, how can we really ever trust our own thoughts? These are all fair questions, and, however it might appear, we are actually getting closer to what I believe to be the answers.

Chapter Thirteen:
The Weird Nature of Morality

As we saw back in Chapter Ten, Descartes has pointed out that we all believe quite firmly in our own "good sense." In a similar way, we all believe firmly in our own sense of moral right and wrong. Further, most of us tend to see morality pretty much the same way – just like we see logic.

In public, an existentialist philosopher may assert that there is no such thing as morality, claiming that the moral terms "right" and "wrong" have no absolute meanings. In private, that same philosopher will probably confess to us that he is firmly convinced that he *should not* be assaulted by those with whom he disagrees. If pressed to defend his "irrational lapse" into morality, our philosopher may claim that "morality" is an illusion which has been bread into our ancestors by the survival advantage which it confers to us. This appears to be a reasonable explanation; but does it really square with the evidence?

Professor J.S.B. Haldane, who originally worked out the mathematics underlying Darwin's theory of evolution, once calculated that a man might be willing to die for two brothers, four nephews, or eight cousins; this is what the mathematics of preserving our own genes might seem to suggest. But what real people actually do can sometimes be a bit of a surprise. Their moral instincts seldom follow the mathematics.

What is it that makes a person feel that it is somehow wrong to tell a "lie," even in those situations where the lie would obviously be beneficial to his personal survival, or where it would obviously contribute to the multiplication of his descendants? We can *observe* that we possess this weird kind of morality, but why is it so very different from what it seems that it ought to be?

I have a friend named Stephen who used to live for himself and cause trouble for everyone else. Over the years, I have had the privilege of being his friend and watching his life change. He eventually found himself rescuing starving disabled children from death as his full-time calling. It turns out that there are still cruel and backward corners of our planet where disabled children are left in gutters to die; Steve eventually left his comfortable middle class life to be close to those gutters. Along the way, he spent some time preaching in men's correctional facilities to some of the hardest men you wouldn't ever want to encounter outside of a prison. Here is one of the stories that he used to tell to those tough cases – to show them the difference between what they had always claimed about themselves, and who they really were inside:

> "Imagine that you are sitting on the most beautiful beach in the world. The weather is absolutely perfect, with just the right amount of breeze to make you feel more alive than you have ever felt before. The sun is shining in a way that makes you think you have never really seen the color blue before.
>
> "But, better than all of this, right next to you, on your beach blanket, is the most beautiful woman you have ever imagined. This is the girl of your dreams. You didn't even think it was possible to put all of the qualities you were looking for into the same package, but here she is. Her yacht is anchored about a mile offshore, and an island that you can see out on the horizon is one of her many substantial properties. No one she cares about will ever have to work for a living.
>
> "But it gets better: She is completely in love with you. There is nothing she would rather do than be your servant, and she has just made it perfectly clear that there are absolutely no limits to her willingness and abilities to do just that. Providing a harem for you is at the top of her to-do list. She has just announced her intentions and has moved over and gently taken your hand in hers. You look into her eyes and ...
>
> "The story suddenly darkens. You hear a cry for help from out in the surf. It is a young child who is in trouble and will drown if you don't rescue him right now. But as you begin to rise, the grasp on you hand starts to tighten.
>
> "'Please don't leave me,' the girl sincerely pleads. You try to pull away but she wraps her body tightly around your arm. 'I can't take

> rejection,' she continues. 'If you leave me now, I won't be here when you get back.' You know she means it."

So what do these “hardened” men decide? What seems strange about this situation is how easy it is for them to make the choice. Even when this question is presented to men who have already murdered their fellow humans for little more than the sake of their personal pride, the answer is always the same. The unanimous consensus was probably best summed up by one colorful response: "You slug the bitch and save the kid."

But why is *this decision* the universal human response? Why do real people actually find themselves choosing the life of one total stranger over as many of their own potential offspring as they could hope to produce in a lifetime? Why is morality so very different from what materialistic mathematics predicts it ought to be? And why does the term “ought” have any meaning at all? Never mind that it carries an imperative that easily outweighs an enormous Darwinian multiplication of *our own* genes in future generations.

The Golden Rule states: “Do unto others as you would have them do unto you." It is generally regarded to be the best summary of what morality requires. It was taught by Kung Fu Tzu (in the Sayings of Confucius 5:12), the Buddha (in the Dhammapada #129), Jesus (in Matthew 7:12, and Luke 6:31), and by many others. This Rule is not unique to any particular culture or religion; it is something which *everyone* seems to understand. Further, it presents a fascinating exception to what is predicted by the theoretical basis for naturalistic evolution – an exception which is observationally verifiable in minds as different from our own as those of hardened criminals.

In what kind of world is our protection of a total stranger (or even of a Darwinian competitor) more important than all of the personal wealth we can imagine? One possible answer comes to mind: We have probably all immersed ourselves in just such a world – in the form of the child’s game of Monopoly.

Monopoly was designed to be very much like real life, making it an excellent metaphor. While we are playing (more as children than as adults) we become immersed in its microcosm; the acquisition of “money” (and the “property” which it can purchase) takes on a virtual kind of reality that can become every bit as “real” to our emotions as physical, real-world, property is. When we are “cheated” out of “Boardwalk” or “Park Place,” we feel that we have been cheated in reality. Real tempers can flare.

The irony is that, in the game, nothing is real except small rectangles of printed paper – and the players don't even get to keep those; they must all be returned to the box when the game is over. Even so, the real-life friendships between participants can be either made or broken during the interaction.

Our parents, understanding this as they watched us play, were more concerned about whether or not we hit our best friend, or our little sister, than they were with whether or not we "took possession of Boardwalk" or who "got to be the race car." They understood that the game was just a game, but that hitting our friend or little sister was real; and that the memory of that attack would stay with everyone for life.

In the game of Monopoly, it is obvious that our concern for the safety of each of our fellow participants (even for a "competitor") ought to be viewed as being more valuable than the sum total of the game's "wealth" (perhaps one hour's rental on the cardboard and plastic from which the game's components are made). In the imagined situation with the drowning child (where we are trying to play by the rules of real life instead of the rules of a game), we saw that we still weigh the safety of a stranger to be greater than the sum of all acquirable wealth; but how is this possible?

If this sounds to you like just about the exact opposite of what we might reasonably expect from random mutations, coupled with survival pressure, then you probably understand what I am saying here correctly. This is another very weird piece of our puzzle.

The wealth of Monopoly is fictional, while real life provides real wealth – at least for as long as we are able to hold onto it; but even if we were to play Monopoly with real dollars, it wouldn't make any difference. When the game ends, all of the "wealth" goes back into the box. This suggests an interesting parallel between Monopoly and real life: In real life, death ends the game.

Some of us leave it earlier than others. My first child only made it through the first three months of my wife's pregnancy before the game ended. One of my aunt's grandsons lasted for about ten years before her car was T-boned by a pickup truck (she was transporting him). My aunt stayed in the game for just a few more days after that; but, eventually, we all "stop playing." When this happens, any "wealth" goes back in the box – figuratively speaking.

This may be why we feel more concern for the victims than we might for virtually *any* personal goal anyone involved might have put ahead of the safety of others. Our built-in sense of moral truth seems to be telling us that "real life" and the game of Monopoly *ought* both to be played by the same rules.

The things we do to others certainly carry moral consequences, but shouldn't those consequences exist only as long as all involved parties remain alive? Let's try putting this into historical perspective and see what happens:

An archeologist might conclude that the ten-thousand-year-old remains of a young woman belonged to the victim of an ancient homicide, but at our present point in time, the observation might seem to be more of a technical curiosity than something to get upset about. Likewise, within a few centuries, my cousin, my aunt's sister (my mother), I myself, and anyone else who had any connection to this incident will be dead and gone. Game over; pieces back in the box.

At that point in time, it might seem like no real or perceived wrong done to us should matter to anyone. For some reason, our sense of morality answers differently: It tells us that any wrong done to another somehow outlives the deaths of all participants – and that, by comparison, life's goals have worth comparable to the plastic and printed paper in a Monopoly game.

I lost my Dad a few years back. I had no idea how dependent I was on him until after he was gone. For years one problem or another would come up and I'd think to myself, "I know how to solve that problem; I'll just ask my ..." and then I'd remember. I'd like to say I never lied to my Dad. I can't say that because it wouldn't be true; and the guilt didn't stop after he died – if anything, it got worse. I was young; but even that doesn't feel like a good enough excuse.

I would like to tell you I never hit my little sister over anything as childish as a game of Monopoly; that wouldn't be true either. Furthermore, my sense of morality assures me that the wrong done will not just remain for the rest of our lives; it will still be wrong after my sister and I are both dead. We may even believe that the murdered "artifact" in the archeologist's dig deserved (and maybe still deserves) justice. What makes us feel this way about morality?

I started life at a very young age; later I became a parent; later still, a grandparent (eleven grandkids at last count). I'd like to say none of them have ever hit each other; unfortunately, that wouldn't be the truth. They are still young; it is probable that each of them will eventually become an adult. Like me, they will learn about guilt and their sense of morality the hard way – by living with the consequences of their actions – judging those actions with the same moral and logical standards with which we are all born. As they age, they will feel the ever increasing weight of their moral shortcomings.

In Chapter Eleven (page 99), when we examined human minds, we noticed that the human kind of mathematics and logic had a "timeless" nature to them. Here we have observed that morality also seems to have a "timeless" quality. This tends to confirm our suspicion that morality might be in a category very similar to math and logic. Another link can be seen in our observation that we generally use *logic* to defend the *morality* of our actions, thereby taking the moral high ground. For contrast, the minds of sharks, turkeys, lobsters and spiders don't appear to have any more use for morality than they do for logic – not having any *logical* basis for sorting *moral* high ground from low ground. Why are logic and morality, together, so important to us humans? This tightening connection between logic and morality may be another odd piece of our puzzle.

And while we're getting philosophical about morality, why is there any such thing as 'morality" at all? How is it that we are able to build logically (or "mechanically") from what merely "is" to what "ought" to be? And even if we could establish any such causal link, then in what *different* way could we ever get from what just as surely "is" to what actually *shouldn't* be? What kind of world is this where we each know what is "right" but still do what is "wrong"? Why do we all think we have a "right" to expect morality from others, when we fail so miserably at delivering it to others?

The history of civilization is heavy with examples of actions which feel morally "wrong." The two atom bombs dropped on Hiroshima and Nagasaki to end World War II resulted in roughly 100,000 immediate deaths, and roughly 100,000 more over the next few months. The United States dropped those bombs in response to Japan's refusal to surrender a week or two earlier. Those bombs are universally regarded to have been a terrible thing, but worldwide, WWII claimed hundreds of times as many lives as these two bombs did; in fact, those bombs are generally believed to have been responsible for bringing that conflict to its final close. Auschwitz alone, that single infamous German death camp, was responsible for many times the number of deaths as those two bombs combined. And after the war, the mere expulsion of Germans from European cities was also responsible for many times more deaths than these two bombs.

WWII was not humanity's only disaster: The combined shifts in power between the Yuan, Ming, and Qing Dynasties of China are believed to have been responsible for about as many deaths as all of WWII. Later, in the name of "freeing" their citizens from the evils of capitalism, Joseph Stain and Mao Zedong were *each* responsible for about as many deaths as all of WWII.

On a smaller scale, the ruling Aztec priests were responsible for many times more deaths by human sacrifice alone than were killed by the bombs dropped on Japan. The war in Vietnam, to "protect" Southeast Asia from communism, was responsible for more deaths than the Aztecs, and ending that war (allowing the Communists to take control) was responsible for even more deaths in Vietnam, Laos, and Cambodia that the war in Vietnam had caused. Cambodia alone probably accounted for as many deaths as the centuries-long series of conflicts between the “Turks” and the “Crusaders.” All of the horror stories told about the real-life Dracula are often regarded to have been an indirect consequence of Transylvania’s unfortunate location on the border between those warring Moslem and Christian forces.

Add to this all of the wars, past and present, which we have failed to mention here; a few dozen “witches” sentenced to death in and around Salem; rampant and senseless violence on our city streets; and we should be starting to be getting pretty sick of “mankind.” There seems to be no limit to the depravity of those who, in one way or another, gain the power to control their fellow men.

From this different perspective, we appear to be seeing the world which we should have expected evolution to produce – not the one modeled by a polite game of Monopoly. What changed? Before we were examining individuals, and here we are studying the actions of people in groups, but why should caring individuals act so differently in large groups? When acting collectively, mankind’s “morality” almost seems to disappear.

When we examined logic (Chapter Twelve, p.108), we noticed that “causality” displaced any grounds for trusting logical validity. We decided that the only way to salvage our belief in our own rationality was to presume our thoughts must somehow be independent of causality. Here we notice that group action seems to displace moral behavior just as effectively. Might morality be like logic in this way as well, and might groups of people be less able to escape causality than individuals are? We will return to this question.

And why does the depravity of mankind depress us? Life is not a safe place; in fact, “nobody ever makes it out alive.” We are all going to die in any case. Why should it matter to us that the inevitable will eventually happen – or even how it will eventually happen? For some reason we do care – and we care quite strongly. This may be yet another odd piece of our puzzle.

Chapter Fourteen:
Are We There Yet?

In the previous four chapters we've examined (observed) different aspects of our human minds using four completely different approaches:

In Chapter Ten, we tried some experiments to differentiate between the conscious and subconscious components of our minds, we explored our feelings about how we regarded those two different parts, and we tried to make some kind of sense out of what we discovered. The oddest thing we encountered was probably the apparent causality reversal for the "master" functionality of our conscious minds. We identified this as a problem which has not yet been solved.

In Chapter Eleven, we considered the various attempts to simulate human minds (AI), – noting the discrepancy between the success rates for simulating the subconscious and conscious functions. We saw that the causality reversal problem seemed to be causing trouble for attempts to simulate conscious minds. We also briefly examined the internal structure of the machines (computers) with which we hope to achieve AI and considered how it would seem if we, ourselves, were part of any such a simulation – particularly, how we might find it difficult to identify any possible bottom turtle that might be "hiding" among the others.

In Chapter Twelve, we took a critical look at our apparent ability to understand and use logic. Here causality became a problem yet again. Although our ability to escape causality and to make "free-will" choices appears to be our only possible escape from complete nihilism; it also appears to be impossible to escape causality, based on what we know about how our minds are "designed."

Mathematics
Logical Reasoning

Comprising /Caused by /Explained by

Conscious Mind

Comprising /Caused by /Explained by

Subconscious Mind

Comprising /Caused by /Explained by

Brains

Comprising /Caused by /Explained by

Nerves

Comprising /Caused by /Explained by

Living Cells

Comprising /Caused by /Explained by

Organic Matter

Comprising /Caused by /Explained by

Carbon Chemistry

Comprising /Caused by /Explained by

Atoms

Comprising /Caused by /Explained by

Space-time
/Quantum Mechanics

Comprising /Caused by /Explained by

Mathematics/God?

According to our causality diagram (left – borrowed from Chapter Ten, p.92.), our minds must be completely "caused" and "explained by" the causality layers below them.

And in Chapter Thirteen, we examined the strange way that all humans view morality. We found that we tend to view "real life" more as if it were merely a game and not like how we would expect if we were playing "for keeps." In "real life" (which is exactly what we are living) we should expect our morality to be much different. Yet humans acting in large groups seem to behave more like what evolution might predict they should – suggesting that "causality" might somehow be threatening morality in the same way that it threatens logical validity.

In case you happened to miss it when this version of our causality stack was first presented (Chapter Ten, p.92), notice that the very top and bottom layers both contain an entry for "Mathematics." This disturbed me when I first noticed it. One possible explanation is that those two words do not really describe the same thing: The kind of mathematics that we have created in our minds is "epistemological." It is a system which we have mentally constructed to *explain the truth* as we observe it. The kind of mathematics at the bottom of the stack must be "ontological." It is whatever *calls the shots* at the quantum mechanical level and *exists on its own* (whether or not anyone is there to observe it).

Although this explanation seems to be completely reasonable, it didn't really ease my mind very much. The remaining problem was something which was suggested by our imagined causality diagram of a series of nested AI worlds. (See column on opposite page, from Chapter Eleven, p.101). Simulated "minds" from every layer in this stack would perceive the "world" below them to have an "ontological" existence which they would, in turn, model "epistemologically" for the corresponding layer above them. The difference, in this case, would be little more than how the two levels were perceived: from "above" or below" in this stack. We will take a closer look at this when we have gathered enough information to better understand it.

While we're thinking about AI and perceptions, we are reminded that any "software" running in an AI simulation is really just an "abstraction" of the layers below it (see p.102). The same thing actually turns out to be true for any layer of any of our "causality stacks."

If we start with the "Carbon Chemistry" layer (see the far left column), we must remind ourselves that "chemistry" is really no more than an abstraction for how the atoms from the layer below it interact with each other. Nothing "new," in any way, has been added to create this layer. "Chemistry" is really no more than an abstract "shorthand" way of describing what atoms would be doing anyway.

In like manner, the "atoms" themselves are no more than an abstract way of describing what quantum probability wave clouds would have been doing all by themselves; nothing new has been added there either.

And quantum mechanics is really nothing more than an abstraction for what "ontological mathematics" and any other possible inhabitant of that still-lower layer might be up to.

So what does "causality" really mean? Is it just another way of describing abstraction? We may be starting to suspect that it is. But if so, what would this imply about any perceived *emergent phenomenon?*

Is an "AI mind" merely an abstract description of a particular complex collection of logic states in an array of gates? Are "human minds" nothing more than *abstractions* for describing particular arrangements of mathematical probability clouds which are interacting statistically? And at the top end of our stack (at left, adding "observation" next to "reason"), are Observation and Reason really no more substantial than mere "abstractions?" It would seem we might be much closer to complete nihilism than we might have feared earlier.

Thrice Simulated
Atoms & World – Etc.

Comprising /Caused by
/Explained by

Twice Simulated AI
Engineers' Computer

Comprising /Caused by
/Explained by

Twice Simulated
AI Mind / Engineers

Comprising /Caused by
/Explained by

Twice Simulated
Atoms & World

Comprising /Caused by
/Explained by

Simulated AI
Engineers' Computer

Comprising /Caused by
/Explained by

Simulated AI
Mind / Engineers

Comprising /Caused by
/Explained by

Computer-Simulated
Atoms & World

Comprising /Caused by
/Explained by

Computer

Comprising /Caused by
/Explained by

Human Engineers & ...

Comprising /Caused by
/Explained by

"Real" Atoms & World

Returning to having “Mathematics” on both the top and bottom layers of our stack: This seems to suggest that we might be part of something like a “causality loop” where the two different kinds of mathematics are really the same – but only appear to be different because we are above one layer and below the other.

We believe that we could (in principle) construct a looping causality spiral upwards, but that would imply that one of the causality turtles in each loop doesn’t really need to stand on the back of the particular kind of turtle which we would be placing below it – it could stand on something “real” (un-simulated) instead.

If we imagine that we ourselves are living within one of those loops (and how could we ever be able to tell otherwise?), then one of the turtles in our own particular loop could be replaced by a completely different turtle which would work just as well. Which turtle might be fooling us like this? We presently have ontological “Mathematics” on the layer at the bottom of our stack; would that mean that there is an ontological form of “logic” which is foundational to ontological mathematics? And what might be foundational to ontological logic?

In Chapter Twelve (p.104), we noticed that “logic” felt like it might somehow be “self existent.” Does this mean logic could be exactly this kind of “otherwise-supported” hidden turtle? Maybe; but then at the top of the very next page (p.105), we also observed (in apparent contradiction) that “logic” seemed to be an inseparable part of human minds (“minds” being up near the top of our causality stack). Were we simply wrong about this? Or do we need to add some *ontological* kind of conscious mind, which is inseparable from logic, to our bottom layer – or maybe to a new layer just below it? Where might we ever stop if we started adding copies of our top layers to the bottom of our stack?

Maybe there is some step in this potentially looping process that we didn’t really understand as well as we thought we did. Maybe we missed some *actual **gap*** in our understanding, and simply took a presumed connection *on **faith***. We have tried very hard not to make this kind of mistake, but we have not always been quite as careful as we might now be remembering. Do any of us remember seeing the two offending words which are highlighted in this paragraph being similarly highlighted back on page 94? We are obviously going to need to be a bit more careful here than we have been.

Here we will sum up everything which we have examined so far to see if we can make any sense out of it. Starting with our summary of Part One (from page 67):

Chapter 1: The universe is different than we may have expected. There really has to be some kind of “bottom turtle.” Furthermore, it really should make sense to us at some level.

Chapter 2: Time and space are not as simple as we may have supposed. Time changes its rate under different conditions.

Chapter 3: Real objects can be rotated between time and space. Time and space behave surprisingly mathematically. Time behaves as if it has “minus one” dimensions.

Chapter 4: The entire farthest edge of space would fit into a lunchbox. As we approach that far edge, space curves back into past time. Time is completely stopped (at the beginning) at that far edge (as seen from our frame of reference). The rest of space and time is “expanding” away from that point in all directions (including three dimensions of space and one of time). Since the creative agency must have been present at that time and place (a single point), and since that time and place is also presently the far edge of space, the creative agency surrounds us. *Something* metaphorically “breathes fire” into the equations and *causes* a universe for them to describe.

Chapter 5: General relativity bends time and space even more, and makes them both even harder to understand – breaking the universe into many separated pieces. The universe is huge and it has several edges, the farthest being a single point with nothing past it. The universe also had a beginning – with nothing before that time.

Chapter 6: We learn from quantum mechanics that individual particles behave in very strange ways. Their individual behaviors cannot be predicted by physical laws, and some of this behavior is simply impossible to explain physically, yet it happens – somehow. On the submicroscopic scale, it appears that individual particles may have no *physical* nature whatsoever, – but instead, may be purely mathematical constructs. On the macroscopic scale, however, all behavior appears to be statistically predictable.

Chapter 7: Whatever agency created this universe requires no time or space in which to operate, yet it surrounds us at the farthest edge of the universe. It has access to virtually unlimited resources. We don’t know what limitations (if any) it might have.

Then summing up what we have seen in this second part:

Chapter 8: Mind (top end) seems to be very difficult to explain. For some strange reason, the bottom (opposite) turtle is also extremely difficult to explain.

Chapter 9: Living cells contain complex little machines which use technology that machinists call computer numerical control (CNC). Some of these machines are like little Escher causality turtles which must all be present and functional before any of them can reproduce. The two most popular modern versions of Darwin's theory of evolution are based on two different kinds of solid supporting evidence – each of which falsifies the competing theory. Evolution has no strong need (or observed inclination) to produce logic.

Chapter 10: It seems strange that we are able to reason and to make observations. Our minds appear to be sharply divided into "Conscious" and "Subconscious" fractions which act very differently – just as if they were generated very differently. The very young, the very old, and the mentally disabled all appear to have properly working "Conscious Minds." We consider the "Subconscious" parts to be like mere tools, while we regard the "Conscious" parts to be an intrinsic part of our selves. The functions of the "Conscious" parts of our mind exhibit a very strange apparent *reversal of causality*. We are satisfied with whatever "Conscious Mind" we happen to have been born with, even if we are satisfied with nothing else.

Chapter 11: AI researchers seem to be having an unexpected amount of difficulty making any progress at all simulating the master-type conscious mental functionality, – while slave-type functionality, which outperforms the best humans, has found its way into low cost commercial products. Expert-level functionality is, unexpectedly, much easier to simulate than novice-level functionality (because of the reverse-causality problem). Conscious functionality does not appear to be emergent with increased complexity. Imagining a nested series of AI worlds suggests that one of our causality turtles may not really need to rest on the one we have placed below it.

Chapter 12: Any "proof" for the validity of "Logic" itself would have to be either circular or invalid. Logic is still the moral high road and seems to be a *self-existent* "bottom turtle." "Logic" is foundational to "Mathematics" and seems to be inseparable from "Mind." *Causality* displaces logical validity, so our reasoning must be *uncaused* if it is to be logically valid. Master-type mental functions appear to require reversed causality. Evolution does not appear to have any incentive to produce logic, and plenty of incentive not to.

Chapter 13: Most of us believe in a similar kind of morality. It isn't like what real-world evolution predicts it ought to be like; instead, it's more like what it ought to be in a "pretend" game world. Moral issues don't seem to end with death – unlike all other normal issues. Morality seems to be tightly linked to logic. Morality (what "ought" to be) seems difficult to explain in terms of what merely "is." When we view the behavior of people in large groups (acting collectively) morality seems to weaken or even to disappear.

Chapter 14: Our causality diagram appears to be fundamentally flawed – especially if each layer is merely an abstraction of the layer immediately below it.

We have just completed a survey of many of the weirdest elements of the current state of the scientific understanding of our world. These issues represent the frontier between our current knowledge and the great unknown; they define the areas of study where new discoveries are to be made and Nobel prizes are to be won. So, we might guess that these would be the questions where scientists would be concentrating their efforts.

We might think so, but this doesn't always seem to be the case. When Robert Shapiro chose "researching the origins of life itself" as his career, he was told, essentially, that he might find more productive uses for his time elsewhere (Origins, Shapiro, 1986, p.278). When Christof Koch decided to track down the seat of human "consciousness," he dealt with a very similar reaction from his peers (Consciousness, Koch, 2012, p.5). Similarly, Roger Penrose, poetically described the search for the causes of consciousness as a "missing science," in the subtitle of one of his books (Penrose, 1994). Anyone who suggests we ought to take a closer look at the disagreements between the gradualist and punctuated equilibrium camps is gently chided and told that a little debate is a good thing in science (apparently forgetting that healthy debate is not an end in itself; its purpose is to locate and eliminate the errors). Stephen Gould was saddened by the persistent reluctance of his colleagues to follow through and invest the effort required to find the actual mistakes (Gould, 1983, pp.261-262).

There are more than just a few isolated instances of ignoring the most interesting frontiers of science; instead, it almost looks like a deliberate conspiracy not to "rock the boat." We are reminded of Alec Guinness' line (as

Obi-Wan Kenobi) from Star Wars, episode IV, A New Hope: “Those aren’t the droids you’re looking for,” (waving his hand in circular motion). If you have spent much time in scientific circles, you will be familiar with this routine. There is such a strong preference for naturalistic explanations that there is a reluctance to take a close look at anything which might suggest a possible error in that paradigm. Some of the more fringe naturalists will even claim that, "Science *only* concerns itself with *natural* explanations.”

Although this is generally the best way to approach science, one important problem becomes obvious when we ask questions like, “What causes *nature itself* to exist?” Obviously, in this context, a *natural* explanation will be circular at best. True science is not shackled in any way at all, and certainly not by any one faction’s philosophical dogmas. *Science* searches for truth wherever it can be found. The bottom line is: At some point, *naturalism must break down*. The only remaining question is, “Are we there yet?”

We have our ducks lined up now; in fact we have amassed an impressive battery of very difficult problems. Our next task is to come up with a way to explain as much of this as elegantly as we can.

Part Three:

The Puzzle's Weird Solution

Chapter Fifteen:
A Thought Experiment

In his layman's book on consciousness (Koch, 2012, p.23), Christof Koch begins his third chapter with the sentence, "Without consciousness, there is nothing." This would have to rival Descartes' observation that "good sense" is so "evenly shared," (p.91), as being another of the silliest things ever written – if it didn't also *brilliantly* capture the way we humans all picture our role in the grand scheme of things. (Koch may actually have been thinking about Descartes when he wrote that, since he goes on to quote Descartes three paragraphs later.) This same sentiment is often reflected in writings on quantum mechanics, where humans' powers of observation are sometimes virtually "deified" regarding their power to shape reality (see Gribbin, 1984, p.212). These *subjective* perceptions of human consciousness seem to assign an absolutely primordial role to it.

In Chapter Ten (page 104 – then again on p.122) we made a similarly *subjective* observation that *logic* "felt like" it might potentially be a bottom turtle; although, on the next page, we made the seemingly contradictory observation that *logic* seemed to be inseparable from our *conscious minds* (which are clear at the *top end* of our stack). What would happen if we were to try putting both *Logic* and *Conscious Minds, together,* at the *bottom* of our causality diagram?

Scientists are free to form any crazy hypothesis they choose – even scientists who carefully test every theory with *observation* and *reason*. What keeps them on track is discarding any hypothesis which fails when tested.

"Subconscious" (Non-conscious) Minds

Comprising /Caused by /Explained by

Brains

Comprising /Caused by /Explained by

Nerves

Comprising /Caused by /Explained by

Living Cells

Comprising /Caused by /Explained by

Organic Matter

Comprising /Caused by /Explained by

Carbon Chemistry

Comprising /Caused by /Explained by

Atoms

Comprising /Caused by /Explained by

Space-time / Quantum Mechanics

Comprising /Caused by /Explained by

Mathematics / (Both Ends Joined)

Comprising /Caused by /Explained by

Logical Reasoning / Conscious Minds

We have seen that there is a serious ***gap*** *in our understanding* of consciousness, that we were *taking this one causality rank on* ***faith*** (p.94), and that this rank ***must*** *be changed* (p.108). So, here we have made a "small" adjustment to our diagram (shown left): we have connected the top and bottom ends of our stack together (joining both entries identified by "Mathematics" – which is now on the second layer from the bottom); and we have cut the "loop" (which this joining created) between "Conscious Minds" (now at the bottom) and "Subconscious Minds" (now top); we have also renamed "Subconscious Minds" as "Non-conscious" to reflect its new "higher" position on our stack. This might seem like a really weird place to cut it, but sometimes the sort of extraordinary evidence we have been seeing throughout this book might call for extraordinary explanations. In any case, this is just a tentative experiment; if we don't like the results, we can always try something else instead.

This odd adjustment isn't really very different from what some of the experts have already suggested. Koch has suggested that consciousness might be a fundamental feature of the universe (Consciousness, 2012, p.132); and that consciousness amasses with the amount of "information integration" which a conscious entity is able to achieve. Similarly, Penrose (1994, pp. 357-371) has developed (in detail) the idea that quantum mechanics plays a major role in the source of consciousness. These experts locate the operative properties necessary for consciousness toward the bottom of the causality stack. In the proposed model, the "unpredictable" properties of quantum mechanics would provide a "window" through which this "fundamental feature" of consciousness might express itself.

Next, we need to examine all of the consequences of this choice, to see whether or not this new arrangement actually causes everything which we have been studying to make better sense than it did before.

Referring to our summary from pages 120-122:

Part 1, Chapter 1: The universe is different than we may have expected. There really has to be some kind of "bottom turtle." Furthermore, it really should make sense to us at some level.

Our Model: Putting "Logic" at the bottom was why we decided to make the cut where we did. It was the only level that felt like it might be able to stand all by itself (being merely an *idea* more than a substance). "Conscious Minds" just sort of came along for the ride. We "felt" they were inseparable from "Logic," so, for the moment, we haven't separated the two. It is at least reasonable that *ideas* (like "Logic") might be tightly associated with "Minds" (where we have always encountered them). We will return to this later.

Chapter 2: Time and space are not as simple as we may have supposed. Time changes its rate under different conditions.

Chapter 3: Real objects can be rotated between time and space. Time and space behave surprisingly mathematically. Time behaves as if it has "minus one" dimensions.

Our Model: Here we seem to be on track. According to this model, "Logic" and "Mathematics" are the *concrete foundations*, while "Time and Space" are merely the *mental abstractions* used to describe what the "Mathematics" is doing. There is no need for otherwise-unconstrained "Mathematics" to follow Euclidean rules. All time and space need to conform to is "Mathematics," which they do.

Chapter 4: The entire farthest edge of space would fit into a lunchbox. As we approach that far edge, space curves back into past time. Time is completely stopped (at the beginning) at that far edge (as seen from our frame of reference). The rest of space and time is "expanding" away from that point in all directions (including three dimensions of space and one of time). Since the creative agency must have been present at that time and place (a single point), and since that time and place is also presently the far edge of space, the creative agency surrounds us. *Something* metaphorically "breathes fire" into the equations and *causes* a universe for them to describe.

Our Model: It seems that we are still on track. Once again, "Mathematics" is easily able to "model" the universe exactly as we see it. But now we also have a "place holder" for that "something" that "breathes fire." We were looking for some kind of source for "initiative" and a "conscious mind" provides exactly that. The question remains: How do you create a conscious mind without any foundation? This is certainly a good question, but on the other hand, we had no idea how to make a "Conscious Mind" no matter what foundation we choose. At least we haven't lost any ground here. (We will return to this issue later.)

Chapter 5: General relativity bends time and space even more, and makes them both even harder to understand – breaking the universe into many separated pieces. The universe is huge and it has several edges, the farthest being a single point with nothing past it. The universe had a beginning – with nothing before that time.

Our Model: Again, none of this is a problem for pure Mathematics; furthermore, properties like "size" and "velocity" are virtually unlimited if the only limiting factor is "mathematical."

Chapter 6: We learn from quantum mechanics that individual particles behave in very strange ways. Their individual behaviors cannot be predicted by physical laws, and some of this behavior is simply impossible to explain physically, yet it happens – somehow. On the submicroscopic scale, it appears that individual particles may have no *physical* nature whatsoever, – but instead, may be purely mathematical constructs. On the macroscopic scale, however, all behavior appears to be statistically predictable.

Our Model: We are still on track. Not only are "Mathematics" and "Conscious Minds" able to deliver the correct results, instead of presenting an enigma to us, it now appears obvious that "particles" should require no substance beyond being "abstractions" of the layer below them. Primordial "conscious mind" can, at least in theory, make up for any of the limitations of mathematical predictability. The QM layer is an "odd reflection" of the wildly diverse tentative layers we had earlier placed below it, because that is exactly what it is: an abstraction of what the diverse components of that lower layer might be expected to be doing. The structure Penrose suggested could, theoretically, serve as a window through which human consciousness and human brains could interface with the physical world.

Chapter 7: Whatever agency created this universe requires no time or space in which to operate, yet it surrounds us at the farthest edge of the universe. It has access to virtually unlimited resources. We don't know what limitations (if any) it might have.

Our Model: The only physical limitations would be "Mathematics" and the "imagination of Conscious Mind." Pick any limit, and you can still multiply it by a million or more. We still don't know about moral or logical limitations.

Part 2, Chapter 8: Mind (top end) seems to be very difficult to explain. For some strange reason, the bottom (opposite) turtle is also extremely difficult to explain.

Our Model: This no longer looks odd; it's exactly what we should expect. Both are from the same (strange) end of the stack – just below the first *natural* layer.

Chapter 9: Living cells contain complex little machines which use technology that machinists call computer numerical control (CNC). Some of these machines are like little Escher causality turtles which must all be present and functional before any of them can reproduce. The two most popular modern versions of Darwin's theory of evolution are based on two different kinds of solid supporting evidence – each of which falsifies the competing theory. Evolution has no strong need (nor observed inclination) to produce logic.

Our Model: This is all easily within the capabilities of "Mathematics" coupled to the imagination of a "Conscious Mind." "Naturalistic Evolution" is certainly a powerful force which is obviously at work within our universe, but it need not completely explain every complex organic structure which exists.

Chapter 10: It seems strange that we are able to reason and to make observations. Our minds appear to be sharply divided into "Conscious" and "Subconscious" fractions which act very differently – just as if they were generated very differently. The very young, the very old, and the mentally disabled all appear to have properly working "Conscious Minds." We consider the "Subconscious" parts to be like mere tools, while we regard the "Conscious" parts to be an intrinsic part of our selves. The functions of the "Conscious" parts of our mind exhibit a very strange apparent *reversal of causality*. We are satisfied with whatever "Conscious Mind" we happen to have been born with, even if we are satisfied with nothing else.

Our Model: Causality reversal is no longer a problem; causality is simply operating in the direction that it should. The two "parts" of our "minds" would indeed be generated very differently; consequently, we should expect to regard them very differently – regarding the "subconscious" parts as mere tools, but the "conscious" parts as our very selves. We should expect the young, the old, and the disabled all to have "evenly distributed" and properly working shares of this – even if the same is not possible for the "Subconscious" parts.

Of course, all of the conscious minds that we are able to observe are operating within the context of the creation – and therefore within "time." Our stream of consciousness seems to involve a sequential operation (more specifically, a sequence of quantum mechanical events). In spite of the clues we have encountered about the non-temporal elements of human thought, it is probably impossible for us even to imagine what primordial conscious mind might be like if we were to encounter it outside of time.

Here is another concept which may be difficult to picture: Because mathematics, logic, and conscious mind are so tightly linked, all three might be parts of the same "substance." (At least there seems to be no way for us to be certain that they are not.) The best chance of our understanding what this might mean would probably come from *thinking about* how *mathematics* and *logic* tie together in our own conscious minds, but that still leaves us wondering how the three might interrelate outside of time.

Chapter 11: AI researchers seem to be having an unexpected amount of difficulty making any progress at all simulating the master-type conscious mental functionality, – while slave-type functionality, which outperforms the best humans, has found its way into low-cost commercial products. Expert-level functionality is, unexpectedly, much easier to simulate than novice-level functionality (because of the reverse-causality problem). Conscious functionality does not appear to be emergent with increased complexity. Imagining a nested series of AI worlds suggests that one of our causality turtles doesn't really need to rest on the one we have placed below it.

Our Model: Master-level AI is simply impossible; "Conscious Mind" must exist "below" where we are trying to create it. However, we do have access to the "slave-level" area and can do whatever we like there. Expert vs. novice functionality problems reflect this same division. Consciousness is not emergent with increased complexity because it doesn't reside where we are putting the complexity. The stack of AI worlds is impossible because our "Logic/Conscious Mind" "turtle" *doesn't and can't* stand on any kind of physical construction at all.

Chapter 12: Any "proof" for the validity of "Logic" itself would have to be either circular or invalid. Logic is still the moral high road and seems to be a *self-existent* "bottom turtle." "Logic" is foundational to "Mathematics" and seems to be inseparable from "Mind." *Causality* displaces logical validity, so our reasoning must be *uncaused* if it is to be logically valid. Master-type mental functions appear to require reversed causality. Evolution does not appear to have any incentive to produce logic, and plenty of incentive not to.

Our Model: Choosing to put "Logic" at the bottom fixed this. Our logical choices are made at the uncaused bottom; anything that happens at the top is a combination of so many different types of causes that it tends to lose any connection to valid reasoning (partly explaining why our memories are, so often, simply wrong). Evolution can only operate on our "Subconscious Mind"; it cannot have any effect on our "Conscious" decisions which are "below" its domain.

Chapter 13: Most of us believe in a similar kind of morality. It isn't like what real-world evolution predicts it ought to be like; instead, it's more like what it ought to be in a "pretend" game world. Moral issues don't seem to end with death – unlike all other normal issues. Morality seems to be tightly linked to logic. Morality (what "ought" to be) seems difficult to explain in terms of what merely "is." When we view the behavior of people in large groups (acting collectively) morality seems to weaken or even to disappear.

Our Model: Individual behavior is what we would now expect. Our "physical lives" are played in a world which we don't really "inhabit." When we "die" in the physical world, we might expect our "conscious minds" to lose contact with our "subconscious minds," but the direction of causality prevents any damage from extending "downwards" (where it could destroy our conscious minds). Our relationships with other conscious minds might be expected to remain unaffected. This arrangement also answers the "is/ought" question. We now locate "ought" with "Logic," at the bottom of the stack – below (and therefore in control of) all of the levels above. We understand what "ought" to happen at the lowest layer; we then simply choose actions which will cause what "is" (or will soon become) to either conform to or deviate from this standard. This lower position makes much better sense than the conventional higher position.

This also allows "what is" to become "what ought not to be." What "minds" choose does not always have to be "good." This allows for worlds, like our own, which contain pain and suffering. As with "logic" (see p.134, Ch. 12), anything that happens toward the top of our causality stack (as when large groups of people interact) tends to result from combinations of *causes* – interfering with personal freedom and reducing group behavior to mere *causal* consequences.

Chapter 14: Our (old) causality diagram appears to be fundamentally flawed – especially if each layer is merely an abstraction of the layer immediately below it.

Our Model: This is no longer a problem. Everything is now properly working as a layered series of abstractions of the same essential bottom "stuff" (whatever that "stuff" might turn out to be).

This is how well everything would fit – if we were to put "Conscious Minds" and "Logic" on the bottom level of our causality stack. Although they may seem like very strange pair of things to put down there, we are not the first to suggest similar possibilities; and this does appear to create a surprisingly good fit. In fact, it appears to produce a much better fit than we had any right to expect. With this one *very weird* adjustment, we have essentially eliminated our entire list of unanswered questions – with many of those questions simply becoming obvious. Does this mean that we now have the correct causality arrangement? That is difficult to know for sure. Science does not produce certainties – only best guesses. Here we have produced a *remarkably* good fit; but we could still be wrong. There might always be a different model which fits even better, or another important question which we have forgotten to ask.

This hypothesis is certainly not a final answer; readers are invited to experiment with their own ideas and questions to see if they can come up with anything else that fits as well or better. My only caution would be that whatever is proposed must be subject to experimental testing, – under the watchful dual perspective of *observation* and *reason*.

At the end of the previous chapter, we noticed that the scientific community seemed to be less than enthusiastic about pursuing the particular difficulties we have addressed here. Perhaps their odd behavior is justifiable: It took the supporters of secular *naturalism* centuries to wrestle the financial control of scientific research and education away from those who held to various traditional beliefs. Knocking *blind* tradition off its throne was certainly progress; placing all observable mechanical truth under the thumb of Isaac Newton’s laws almost made that triumph complete. Having once achieved an almost complete conquest over “superstitious ignorance,” we might understand why our new guardians might be reluctant to surrender ground; they had a difficult fight. Maybe Galileo’s claim was true that his critics *refused to see* the evidence which his telescope provided. Perhaps we can understand and even sympathize with the present reluctance to look into the new “telescopes” which are being proffered by the modern-day “Galileos.” We are reminded of Bilbo Baggins in his last years:

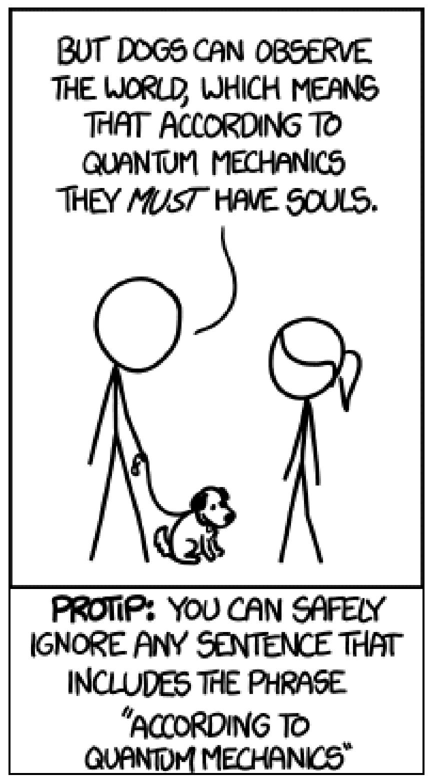
> He used often to say there was only one Road; that it was like a great river: its springs were at every doorstep and every path was its tributary. "It's a dangerous business, Frodo, going out of your door," he used to say. "You step into the Road, and if you don't keep your feet, there is no knowing where you might be swept off to." – (Tolkien, 1965, p.110)

Are we ready to take that step? What sort of world does our “bottom turtle” inhabit? Our next question has to be, “Who Designed and Created *Logic and Conscious Minds*?”

Chapter Sixteen:
Who Designed Logic?

In the previous chapter (pp. 130+) we speculated that the "unpredictable" properties of quantum mechanics might provide the "window" through which consciousness could express itself (following the lead of Penrose). This would be the only possible way that any "nonphysical" kind of consciousness would be able to access the physical world without breaking any of the *observable* physical laws, but we have not made a valid argument that this does in fact happen – or even that it can. We based this conclusion on a mere *choice* we made: that our faculties of *observation* and *reason* were valid; however, we have no *proof* that they are.

In the present academic climate, any argument invoking nonmaterial causes is automatically suspect, and quantum mechanics, being the leading offender of that ilk, is particularly regarded to be a path upon which we dare not set our feet lest we be swept away. (See right – xkcd.com/1240/ Randall Munroe)



For this reason, we need to take a closer look at the evidence which bears upon this question; not too surprisingly, this evidence comes from phenomena which are not well understood. In earlier chapters, we have made several references to the work of Roger Penrose (see pp. 93-95, 125, 130, 132, 137). Here we will examine one of the arguments that he has made (Penrose, 1994, pp. 357-371). It combines a few very different fields of scientific study:

Firstly, from *microbiology*, a paramecium is an oblong single-celled organism which is propelled by rows of little “oars” called flagella. It exhibits surprisingly complex “behavior,” when we observe it under a microscope, including apparently-deliberate motion toward food and away from threats. This complex behavior could easily be understood to be a consequence of random mutations and survival fitness – if it weren’t for the fact that this creature comprises only one single cell (and, of course, that single cell is not a brain cell!) So, how does this creature produce its apparent “intent”? This is very poorly understood and is the subject of some speculation.

Secondly, from *clinical chemistry*, there are a number of anesthetic gases including diethyl ether, nitrous oxide, and xenon which, in correct doses, will cause temporary unconsciousness in humans. Many theories have been proposed to explain how these gases might work on nerve cells, but this is still a subject of debate and ongoing research. Many very different kinds of substances work as anesthetics, but they don’t seem to have much in common with each other. Of particular interest, xenon is an “inert” gas; this means that it hardly ever reacts chemically with anything at all. This makes it particularly difficult to propose a theory which explains how xenon works on human nerve cells.

Thirdly, when a paramecium is exposed to these anesthetics, at the correct concentrations, it will temporarily stop moving. Activity resumes when they are removed (assuming the concentrations weren’t too high). It appears that whatever it is about these anesthetics that suspends *conscious* activity in human minds, also suspends *observable* activity in paramecia. Remember, a paramecium has no brain cells. So what is happening here?

Finally, as mentioned before (e.g. p. 93), Penrose has proposed that consciousness occurs as a result of *quantum mechanical* interactions. Although QM effects are normally regarded to be way too small to affect “large” systems (like a paramecium), there are quite a few exceptions; these include experimental setups and structures used by scientists to study these QM effects. One of these structures is a tiny tube which is about the thickness of a quantum wave length (quantum wave guides). Penrose has pointed out that “structural” tubes having about the correct dimensions can be found both in paramecia and in human brain cells. Further, Penrose has shown how anesthetic gases, in the proximity of these tubes, can disturb any QM effects which those tubes might otherwise support.

Whether or not this proves anything is still a subject of debate, but at least one possible path has been identified by which it might become theoretically possible for QM to provide a connection between nonmaterial "pure-logical processing" and otherwise-mechanically-caused phenomena. For our present purpose, we will tentatively assume that Penrose is correct; if evidence to the contrary emerges at some later time, we can always change our minds and make a different assumption.

At this point, we may finally be ready to take on the question: "Who designed God?" We already know that "the creative agency" must have an extra-natural existence (outside of space and time) in order for it to be *the source of* space and time; therefore, we know that it must be able to reside outside of space and time (putting it somewhere within the bottom two layers).

It should not surprise anyone that the *first cause* we have been seeking belongs at the bottom of our causality stack. What we have learned, from the preceding chapters, is which other things also belong on the bottom part of our stack (right column, adapted from p.130). These include "conscious mind," "logic," and "mathematics." Furthermore, these are likely to be candidates for the kind of "substance" which this agency might comprise. These things all exist in "timeless" levels, or possibly in one unitary "timeless level" (singular), where change (as we understand it) is impossible – change being possible only within the context of "time," which is, itself, a created thing. We already know that this agency does not (at least not exclusively) occupy the "quantum mechanics" and higher layers, because those layers suffer the same fate as "giant pink bunnies" – they depend upon space and time in which to operate.

Non-conscious Minds

Comprising /Caused by /Explained by

Brains

Comprising /Caused by /Explained by

Nerves

Comprising /Caused by /Explained by

Living Cells

Comprising /Caused by /Explained by

Organic Matter

Comprising /Caused by /Explained by

Carbon Chemistry

Comprising /Caused by /Explained by

Atoms

Comprising /Caused by /Explained by

Space-time /Quantum Mechanics

Comprising /Caused by /Explained by

(ontological from above)
Mathematics
(epistemological from below)

Comprising /Caused by /Explained by

Logical Reasoning / Conscious Minds

Various scientists have proposed that mathematics might be the underlying cause of all that exists; however, this idea has prompted Stephen Hawking (and others – echoing him) to ask what might have "breathed fire into the equations" and enabled them to be expressed in the form that we experience as this universe (p.43). If we are on the right track here, Hawking's "fire" would appear to be the primordial version of "conscious mind" (tending to confirm that "conscious mind" may be a part of the creative agency we are seeking). This could certainly provide the "spark" necessary to initiate "physical" existence.

The fact that our minds also appear to be made, in part, from this same bottom-layer kind of conscious mind, suggests a way for us to determine whether the creative agency accomplished the design and construction of our "conscious minds" directly or indirectly (through other agencies, such as mutations and survival fitness): Higher levels of causality cannot have any effect on lower levels (thereby forming "causality loops"). This means the conscious components of our minds *must be the result of "direct" acts of a "bottom level" cause.*

It might even be fair to say that the designer/creator "made us in its own image;" but even with this much potential, it appears that our powers have been greatly restricted. This is quite reasonable – remembering the lesson we learned from the ultimate glue (p. 64); this restriction limits the amount of logical and physical damage we can cause (although it does not completely eliminate it).

It is also worth noticing that this means there are other parts of our minds which *are* subject to physical forces (e.g. to evolution or to natural deterioration). As we can plainly see, all of the functionality of our "subconscious mind" (our memory, balance etc.) is easily affected by these forces – for better *and* for worse.

We have concluded that our creative agency probably comprises, at least in part, "conscious mind" (providing the necessary "fire"). We must also conclude that "Logic" *shares* this bottom causality level (instead of being one of its "creations"), because if logic weren't a part of this agency, then it is difficult to imagine how this *consequently illogical* agency could ever have designed logic in the first place. If, on the other hand, we were to assume that somehow "logic" caused "conscious minds," we would need to explain what "breathed fire" into logic and created a mind with which the logical processes could interact. We appear to be forced to conclude that "logic" and "conscious mind" both occupy the bottom causality layer. Since the beginning, primordial mind has existed with logic and is probably of one substance with it (since logic and mind are mentally difficult to separate). As Koch observed, "Without consciousness there is nothing." (Koch, 2012, p.23.) Yet logic has an equal claim to this primordial turf.

The logical rule of "excluded middle" states that logical propositions must be either "true" or "false." Any propositions which violate this rule (for example, assumed propositions which are paradoxical) lead to meaningless or contradictory conclusions. This tells us that primordial logic must inhabit a world of black and white – of truth and falsity. Our creative agency, being of one substance with primordial logic, would probably represent the primordial embodiment of this sort of world. This might help us get a possible view of how this agency might approach logical questions, it would probably have a tendency to see things as being cleanly true or false – with no shades of gray.

"Mathematics" may also be part of this agency's composition. The native environment of mathematics is independent of space and time, so the concept of "change" is foreign to it – except within the context of a creation (a construct of time, space, matter, and energy). Alternately, mathematics might be a construct, or abstraction, of mind and logic. (It might be difficult for us to determine which, assuming that there is any actual distinction at all.) However, envisioning mathematics as an abstraction of the same substance produces a simpler model.

Because of all of the similarities we have noticed between "logic" and "morality," we might assume that "morality" also resides on this lowest layer (or possibly *layers*). If so, we would expect the creative agency to be a "moral" conscious being. Logic acting in conjunction with morality would suggest that this being might also view moral questions in "black and white" terms. Our perception of moral "gray shades" is likely a failure on our part to see all issues in clear focus. If we saw all situations without our limitations, we might be less likely to *mix the black and white details;* the same would probably follow for "right and wrong," and for "true and false."

For our next step, time, space, matter, and energy appear to be (at least in part, and possibly completely), logical and mathematical constructs. "Nature" might be produced as easily as consciously-created mathematical derivations can be – the only limitations being those restrictions to which mathematics is subject. This would appear to provide a virtually limitless supply of resources, including "energy." As we have seen in Chapter Seven (pp. 62-63), the creative agency actually does appear to have access to virtually unlimited energy.

As we have also seen (p. 65), this agency completely surrounds us at the farthest reaches of the universe; if we assume it is no more restricted than we are, it is likely to be closer to us as well.

All of these attributes follow from what we have learned by using our powers of observation and reason. A few of these attributes are partly speculative, others are reasonably certain.

By now, we might be starting to wonder if this creative agency is still hanging around – and whether it is able to meddle with our lives. The same quantum-mechanical "back door" (through which we all now seem to control our own physical actions) could also serve as a portal through which this agency could operate. In fact, the "act" of creation required "action"; this means this agency did have a portal through which it could and did act. Assuming this agency's "conscious mind" is anything like our own (and would probably, therefore, have acted as we would have acted in the same situation), it is virtually certain that it has retained greater access to the creation than it has granted us (also presuming, as seems obvious, that we are *creations* of this agency and not equally powerful peers). It has probably retained enough control to fine-tune the universe in any manner it chooses (including the potential to meddle with DNA strands as desired).

As we might have expected, our answers multiply our questions:

In what other processes might this agency have been involved?

Is this how the extreme improbability of the first living cell was overcome?

Might this agency's actions resolve the apparent contradictions between the competing evolutionary theories of "punctuated equilibria" and of "gradualistic" population genetics?

Might it be able to communicate with humans? Has it ever done so?

Might our senses of "morality" be part of such a communication?

Might it be intrinsic parts of our own conscious minds?

Might it be a combination of both communication and minds?

What, specifically, causes our minds? How do they connect to our brains?

Do the choices we make carry meaningful consequences?

Might we be held accountable for these choices?

Might this agency expect anything else from us?

Is there any possible way in which we might be able to meet any such expectations?

Might our conscious minds be expected to "outlive" our brains?

Is there any possible way that our minds *even could* cease to exist as a consequence of the physical and temporal death of our brains?

Might there be a *different* mechanism whereby they might enter or leave existence?

Does the fact that our physical brains contain no memories of any "previous" existence tell us anything meaningful about this? ...

These are all very interesting questions, but we don't really need to answer them here. Besides, we probably already have enough information by now that the answers (some of them very strange) may already be suggesting themselves.

Another answer which should also be suggesting itself at this point is the answer to the question, "Who or what designed and created God?" We might just as well be asking who or what designed and created logic and mathematics – because those two would be part of the same substance under the suggested model. As we understand them, math and logic do not require a designer or a creator; they are self-existent and are the terms in which all other things are ultimately explained. This sort of "self-existence" can actually be understood.

And if this world's physical existence is no more that a mathematical derivation (or something like what we might call a "simulation" from inside of our own world) – one which is "sparked" by conscious intent – then physical existence might be within reach of our comprehension. "Where did the original primordial matter came from?" This becomes no more of a mystery than, "What causes arithmetic to work?"

Placing consciousness in the same kind of world as mathematics may feel like a very strange thing to do – until we remind ourselves that we have never really *experienced* "logic" (or anything else, for that matter) in the absence of "consciousness." The really puzzling question is, "What kind of primordial bottom-layer "world" are we dealing with here?" We don't have any direct way to "observe" it. How many dimensions does it have (if any)? Does anything analogous to "time" or "causality" exist there? What rules does it follow (if any)? Is there is anything like a "flying spaghetti monster" there?

Although we cannot observe this "primordial world" directly, we can get a few "blurry glimpses" at its "dark reflections" from the edges of our own world; our logical abilities provide this interesting clue: If the undersigned designer inhabits any kind of world at all, we would then have to ask who or what was responsible for designing that other environment. Since we are seeking to avoid adding infinitely many "turtles" to our causality stack, at some point we will need to say that the absolute "first cause" exists in a manner which requires no environment which is external to itself. However many layers might exist (or might not exist – if we are to follow the lead recommended by Occam's razor) between us and the absolute first cause, our quest here is for that creator which inhabits no external environment. That creative agency, the one which we have been tracking down, requires neither creator nor designer, nor can it have either.

The final question which we need to address is, "Can this agency ("moral" or otherwise) be trusted?" This could be very important to us since we now have reason to believe that it was responsible for the creation of our *conscious minds* (and maybe, at least partly, for the designs of our *unconscious minds* and of our brains as well). Deciding this is critical, if we intend to put any "faith" in our own decisions – based on our own powers of observation and reason.

When we encountered this question before, we didn't know enough to make any assertion; we just left it hanging. We don't really know any more now, but we do know how to make the same kind of choice we made earlier:

A) We can choose to trust whatever was responsible for our thoughts.

OR

B) We can choose not to.

As before, this choice must be completely "uncaused," and it will lead us in exactly the same two directions as before: The "B" path terminates all logical arguments – including this one; but following the "A" path, as we are now doing (at least provisionally), means that we are assuming that this agency is trustable – at least in its dealings regarding the design of our minds.

Also as before (under the "A" path), we must assume that this agency has allowed us the required "free will" to be able to make that choice. This, admittedly, must be a somewhat arbitrary decision, but it is the only path left to us – if we are to continue to live by faith in our powers of observation and reason. Denial of this is, essentially, denial of the only chance we have that we might be able to trust those powers.

As most readers will have noticed, the attributes of this particular designer/creator – which we have just sketched out here, using observation and reason as our guides – appear to be quite similar to those spelled out in a few of the world's closely related major religions. This may be a result of the particular religious culture under which the scientific method was born (the two certainly seem to be compatible). It may also be more fundamental, and it may suggest a potentially productive direction for further study.

In any case, following the "A" path must be a "freewill choice." At any time we may leave the path of observation and reason and put our faith in Zeus, Enki, the Easter bunny, or in any other foolishness we might choose; and, of course, we must accept, without excuse, the consequences of any such choice.

Part Four:

The Weird Appendices

About the Author:

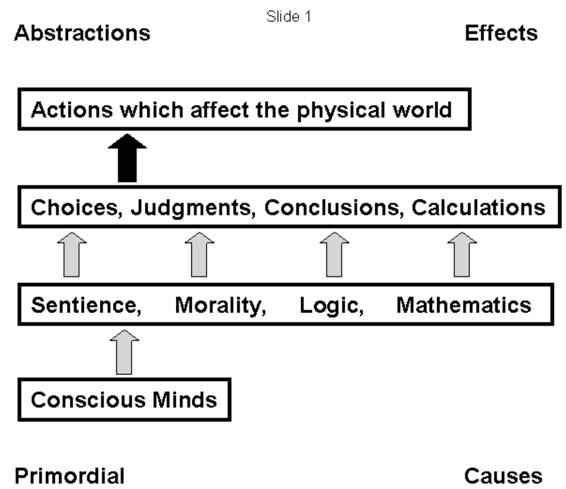
Don Stoner is nobody in particular.
What was I thinking when I started this project?

Dedication:

I had no interest at all in Down's syndrome until November 15th of 1997, when my trisomy-21 son, Joshua, was born; then I became inspired to follow any research which showed promise of treating Josh's learning disability. During the years before the first effective treatment was finally discovered, Josh provided an enlightening window into how a conscious mind might function in the virtual absence of any high-level subconscious information processing support. In spite of this, Josh never provided the slightest hint that his conscious abilities were in any way diminished. To the contrary, Joshua taught my family how to see ourselves more clearly – from a less encumbered perspective.

Furthermore, I had no idea that the treatment I would finally encounter for my son's condition would also turn out to be a treatment for my own rapidly deteriorating memory – making the completion of this project possible.

Thank you, Joshua, for everything you've done for my family and for me. This book is dedicated to you.

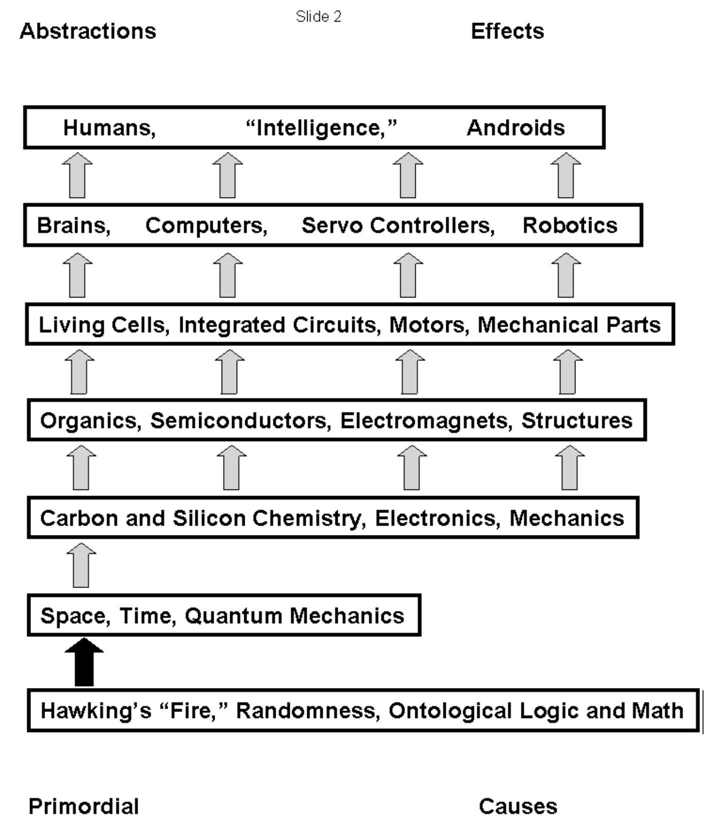


The question is where to overlap the two diagrams. The obvious solution is to overlap the "Conscious Minds" block of Slide 1 with "Intelligence" in the top block of Slide 2; however, I have suggested (as an experiment) overlapping the bold arrows from the two slides instead.

The labels "Abstractions/Primordial" and "Effects/Causes" seem to throw a serious monkey wrench into these diagrams: Some questions which now suggest themselves are:

Is Human "choice" an illusion; or is it real?
Is Human "reason" valid or is it more like the last domino in a series of causes.
Is "logic" self existent and valid, or is it somewhat arbitrary.
Is it actually possible to know anything?
Is it actually possible to cause anything physical to happen?

What do you think the answers are?



Bibliography:

(Still a bit of a mess – Citing does not necessarily imply endorsement)

Abbot, Edwin A., (-) 1963 edition, Flatland, a romance in many dimensions
Amthor, Frank, 2012, Neuroscience for Dummies
Beiser, Arthur, Modern Physics, and introductory survey
Calder, Nigel, Einstein's Universe
Crick, Francis, 1981, Life Itself, its origin and nature.
Crow, James, & Motoo Kimura, 1970, An Introduction to Population Genetics
Crutchfield, James P. and Peter Schuster, 2003, Evolutionary Dynamics, exploring the interplay of selection accident, neutrality, and function.
Darwin, Charles, ~1860 (1962 edition), The Origin of the Species
Dawkins, Richard, 1987, The Blind Watchmaker, why the evidence of evolution reveals a universe without design.
Dawkins, Richard, 2006, The God, Delusion
Descartes, Renee, 1968 translation, Discourse on Method and The Meditations
Dreyfus, Hubert L. and Stuart E. Dreyfus, 1986, Mind over Machine, the power of human expertise in the era of the computer
Einstein, Albert, Relativity
Ferguson,Kitty, The Fire in the Equations
Freeman, David Hugh, Logic, the Art of Reasoning
Gamow, George, 1988, One Two Three ... Infinity, facts and speculations of

science
Gould, Stephen Jay, 1977, Ever Since Darwin, reflections in natural history
Gould, Stephen Jay, 1980, The Panda's Thumb, more reflections in natural history
Gould, Stephen Jay, 1983, Hen's teeth and Horse's Toes, further reflection in natural history
Gribbin, John, 1984, In Search of Schrödinger's Cat, quantum physics and reality
Hawking, Stephen, 1988, A Brief History of Time
Hawking, Stephen, Nutshell
Hofstadter, Douglas, 197, Godel, Escher Bach, an eternal golden braid
Hoyle, Fred, and Chandra Wickramasinghe, 1981, Evolution From Space, a theory of cosmic creationism.
Hoyle, Fred, 1987, Mathematics of Evolution
Jastrow, Robert, 1978, God and the Astronomers
Jastrow, Robert, 1977, Until the Sun Dies
Johanson, Donald, and Maitland Edey, 1989, Blueprints, solving the mystery of evolution
Johanson, Donald, From Language to Lucy
Johanson, Donald, and Maitland Eddy, 1981, Lucy, the beginnings of humankind
Koch, Christof, 2004, The Quest for Consciousness, a neurobiological approach
Koch, Christof, 2012, Consciousness, confessions of a romantic reductionist.
Kramer, Samuel Noah, Sumerian Mythology
Lenninger, Biochemistry
Lewis, C.S., Mere Christianity.
Lewis, C.S., Miracles, how God interferes in human affairs.
Lewis, C.S., The Problem of Pain.
Lonergan, Bernard, (Method? Insight/GEM?)
Munroe, Randall, xkcd.com (web comic), 263 Certainty, 435 Purity, 1163 Debugger, 1240 Quantum Mechanics
NASA COBE info on web
Newton, Isaac, (1642-1737), 1995 edition, The Principia
Orwell, George, 1984
Paige, Lowell J. and J. Dean Swift, Elements of Linear Algebra, pp. 170-171
Pelczar, Michael J. Jr. and Roger D. Reid, Mocrobiology
Penrose, Roger, 1989, The Emperor's New Mind, concerning computers, minds, and the laws of physics.
Penrose, Roger, 1994, Shadows of the Mind, a search for the missing science of consciousness.

Penrose, Roger, The Large, the Small, and the Human Mind
Russell, Bertrand & Alfred North Whitehead, Principia Mathematica
Shapiro, Robert, 1986, Origins, a skeptic's guide to the creation of life on earth
Shapiro, Robert, 1999, Planetary Dreams, the quest to discover life beyond earth
Stoner, Don, Hell Bent
Stoner, Don, 1992, 1997, A New Look at an Old Earth
Stoner, Peter, Science Spaeks
Weinberg, Stephen, The First Three Minutes
Williamson, Jack, The Humanoids
Tolkin, J.R.R., 1965, The Fellowship of the Ring

The Bhagavad Gita
The Bible
The Book of the Dead
The Dhammapada
The Gods of the Egyptians
The Qur'an
The Sayings of Confucius

Easter-egg hunt:	(page)
Job 26:7	(16)
Isaiah 40:12,48:13	(65)
Luke 1:35	(84)
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