Who Designed God?

The Theology of Observation and Reason

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Contents:

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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 – or 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; and it spun crazily on its rotating mount. I stared in disbelief as the collection of steel arms, mirrors, and other optical paraphernalia spun 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 this young man’s frustration, and the accompanying outburst, and 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 to 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. 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. I, obviously, wasn't any older 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 surprised the people who had originally done it – just like it was surprising 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 became known as the Theory of Relativity.

The atmosphere in the laboratory began to relax. There was a bit of laughter around the lab 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 semester, 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 state-wide 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 did that. Somebody had to be a member of the team that took the laser disc, from an idea, to the CDs and DVDs we have lying around our living rooms; working as a member of that team was my first real job out of college.

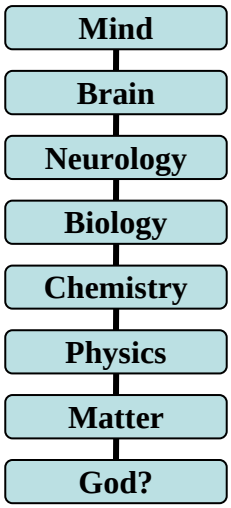
How hopeless a geek am I? It's pretty serious. I have received more patents and awards than the number of times I have watched professional hockey, soccer, and basketball games combined. (If I include baseball and football, I think it might be about a tie.)

So, 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?" The answer is because those questions are every bit as much philosophical and scientific as they are theological. A theologian might ask how "God" created the universe; but *we all wonder how it is even possible that we exist*. The mystery of *existence*, and of *initial causality*, has haunted men since the beginning of history – if not

from yet earlier times; and the answers we have heard have not really been that convincing.

The truth seeker asks, "What keeps the world from falling?"
The wise sage replies, "It rests on the back of a giant turtle."
The truth seeker asks, "Then what keeps the turtle from falling?"
The wise sage replies, "It rests on the back of a second giant turtle."
The truth seeker asks, "Then what keeps the second turtle from falling?"
The wise sage replies, "It's "turtles" all the way down!"
– adapted from a story told by Richard Feynman

Reason demands satisfying explanations for everything. No matter how many steps it takes, there must be something understandable at the very bottom of "the stack." The explanation that "the earth rests on nothing" might not have satisfied an ancient truth seeker, but when enough of the missing pieces (including universal gravitation and planetary orbital mechanics) were finally supplied, the simple answer made sense.



Our search for initial causality for the universe, and everything it contains (including *mind*), should be no different. An oversimplified outline of the stack of causality supporting our mind is pictured on the left. Every layer is supposed to be, at least in principle, completely explained in terms of the layers below it. The only *obvious* problem is that bottom layer. If we are told that the source is primordial matter, then we must ask how primordial matter got there. 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 will still be left wondering, "What supports the bottom turtle?"

The theologian may argue from the evidence of intelligent design (as seen in the creation) that there *must be* a designer; but *we must also ask how that designer's intelligence could have come into being in the first place*. How can we ever get any kind of handle on initial causality?

The situation may appear hopeless, but causality cannot evade its responsibility forever; even causality *must have something reasonable at the very bottom of its "stack."* 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.

Being a technical geek, I have had more than my fair share of experience at studying how complex technical systems work. This book's featured question, "Who designed God?" is certainly a difficult problem; but there are ways of approaching even the very toughest questions. We will start by examining a few small pieces of the problem.

One of the things I have learned how to do over the course of my life is how to design 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 logical 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 component or system at a time, building in complexity at a manageable pace, until the entire system becomes comprehensible.

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 PhD. in geology or oceanography, he might have been able to explain how each pebble or shell tied into the whole system of which the world's oceans were only a part.

In my own work as a technical designer, 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 any new part "tells" me about itself, when I first encounter it in isolation.

There are many different kinds of clues that 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 will tell more than just what it is supposed to do. It will explain what environment it was designed for, what size of production run it came from, 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 felt the 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 the cruise control designer tried to defend his competence, and the probable flack he would have received from management. All of that seemed apparent from merely driving the completed machine.

It isn't really 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.

Similarly, a single pebble selected from a beach holds clues to tracking its own history through time. How long have the waves pounded against it? Was it broken off of the local rocks? Or was it carried down a river from a point of origin many hundreds or thousands of miles away? Was the rock originally formed by a volcanic eruption? Or was it a sedimentary composite of other pebbles which, themselves, had once been ground to powder on the shore of some ancient and forgotten sea. And, finally, where did the first pebble come from – and what created that pebble's creator? Ultimately, this brings us back to questions like "Who made God?" or "Who designed God?

In addition to being a technical geek, I have also been a lifelong student of physics, biochemistry, cosmology, geology and a few other disciplines bearing on the universe in which we live. Whatever sort of "designer" or "builder" might have been involved in bringing us to where we presently are, there is bound to be enough evidence to identify this "creative agency." Since *we are in fact here*, there ought to be a way to figure out how it is that this agency was able to exist, and to create us.

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

Some may want to challenge this claim – particularly those who have seen me in church (occasionally even addressing the 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 this from the same perspective.

Chapter 2:

Einstein's 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 kind of intelligent decision about what might have been necessary to *design* that agency.

Of course this means that we must *first* understand the universe. In particular, we must have *real answers* to *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 young student in the previous 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; and he had definite opinions about how time and space *ought* to behave. When he was confronted with the 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 try 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" 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.

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 revolution 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 correction for sidereal rotation). 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 more than 66,500 miles per hour. (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 will 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 cars which are overtaking us from behind to pass us more slowly than those which are coming from the opposite direction. What Michelson discovered was like saying that the cars would be passing us at exactly the same rate in both directions – as if we were completely stopped. Michelson knew that the earth was moving!

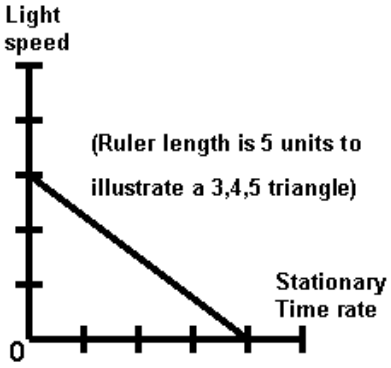
The scientific community (and the young student) had as hard a time accepting this as you might now be having. In fact, it was suggested that Michelson's instrument might have been "broken." Fortunately, Michelson was given lots of money to reconstruct a bigger and better version of it. The experiment 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 circled it, or new laws of physics were needed. Einstein was able to figure out what had happened with Michelson's experiment; he provided the necessary new laws of physics 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; instead other things like the very rate of time itself would change. When Einstein supplied this realization and the proper equations, Michelson's experiment made sense.

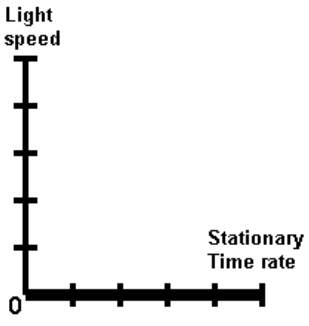
The rate at which time proceeds really does change; clocks "tick" time off faster under some conditions than they do under others. As incredible as this sounds, subsequent experiments confirmed it. Elapsed time for a very high speed particle can be shown to be quite different from that experienced by 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. Without torturing you with the equations, I can still show you how to picture the results:

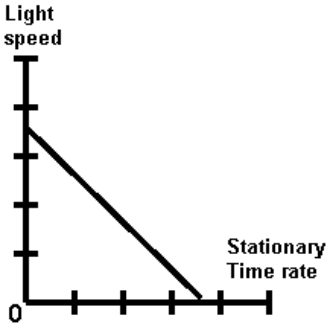


All you need to do is lean a ruler against a wall, with one end on the floor. If the velocity of a spaceship (as a fraction of the speed of light) is represented by the height of the top end of the ruler above the floor (as a fraction of the length of the ruler), then the rate of time in that spaceship (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.

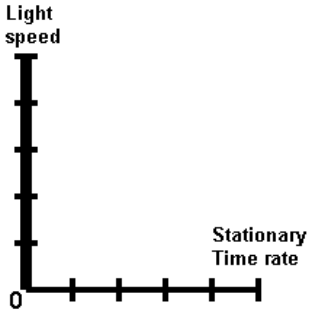
Trying out a few specific examples will help explain this model: If we are moving relatively slowly (say a "mere" three thousand times the speed of sound), we would be moving with such a small fraction of the speed of light that it would be difficult to tell that the ruler wasn't laying perfectly flat on the floor; the high end of the ruler would be raised above the floor by only 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 it very carefully in order to see the difference at all; the spaceship's clock would only loose a couple of minutes in a year



If we were to increase the spaceship's velocity to seventy 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 percent of its length away from the wall (also about eight and a half inches), The spaceship's clock would slow to seventy percent of the rate of a stationary clock – or to about seven seconds of spaceship time for every ten seconds of stationary time.



If we could make the spaceship travel at exactly the speed of light, the ruler would have to sit vertically against the wall; its bottom end would have no separation from the wall. This means the clock in the spaceship would stop completely!



It has been shown by many different experiments that this really is what happens. We don't usually notice it because hardly anything ever moves fast enough. However, some things do move this fast.

For one obvious example, light itself moves at "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). As strange as this might seem, we will encounter things which are even stranger than this in the pages that follow!

In the next chapter, we will encounter something else that moves at the speed of light. In order to understand that, we will need to remember what we have learned here.

Chapter 3:

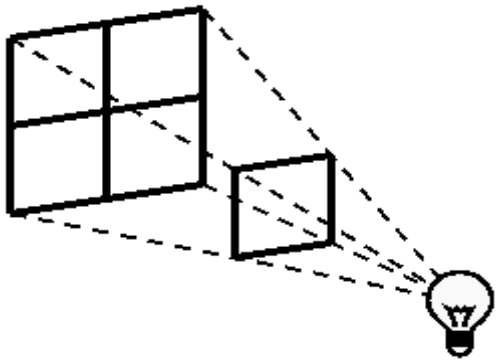
The Big Bang

In the early nineteen hundreds, 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 discovered 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, in general, 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 was the result of a very large explosion. It also implied that the universe had 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 complaining about it.)

In spite of this, many different attempts were made to avoid coming to terms with the moment of creation. Some of these attempts involved 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 went as

far as to suggest ways to deal with the problems presented by the various conservation laws or the relentless increase of entropy.

Unfortunately, none of these attempts will help us explain initial causality; they all evade responsibility by proposing endless "stacks of turtles." Since we are looking for more meaningful answers here, we will simply deal with the *present* big bang as if it was either the *first* of the series – or was the *only one ever*. The "bottom turtle" is the only one that really needs explaining.

No matter where its position is in any imagined "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 the instant the universe first became "transparent." (This was when its matter became spread out enough that radiation, like light, could shine through between its separating chunks of matter – this was very soon after the explosion). *Observing* this radiation 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 we now know what happened; the bad news is Hoyle's fears became real and we now have to come to terms with 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, his would be an incorrect impression. This may take a little bit of time to explain:

To begin, the most distant galaxies in the universe 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 closer to light speed than the light from these most distant galaxies. In fact, the farthest edge of the universe appears to be moving away from us *at the speed of light!*

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 creation! Not even a photon can escape this edge.*

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 is *a single point*. The entire far edge of space would fit inside a lunchbox. If you are thinking that's impossible, then you probably have the correct understanding of what I am saying.

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 travel (north, south, east or west), if we continue in a "straight line," we will eventually arrive at the point which is exactly opposite to where we start. Of course we are not really walking 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 make things "simple," let's pretend we live in a two-dimensional (flat) universe which occupies the surface of a sphere. This is easier to picture – since we do live on the *apparently* two-dimensional "flat" 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 from our location on 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 (it would require some kind of time travel – putting 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 too far from the truth. If we could visualize that third dimension of space (the one we left out to simplify our model) we would, pretty much, have the correct 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.)

Actually, there are a few other complications which we have ignored; these include the time it takes for light to reach us from different parts of space and the fact that gravitational mass and acceleration also bend the "fabric" of space. These merely contribute to the same general conclusion that we have just reached.

At this point, we are ready to answer some of those difficult questions which we asked before:

Q. How big is the universe?
A. About as big as the distance light could travel (in all directions) in 13.7 billion years, at 186,000 miles per second. This works out to be about 80,000,000,000,000,000,000,000 ($8x10^{22}$) miles (in all directions).

Q. What is the edge of space like?
A. It's the single point (in space and time) of the big bang (the balloon's "neck" in our model). It's very hot and very dense. Any direction we might point will always be *right at* this single point.

Q. What is beyond the edge of space?
A. Since (hypothetically allowing time travel) we could approach this point from any direction – and it's just a point when seen from every angle, there 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 all sides. But a word of warning: The "edge" of space is also the beginning of time – and therefore we would be "staring down the bore" at the very nasty "big bang" (if we could really get that close).

Q. Did it always exist?
A. No.

Q: What was it like "before" the Beginning?
A. Time is the distance from the neck. Since it is like a "radius" it can not assume a negative value. The question is like asking, "What does a circle with a negative radius look like?" Since, as we are assuming, there really was a "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;" it began as a point and expanded with the spreading matter of the universe.

Our powers of *observation and reason* seem to have brought us a long ways. (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 exercised our minds harder than we are normally accustomed to doing.) But we are not finished; these powers will take us further yet!

Chapter 4:

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, it grew quickly as space and time stretched outward from nothing – growing with the universe's rapidly spreading matter and energy.

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," which is a nearly perfect description of what we mean here. Unfortunately, that term carries a load of emotional and historical baggage which might be better avoided. Similarly, we should 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 any of 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. The real creative agency must be able to operate from outside of space. 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.

Unfortunately, the details of how the big bang got started are far from being "nailed down;" our personal bias is likely to play into how we attempt to fill in these details. Physicist Stephen Hawking, for example, seems to be biased (quite reasonably) against leaving anything hanging at the beginning that might appear to require any kind of extra "turtle" which is causally supporting the universe. Instead, he has proposed a model which attempts to eliminate all boundaries which would require *any kind* of explanation.

Instead of approaching a "loose end" at time zero, Hawking proposed that the "direction of time" rotated "ninety degrees" as it approached "time zero." (He calls this new direction "imaginary time" – which is the same as saying a "direction of space" in the language of theoretical physics.) In our balloon model, this is like saying that the balloon's radius bends smoothly to blend with its surface – thus eliminating the problematic fill stem. Under this proposal, Hawking claims that there never really was an instant when the universe began. By this trick, he claims it can be "self-existent" in the same sense that a theologian might claim that "God" is self-existent.

Like Hawking, I have my own bias, so, instead of hopping on the band wagon and patting Hawking on the back, I looked for a mistake in his proposal. It turned out to be difficult to locate, but obvious to see – once it had been found:

Although the dimensions of time and space are similar, there is a very important difference between them – at least when they are viewed from the instant of the big bang: While time is a single-ended dimension, the three dimensions of space *each* extend away from that point in *two* opposite directions (right/left, up/down, and front/back). By smoothly curving time, Hawking removed the "corner" from each of the six spatial half-dimensions into a smoothly connected pair (each now a line) – eliminating the six (3x2) axial boundaries.

By the same trick, he also seems to have claimed to have smoothed time into a fourth line of space. Unfortunately, he did not propose any way that the *other end* of this *now two-ended line* could escape the singularity without simply being cropped (creating essentially the same boundary he claims to have avoided). Nor does there seem to be any way to eliminate this problem; the *odd number* of loose ends (3x2 space +1 time) means that something very strange must have happened at this moment. We really seem to be dealing with something which is "unnatural" or perhaps "extra-natural" (as defined above). The question is figuring out *what* this "something" must be like.

Fortunately, there is a lot more we can learn if we keep looking: For example, we know that this "creative agency" had sufficient power to bring all of the mass and energy in the entire universe into existence. Further, we know that everything must have been accomplished 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 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.) This is the amount of energy the creative agency had to come up with (mostly in the form of unburned hydrogen) to keep all of the stars burning for billions of years. This energy all had to be produced at the very first instant – sort of like filling the gasoline tank before a very long trip.

Remember that each one of those zeros makes the number ten times larger than the last one did. This 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, 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, effectively, purchased the entire earth. This involves just about as much control 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.

That number represents a whole lot of energy! But as large as it is, this is really much smaller than what was required to "wind up" the universe. I 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. I have also left out the energy which was released by the big bang itself, and by many other processes which have used huge fractions of the universe's total energy budget.

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 even imagine! We know that the creative agency must be incomprehensively powerful.

Since this creative agency appears to have 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 limitations this agency might 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 (infinite force) to lift an unliftable rock (immovable object) 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? Not if it happens to be bound by logic. But is it?

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).

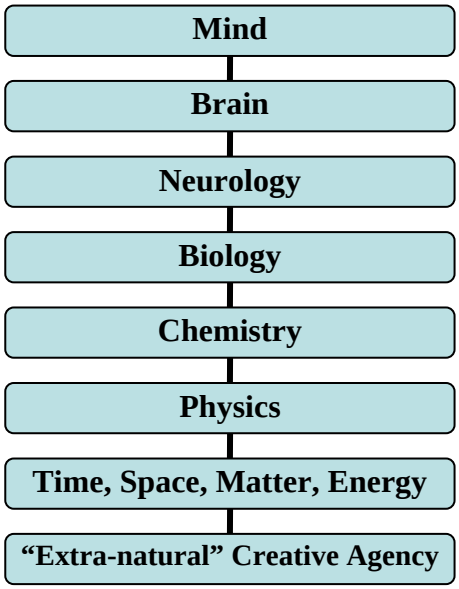
Since we already know that our agency is able to operate without any passage of time, then it is at least able to exist in an environment where change (requiring time) is impossible. Whether or not this creative agency is, metaphorically speaking, "logical," "truthful," or can be "trusted," is yet another 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 must be lawless and beyond reason. The possibilities are: physical constraint, logical constraint, or no constraint. In later chapters, we will collect more information and will be able to narrow this down further.

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 *straight toward* this event's location in space and time.

Wherever else this agency might also be located, it at least completely surrounds us in a shell which has a 13.7 billion-light-year ($8x10^{22}$ mile) radius! And since this is also 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, answer 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 (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). Its existence cannot depend upon time. It must depend exclusively on lower-level causes.

This makes this agency self-existent in the same sense that Hawking hopes the universe might somehow turn out to be; the creative agency itself *cannot be created*.

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 – assuming that it did not cease to exist the instant "after" the big bang happened).

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 which had been self-existent). We also don't yet know, what sort of constraints (physical or logical), if any, might limit this agency.

Chapter 5:

Quantum Mechanics

Relativity is not the only weird thing that has been discovered about our universe. Equally strange is the discovery that all elementary particles (including photons) act like little "clouds" of "probability waves." What this means may take a little bit of explaining:

Imagine a series of ripples on a pond; if we float a cork on the surface, the cork will bob up and down as the ripples pass. Next, imagine a second set of ripples approaching that cork from a different direction at the same time; if these ripples are shaped and spaced properly, the second set of ripples can be made to cancel the first set, at the spot where the cork is floating. Even though two different sets of ripples pass that cork, it can remain completely stationary. However, a second cork, only a few inches away, can experience a different combination of the same two sets of ripples, and bob up and down with twice the amplitude as it would with a single set.

A "probability wave" (normally called a "wave function") is like a normal wave, except that the "wave crests" are areas of high probability and between them are areas of low probability. "High" probability corresponds to a region in the "cloud" where a particle is more likely to interact with other "particles" (which are also "clouds" of probability waves), and "low" probability zones are where it is less likely.

A "cloud" of probability waves is not really like anything we ever encounter in normal life. We might imagine a set of ripples on a pond, but it would

have to be a very strange set of ripples. These waves (representing perhaps a single electron or photon) might appear to be spreading out in all directions; then they might suddenly appear to jump together into a tight little group the very next instant. Two sets of these strange ripples might seem to pass through each other like normal pond ripples, or they might ricochet off of each other, restarting as two new point sources, and then taking off in different directions. Under some conditions, these "ripples" might even change spontaneously into completely different kinds of wave groups.

These "ripple clouds" all follow very well-defined mathematical laws; but the laws only predict *how likely* it is that any "particle" *might interact* in any particular way at any particular position and time. The laws simply cannot predict in *exactly which* of those probable ways, positions, or times a specific particle *will actually interact*. This may sound a little bit vague; let's get more specific:

Imagine a single file of electrons colliding, one at a time, with a particle detector. Each time an electron hits the detector, the detector will output a pulse of electricity. Next, aim two identical electron beams at the same detector. Depending on the details (including the exact location of the detector), the two beams of "particles" might actually *cancel* each other at the location of the detector, and no collisions will be detected! At the same time, a second detector, a microscopic distance away, could be detecting twice the number of electrons that it would normally. This is very much like the cork on the pond, except that the behavior is caused by things that are normally considered to be "particles" instead of waves.

Next, imagine that we aim one of these single-file beams of electrons at two separate side-by-side holes in some kind of barrier. Each electron can actually pass through both holes at the same time! If electrons were the simple point-like particles that we normally imagine them to be, this would be impossible; but since each electron is really a little "cloud" of waves, it passes easily through both holes. When each electron (singular) emerges from the two holes on the other side, it continues on as *two separate sets of probability waves* (each with only half of the total probability). These two groups can pass through each other like any two sets of ripples might. When this electron (still singular – even though it is now comprised of two overlapping wave groups) finally strikes a detector, *both wave groups* suddenly collapse into the *same location* on that same detector.

Like two sets of ripples converging on the surface of a pond, there will be some places where this single electron is "allowed" to impact, and other places where the probability amplitudes cancel and it cannot hit. The *probability* that the electron might hit any given spot can be calculated with great precision; but *which path* any particular electron will actually take, *cannot be calculated at all!*

If this sounds too weird to believe – or even to picture mentally, then you are probably following my explanation so far. Unfortunately, we can make the situation even weirder and harder to picture:

Again we will send a series of electrons, one at a time, toward two holes; but this time we will send whatever "probability fraction" of each electron comes out the far side of each hole in a completely different direction. We will also keep the two paths completely separate from each other, and put a detector at the end of each path. The result is that the electron will always hit one detector or the other; it will never hit both. This makes it *seem like* the electron must have passed through one of the two holes or the other – but not both. In fact it can be shown that it really passes through both holes – but that, in every case, one half of the electron's cloud or the other just seems to disappear as soon as the electron is detected on the far side.

This is true even if the two detectors are so far apart that it would be completely impossible for any signal (even if it were traveling at the speed of light) to make the trip from one half of the wave function to the other in time to prevent that other half of the wave function from also hitting the other detector. The electron (singular) will always hit only one detector – even if it is impossible for us to understand how this can happen.

To make things even worse, if the two isolated electron beams are brought back together again (without first hitting any detector), then the cancellation patterns within the target area will prove that the electron actually traveled both routes; but if any observation is made to determine which of the two routes each electron has taken, then the cancellation pattern can no longer be detected. Somehow, every part of a probability wave knows what is happening everywhere else in that cloud. The question is, "How?" According to relativity, this is impossible. Information *cannot* travel faster than the speed of light, yet experiments have been performed which prove that, in this case, it *must*.

This isn't all that is strange about the quantum mechanical world; weird kinds of particles like positrons (positively charged anti-matter electrons) were produced and studied in physics laboratories. Positrons turned out to be mathematically identical to normal electrons which were traveling *backwards in time*. Photons turned out to be mathematically identical whether they were presumed to be traveling backwards or forwards in time (remember no time passes for the photon itself – *it doesn't care which direction time travels*).

Consider an electron and a positron which collided, and destroyed 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 different descriptions of the same event; the mathematics would be identical either way.

Many other types of strange behavior were discovered. Maybe weirdest of all is the *observable* fact that some particles seem to be constantly popping in and out of existence. For example, the electrical repulsive force between two electrons turned out to be the result of the constant emission and absorption of photons which were simply popping in and out of existence, flying between electrons, and seemingly violating the conservation laws of position, momentum, matter, energy and time. However, all of the "violations" were within very small and mathematically predictable limits.

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

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

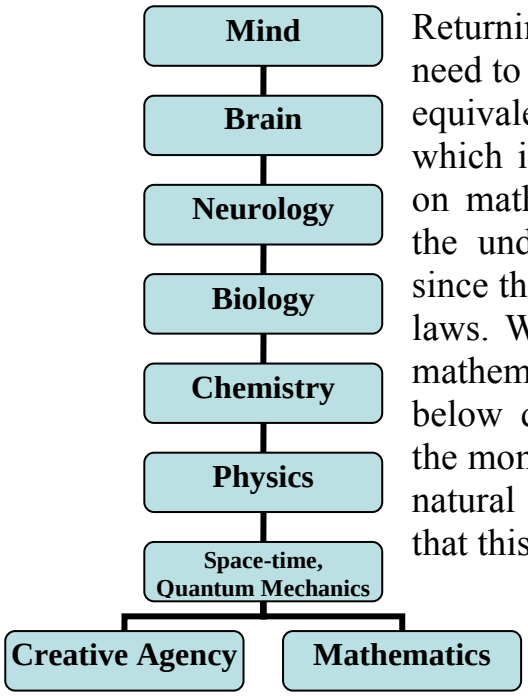
As the evidence kept, confirming the "rogue" behavior of elementary particles, physicists began to question whether "matter" had any substance at all, beyond the pure statistical mathematics of how "waves" and "particles" (sometimes called "wave-icles" in jest) interacted with each other. Since the behavior of particles (as much as it could be predicted at all) appeared to be dependent upon mathematics alone, there seemed to be no reason to assume that there was anything present except mathematics. Table tops still "felt" solid when physicists banged their fists on them, but those physicists began to suspect that "solidity" was exclusively a mathematical effect.

It was as if "mathematical law," and not "matter," was the primordial substance from which all other things were 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 tiny 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 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 quantum mechanics.



Returning to our causality diagram, we probably need to replace "matter" (and it's 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. We don't know exactly where to squeeze mathematics in, except that it belongs somewhere below quantum mechanics 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.

Since mathematics seems to be the underlying basis of space time as well as of quantum mechanics, 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 of expanding? In our simple balloon model, time was the radius of the balloon. If gravity were pulling the galaxies together, and if this radius was getting smaller, would this mean that time would be going backwards?

For another example of a strange question raised by quantum mechanics, consider this: If "anything" *might* happen in the world of quantum mechanics, 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? How can we answer questions like these?

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" simply seems to proceed from past to future. Those who may choose to argue with us must, at the very least, abandon the "*observation*" part of their dual foundation; we have staked out the "morally higher" ground. 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 "time" only follows the single path which we observe it to follow. This is also the "higher" ground.

But *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 law-abiding particles.

In spite of the underlying reality (whatever it may turn out to be), it is common to speak in terms of primordial "matter," as if it were something simple and comprehensible (especially in university philosophy departments). In normal life, it complicates things unnecessarily to drag out the horrifying details which are present in the real picture.

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.

Chapter 6:

From Quantum Mechanics to Brain

Before we try chasing the mysterious “tails” of our stack of causality, it may be helpful to take a closer look at the rest of the stack between those tails. Remember, the requirement is that each step in the sequence must provide enough foundational information that the next step up can be, at least in principle, fully understood. Our confidence may have taken a bit of a jolt in the previous chapters, but it should be smoother sailing for awhile. The next few steps harbor very few surprises.

As explained in the previous chapter, a free electron's probability-wave cloud can be spread out over *many times* the atomic spacing. However, when an electron binds itself to one particular atom, its wave function collapses into a much more compact configuration. While "collapsed," the electron does not abandon its wave nature; it merely "wraps" it tightly around an atomic nucleus.

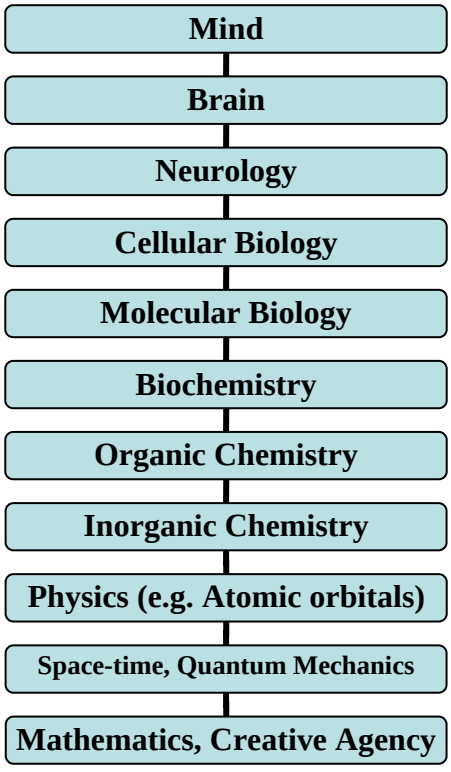
Instead of simply “orbiting” the nucleus of an atom, each electron occupies one of many oddly-shaped but mathematically defined probability clouds which surrounded the nucleus at different distances. These differently shaped clouds are named “orbitals.” They are assigned different letters (s, p, d, and f) to identify their specific shapes. The “s” orbitals, for example, appear to be shaped like “spherical” shells surrounding the nucleus; the “p” orbitals look sort of like figure eights (or more like two tear drops with their pointed tails touching back-to-back at the nucleus). The “p” orbitals are

arranged in groups of three in x, y, and z "polar" directions. The "d" and "f" orbitals have more complex shapes.

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

A chemical bond results from two atoms which each have a partly-filled orbital (containing only one electron each). 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 the Periodic Table of the Elements (which predicts how different elements 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.

This means that, the foundation for chemistry can be understood from the principles of quantum mechanics. Likewise, chemistry and biology flow smoothly through a sequence of connecting steps which might look something like what this diagram shows. Continuing up the chain, we can build smoothly through the study of the electro-chemistry of a single nerve cell, through interactions between multiple nerve cells, all the way up to the higher-level study of neurology where the human brain is studied as a whole. At the top of the stack, we finally reach that other mysterious tail – the subject of "mind." For some reason, *both* tails of this stack, are far from being well understood, while the rest of it flows together seamlessly.



It may be worth emphasizing that each higher step, in this stack, rests on *more* than just its immediate predecessor. "Biology" rests on "physics" as well as on "chemistry." It has even been suggested (by Roger Penrose) that, in some way, "mind" rests directly on "quantum mechanics." 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."

It may also be worth noticing that, with two exceptions, the layers are organized with the "hardest" sciences (the best understood, and the least tolerant of variation from the rules) toward the bottom of the stack, and the "softest" sciences (the least understood, and the most tolerant of variation from the rules) toward the top. The first exception is, of course, "the creative agency," which is tentatively stuffed in next to mathematics on the bottom layer, and which is probably the least-well-understood entry in the group; the second exception is quantum mechanics (on the next layer up) which is an odd mixture of being both the second best understood (most like pure mathematics) and second least understood (unpredictable) of the entries. For some reason (perhaps ironically), this is an odd reflection of the two entries on the supporting layer immediately below it.

Continuing up the chain, Carbon is the element on the periodic table which exhibits the most complex chemical behavior. It is the smallest atom which has four half-filled orbitals in its outer shell – making it combine to other atoms in the most complex different ways. This makes it the basis of organic chemistry and the foundational element underlying life. (Second place might go to the silicon atom which is the basis of semiconductor electronics which, in turn, is foundational to computers.)

Once given the remarkable carbon atom, it is not particularly amazing that it is able to combine with hydrogen, oxygen, nitrogen, and other atoms to form the complex arrays of atoms which are necessary to construct the primitive building blocks which are necessary for life. These blocks include many kinds of sugars, amino acids, purines and pyrimidines (which make up the "ladder rungs" of nucleic acid molecules RNA and DNA), and a great many other fascinating components.

Likewise, given these necessary blocks, it is not difficult to see how they can be combined into even more complex structures. Some of these structures include nucleic acids and proteins which are both necessary to make up the organelles and other structures necessary to assemble an operational living cell.

And next, given living cells, it is easily understood how subtle differences in the design of these living cells can make them perform different functions and even join together to make complex multi-celled creatures having functional nerves and brains. This takes us up our causality stack to the level of "brain."

Although there is no problem in this part of our chain from the standpoint of *causality* alone, there are a few serious *improbabilities* here which bother quite a few scientists. In fact, after doing the math, astronomer Fred Hoyle (the same rebel whom we encountered earlier), 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). In fact, because of this problem, several high-profile scientists, including Nobel Prize winner Francis Crick (in addition to Fred Hoyle) have 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."

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, "Origins, a Skeptic's Guide to the Creation of Life on Earth." Although that book is a little bit out of date and there are probably more up-to-date books available by now, I do not happen to know of a better or more recent book.

At least *causality* itself is in no danger from the relatively minor problems presented by this step. The problem of *original causality* is greatly more difficult than how *existing atoms* might have been organized into the earth's first life forms. For this minor step, causality would be equally well served by several of the different possibilities which have been suggested:

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.)

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; but his position is a commonly held one.)

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 we are trying to answer here – 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 that very small changes to the DNA molecule alone would accomplish *exactly* what is seen in the fossil record.)

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. Once given the first living cell, the necessary cellular machinery to replicate that cell, and the complex pattern on a DNA molecule that specifies *how to replicate all of that machinery* along with the 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 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. 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: According to evolution, a plausible path has been sketched out 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" 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.

This explanation certainly appears to be adequate to serve whatever need causality requires – even if it is a bit oversimplified; like relativity and quantum mechanics, "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 reason and it is based on both laboratory-based and field-based scientific observation*. (See An Introduction to Population Genetics, 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 has happened 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 Evolutionary Dynamics, by James Crutchfield and Peter Schuster.)

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 the method described by population genetics could not be what has actually happened during the course of life's history; but

that too would be an oversimplification. 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 a clue to the puzzle we are attempting to solve here. Either way, this is the evidence as we *observe* it – even if how we decide to *reason* out this paradox 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 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; this means his model for "God" must be "simpler" than the first living cell in order to make the argument plausible. Although Hoyle might have taken exception to this, I am willing to concede something that is effectively *more* than Dawkins is asking: I concede that the bottom "turtle" (on whatever stack I might propose here) *must not require any kind of causal supporting infrastructure at all*. This is, I believe, an even more constrained criterion than the one Dawkins has proposed.

In this chapter, I have carefully avoided taking the last step from "brain" to "mind." That step is sufficiently complicated that it deserves at least one chapter all by itself.

Chapter 7:

From Brain to Mind

Although our minds are far from being understood, our powers of *observation and reason* do fill in some fascinating details: First, and probably most fascinating, is the fact that we are able to "observe" at all! Our minds have what we call "awareness." We are not only aware of our surroundings, we are also self-aware; we can observe our own ability to observe! But whether we are observing "self" or something else other than "self," "awareness" is still a very strange phenomenon.

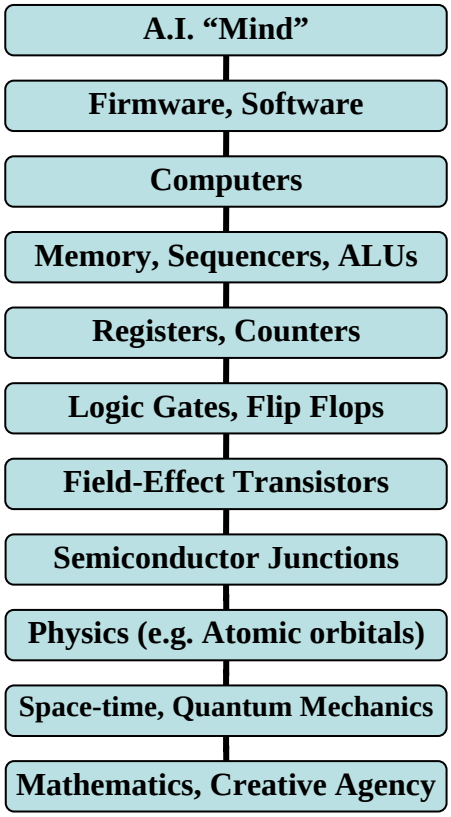
This *observable* fact is so amazing that many people have chosen to assert that awareness is merely "an illusion." It is *so* hard to understand how "awareness" can possibly be produced from the mere chemistry and physics of interacting particles, that sometimes it seems as if simple denial of the phenomenon would be an easier 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 what we can clearly *observe*. We especially cannot deny *observation* itself. Either we must accept the fact that we are able to make "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 use *reason* to sort truth from error? If a computer makes a mistake, it will simply report that mistake as if it were the truth. Why is a human mind sometimes able to tell the difference between its own mistakes and the rest of the conclusions it produces?

One interesting attempt to understand this problem is found in Penrose's book, The Emperor's New Mind. As hinted at in a previous chapter, Penrose has suggested that a causal foundation for some of the stranger features of "mind" might be found in a direct link to the "quantum mechanical" causality layer; he has even gone as far as identifying neural structures which may allow for this link. However, it is still fair to ask why we should expect *random* quantum behavior to be any more likely to produce *awareness* or *reason* than normal predictable causes might be.

Penrose and others have attempted to understand our minds through the study of artificial intelligence (AI). From very humble beginnings, like electro-mechanical Tic Tac Toe machines, AI has made some amazing progress. This includes Chess programs which have been able to beat human grand masters.



The foundational structure behind artificial intelligence may be organized something like what is shown here. All of the steps from the mathematics and quantum mechanics of semiconductor junctions, clear up to high-level Chess programs, are so well understood, that they have now become parts of low-cost consumer products. Practical applications are seen in such diverse fields as engineering, management, accounting, production, 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 AI experts completely baffled.

Historically, the problem has been divided into two categories called "weak AI" and "strong AI." "Weak AI" is the first step – the attempt to simulate every aspect of the human mind except for the "awareness." "Strong AI" is the attempt to take the technology all the way to a real self-aware "mind." Although at least the first step (weak AI) was generally expected to be possible, for some reason a few aspects of simulating the human mind still remain beyond our reach. Even "weak AI" has eluded the experts.

I'm going to suggest that this particular division (strong vs. weak AI) is misguiding us to some extent. An examination of the normal way psychologists separate the same two functions may illustrate the problem. This "normal" division of mind is between its conscious and subconscious functions. In one subtle but still very important sense, this division turns out to be *quite different* from AI's strong/weak division.

We will begin with a few experiments to illustrate this division between the conscious and subconscious 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" should disappear. (We can 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 this same approximate place.

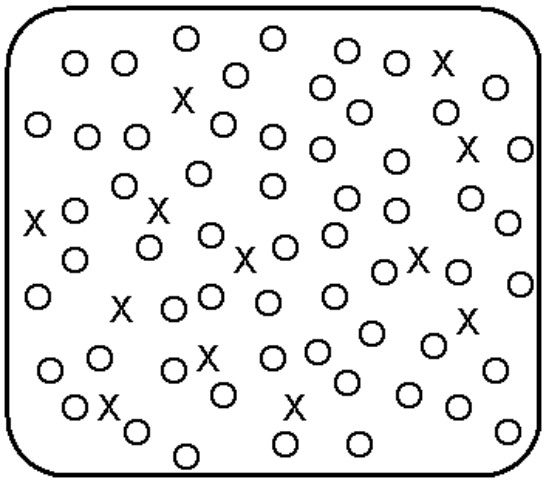
L **R**

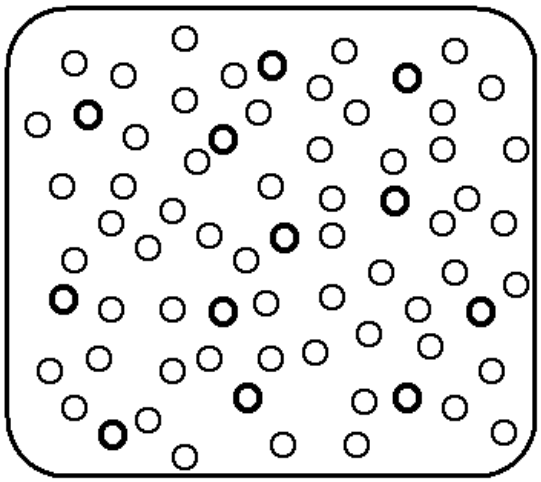
If we are trying this experiment for the first time, the result is likely to surprise or even *startle* us. We are unaccustomed to having obvious things simply disappear from right before our eyes. Yet this is what happens.

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, it 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 (**L**) example, try it with the highlighted characters in (**R**) this line; while the highlighting disappears, we somehow get the impression that the text is still all there (although it may seem to be a bit indistinct).

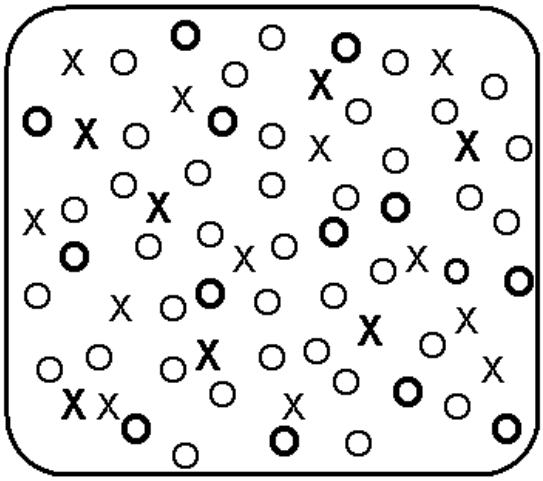
This experiment gives our *conscious mind* a chance to catch (or *observe*) our *subconscious mind* in the act of performing one of its many routine tasks. Notice that this is a *sharp* division. No matter how hard our conscious minds might try to fill in our blind spots differently, our subconscious will always fill it the same way. It is a trivial matter to separate, mentally, the two parts of our mind; 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 one, or the bold "O"s in the right? It should be pretty easy. This is because our subconscious mind locates them for us.





Next, how difficult is it to locate characters which are both bold and "X" in the pattern to the right? This time, our subconscious mind will not be helping us out as much; it hasn't been "wired" to identify these two characteristics at the same time. It's almost like 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 "train" it to locate patterns or solve problems which it wouldn't normally be able to do. As I type this, chapter, my fingers transfer the word 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. (Unfortunately, because of the content, I really was thinking about what I was doing while I tried to write that last sentence – and, as a result, I very nearly forgot how to type and spell).

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.

There are many other experiments we could perform to help identify the differences between these two parts of our minds; but we are sufficiently familiar with our own minds that it 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 – looks for solutions
Pulls own name out of noise	Must listen to every word
Remembers facts and conclusions	*Observes and Reasons*
Memorizes logical theorems	*Feels* axiomatic truth
Suggests alternatives	*Chooses* from alternatives
Provides information	*Requests* information
Learned reflex motor control	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), seem to be the first to express itself in very young children; it is also seems to be the last to go in old age (when memory and other automatic functions are well on there way to deterioration). This suggests that these two parts of our mind might be generated *very differently*.

There is also an extreme difference in how we relate to at least some of the entries in the two parts: If by some operation we could improve our capacity to remember, or increase our ability to learn, most of us would consider the operation to be worthwhile – or even valuable; but if a similar operation were available which promised to improve our ability to "choose" or to "reason," most of us would be horrified by the prospect. It is as if we regard at least some parts of the left column to be mere tools, while *we ourselves* live in, at least, some parts of the right.

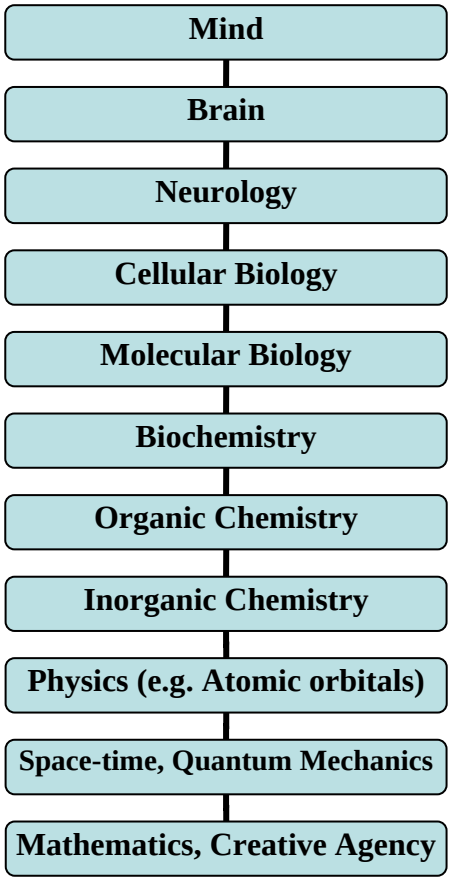
As a first guess, it might seem that "weak AI" would involve the subconscious functionality; and "strong AI" would also include the conscious functionality. As a closer look reveals, that is not really the correct division; in order even to simulate a human mind, *both* columns must be handled in a convincing manner. *Even "weak AI" must somehow simulate consciousness.* Of course it is the *conscious* functions which are presenting the most stubborn obstacles – even to "weak AI." Terms like "observes," "reasons," "feels," "chooses," and "requests," in that column ,all imply some kind of "initiative" or "will" which has been very difficult to simulate. The terms 'slave" and "master" also seem to do a pretty good job of sorting areas of AI functionality with regard to "success" or "failure."

There is something very strange about this conscious/subconscious division; it seems completely backwards that "expert" level functionality should already have been achieved, while "novice" level functionality is among the things which remain beyond the abilities of the experts to simulate convincingly. Why should A.I. 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. It is almost as if the order of difficulty of those two tasks is *reversed* in some mysterious way.

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 has suggested that this might not be the case. This problem might have been anticipated by studying a very young or mentally-challenged child. In these cases, all of the "master" functionality

seems to be in place (children *never* seem to be particularly "challenged" in the area of "will") – even when there is insufficient "slave" functionality to cobble together something as simple as a trivial counting mechanism.

Most AI researchers are either looking for the solution to the problem which seems to be holding things up, or pressing ahead, performing "miracles" with what the working parts of the technology are already able to deliver. Others are "cheating" by cloning organic neural tissue to assume the "master" role in their experiments.



In any case, with two exceptions, causality seems to be behaving itself as it ought. The first exception is, of course, that haunting first step – from nothing to something. In the final chapter, we will try to make some kind of sense out of this.

The second exception is that last "little" step from brain to mind – particularly to *conscious mind*. Although this connection failure is present in both biological understanding and in artificial simulation (suggesting the gap might have substance which is independent of specific methodology), it is so near the top of the stack that it hardly seems to matter if we just ignore it. 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 gap as they have closed all of the others.

Or maybe both gaps are important clues to solving the puzzle we are trying to tackle here.

Chapter 8:

From Mind to Logic and Mathematics

The concept 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).

As flimsy as logic's foundation may seem to be, logic still has a lot going for it. For one thing, almost everyone seems to understand its rules the same way. For another thing, it enables us to accomplish great things – like the design of sophisticated, (and very useful) computer systems. When we chose "*observation and reason"* to guide our search here, 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 does. In fact, most people seem to feel that logic has an almost primordial existence; most of us seem to be convinced that somehow *logic* would remain – even if our minds and the rest of the universe were to be removed.

What is it about logic that makes us all seem so convinced of its validity? In an argument, when we are convinced that our adversary has somehow come to the wrong conclusion, we almost always attribute his error to misinformation rather than to an inability to reason logically. For this reason, we nearly always appeal to his sense of *logic* as the basis for our argument.

Why shouldn't we be as likely to assume that our adversary is simply unable to *reason* logically? The first two sentences of Rene 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 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 ourselves and each other.

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*, most 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. We encountered this briefly in an earlier chapter.

Although we are still a long way from understanding how the conscious part of the human mind works, logic seems to be an *inseparable* part of it. The minds of sharks, turkeys, lobsters 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 that is better described as mere "instinct." Humans, on the other hand, all seem to embrace logic – even when we cannot be made to agree on anything else.

It might help if we take a closer look at what logic is and how it works. To begin, there is an important difference between "logic" and "truth." A *logically valid* conclusion is not necessarily the truth; it will be no truer than any premises upon which it is based. For example, if I am given the following two statements …

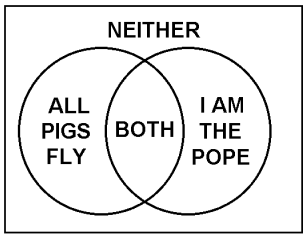
1) All pigs fly
2) Wilbur is a pig (I mean the four-legged kind in both statements)

… I can reach the *logically valid, yet untrue* conclusion that Wilbur flies. As they say in the data-processing industry, "Garbage in – garbage out." We must have true information before we can reach a true conclusion.

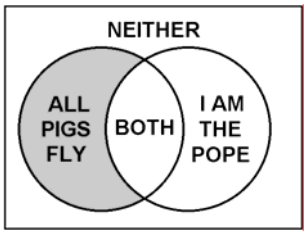
Having a false premise is not the only way to reach a false conclusion. "Logic" *must* deal with "black and white" propositions. Formally, this is called the "Rule of Excluded Middle." A proposition must be either true or

false; it cannot assume any value in between (thus being neither completely true nor false). This is not just an arbitrary restriction; even *valid* logic can be made to produce some completely absurd results *if we feed it any kind of contradictory information* (information which is neither exactly true nor false).

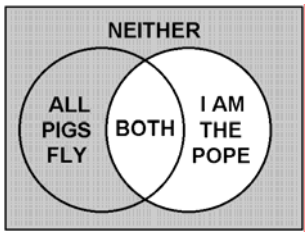
If we assert that any proposition (for example, "all pigs fly") and its negation ("it is *not true* that all pigs fly") are *both* true (or are both false), then we can prove absolutely anything at all to be true. For example, here we will assume that all pigs both *do* and *do not* fly; from this we will reach the logically valid, yet completely false and *unrelated* conclusion that I am the Pope:



Part 1: In this diagram, the interior of the left circle (including the area labeled "both") means that "all pigs fly;" and everything outside that circle means that "it is not true that all pigs fly." Likewise, the inside of the right circle means "I *am* the Pope" and its outside means I *am not* the pope. The area labeled "both" means both that pigs fly *and* I am the Pope; while neither is true in the border area outside of both circles.



Part 2: Here we only consider those cases where I *am not* the Pope, focusing on the two areas outside of the right circle ("neither" and the left crescent-shaped area). We start by assuming that it is *not true* that all pigs fly. This eliminates the shaded crescent part of the left circle (where I am not the Pope and all pigs fly). This does not eliminate either of the two areas where I am the Pope; it merely ignores both of them.



Part 3: Still focusing on *only those two areas where I am not the pope,* we now apply the contradiction – treating "all pigs fly" *as truth*. This step eliminates the additional area marked "neither" where pigs do not fly. As before, we ignore the two areas where I am the Pope. At this point the only possibilities which we have not eliminated are inside the right circle where I am the pope! This forces the logically valid (yet false and *unrelated*) conclusion that I must be the Pope.

In parts 2 and 3, we deliberately ignored any conclusions that might have been reached by assuming that I was the Pope. The premises that pigs both do and don't fly certainly *could* have allowed us to eliminate the two parts of that area as well as the two we did eliminate. Instead we deliberately ignored these possible logical conclusions so that we could "prove" that we are the Pope (in part 3). Although this was ignoring conclusions that we *could have* made, we did *not* actually make any conclusion which *violated any logical rule*. We used *correct* logic – even if we did not explore every possible logical conclusion.

The point is that a problem *can occur* when we have contradictory premises (even when we are using valid logic). Notice that it doesn't matter a bit what labels happen to be written inside those two circles. Instead of, "I am the Pope," the right circle could have contained, "the moon is made of green cheese." Likewise, the left circle's contradiction might have been, "all mice both *are* and *are not* space aliens." No matter what labels are selected, if both a statement and its contradiction are presumed to be true (or both presumed to be false, for that matter), then absolutely anything at all can be concluded.

There are some other kinds of trouble which we might encounter: For example, consider the statement:

"This statement is false"

If this statement is assumed to be true, then we must accept what it says; unfortunately, what it says it that it is false. If, instead, it is assumed to be false, then what it says is in agreement with the truth – making the statement true. This single statement violates the rule of excluded middle all by itself. Since the statement implies its own negation, and vice versa, then we can use it to "prove" that we are all the Pope, the moon is made of green cheese, or anything that else we might wish to prove.

What we need to remember here is that the world of logic is a world of black and white – of true and false statements. It is important to avoid premises which violate the rule of excluded middle. Assuming this sort of "shade of gray" for our premises might lead to some meaningless conclusions. (For example, as will be shown in the appendix, Gödel's famous incompleteness theorem turns out to be an error; it is based on this same sort of faulty "middle valued" assumption.)

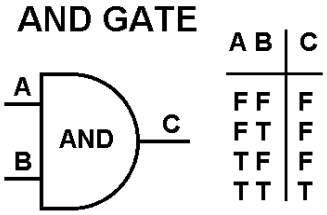
For the next step, although the world of computer logic has much in common with the kind of logic and mathematics that humans use to construct proofs, there is one very important difference When a student of algebra studies the sequence of characters: "N = N + 1," he sees an "equation" which expresses 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 the number "N" and assigns it a new value to it by adding "one."

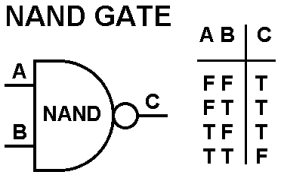
The difference is *time*. Computer based arithmetic and logic happen *sequentially within time*. But normal human symbolic logic and algebra are comprised of symbols which "sit still" on the paper. To the student of algebra, both sides of the "equation" (to the right and left of the "equal" sign) have *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 the "result" *after* the statement is executed. That "N" is used to identify a location to store the result. If "N" had been "2" before execution (of N = N + 1), it would be "3" afterwards.

In some ways, symbolic logic and algebra seem to personify conscious human reason; while 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, some of the thoughts that form are truths whose native world might very well have no use for time. On the other hand, the electrical states within a computer circuit 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.

When a student of symbolic logic says that "A AND B is TRUE" they mean that "A" is "True" and "B" is "True." A student of computer science represents the analogous function with a digital logic AND gate.

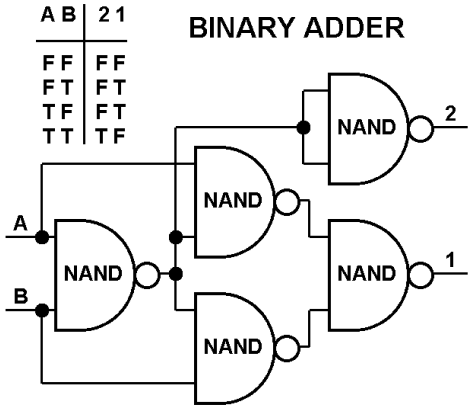
A digital logic gate is a simple electronic circuit which accepts one or more inputs (A and B) and, shortly *afterwards*, generates an output (C). The AND gate (symbol on right) performs the logical function: "C IF AND ONLY IF A AND B." The "truth table (also right) shows the different states "C" will assume for all four possible combinations of "A" and "B."

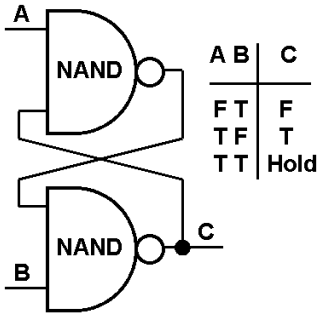




For various reasons, a NAND gate (left) is more commonly used than an AND gate in computer design. A NAND gate simply outputs the opposite, or *inverted*, state from what an AND gate outputs.

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.



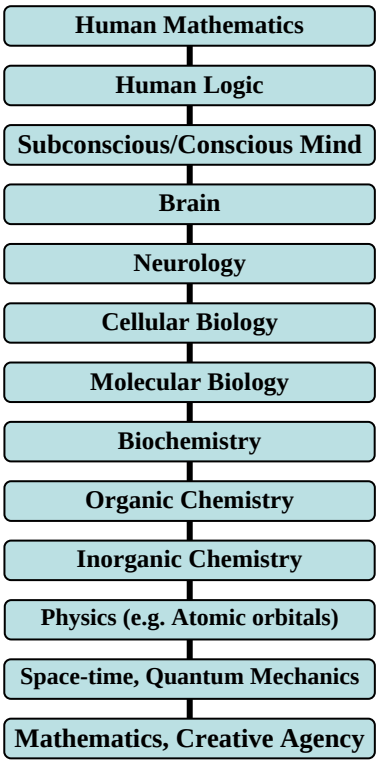


Because computer logic happens within time, "memory" circuits become necessary to hold patterns of information. A simple memory circuit, called a "flip flop," can be constructed with two NAND gates as shown (left). Applying a "False" signal to input "A" causes output "C" to become "False;" applying a "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.

Any of the logical operations which a complex computer system can do could, in principle, be done with some combination of NAND gates; this means there is *nothing* that a computer system does which cannot be done with some combination of primitive logical operations. Since computers are, in principle, capable of performing any mathematical operation, it would

seem obvious that primitive logical operations comprise the complete causal foundation for mathematics. This is interesting to us here because it demonstrates the causal bridge between computer logic and mathematics.

It has also been shown (see *Principia Mathematica* P.M., by Bertrand Russell and Alfred North Whitehead, published 1910-1913) that the "time-independent" human form of mathematics can be derived from a small collection of logical rules and axioms (the time-independent form). Russell and Whitehead specifically derived addition and multiplication for natural numbers, but the remainder of arithmetic follows logically from this start. (And, of course, logic seems to be inseparable from human minds.) This means we can add some steps to the top of our causality sequence: From mind, we also get logic, basic arithmetic and then all of mathematics.



Unfortunately, now we have a real problem: We have "mathematics" at both the top and bottom of our chain of causality. The good news is that we have "eliminated" the "uncaused" hanging tail from the bottom of our chain; the bad news is that we have created a "loop" – which is probably even more absurd! If *reason* means anything at all, we can be certain that this loop is falsely joined at some point. This means we have made some kind of mistake – which we must now locate and repair.

Chapter 9:

Can Logic be Trusted?

As I explained in the first chapter, and, as I have frequently repeated, this book will depend upon our powers of *observation and reason* to reach its conclusions. Everything must be tested by these powers to keep us from accidentally heading off in a wrong direction. In spite of this, we have strayed from the "straight and narrow" somewhere; and we must now 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 happens if we turn these powers against themselves? For example, what happens if "reason" is tested by "reason" itself? It turns out that the exercise is quite interesting; it even provides the final missing piece of the puzzle which we are trying to solve here.

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, one such word is our English word "because" which plays a key role in our concept of how logic itself works. Lewis explained that 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 healthy," I mean that the healthy food which I eat is a *cause* which produces the *effect* that I am healthy.

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 healthy 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.

Notice that my good health does not cause the food I have eaten to be healthy; nor is the fact that I eat healthy food necessarily grounds for concluding that I am, or 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 were 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 were 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 mechanically caused. 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 now 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 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 evaluation of the results.

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?

We are reminded of our failed attempt, in a previous chapter, 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 will have to make a completely arbitrary decision:

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

If we choose "B," then we can stop 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*.

But if we continue with the argument, as we are presently 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 other logical discussions as well). However, as long as we proceed, we are doing so on the assumption that our thoughts have meaning – and, that we are potentially able 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 deal with later; first, we will merely follow the argument to wherever it takes us:

One consequence is that our *choice* has to be *real*. If our "choice" is merely the end result of a chain of causes (because[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 consequence that *choice* (implying an *uncaused* or "free" will) must exist at some level (as we seem to *observe* that it does).

The question of the existence of "free will" is a very controversial one. Oddly, most of those who consider "free will" to be merely an illusion, also claim to 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 the paradoxical elements. The result of this "paradox" has elements which

are very strange; but at least they are no stranger than the concepts we encountered with relativity or quantum mechanics.)

Next, assuming we are still on the “A” path, this choice forces us to assume that the terms "true" and "false" (which logic assigns to propositions) can acquire the status of being objective facts about the real world. In the previous chapter, we saw that logic was a world involving non-contradictory black and white statements. By taking the “A” path, we have simply endorsed logic and have stepped into that world ourselves. Denying this would, as before, be denying the validity of logic – and our ability to use it.

Next, still following the “A” path, we can see that it would be "right" to assign the term "True" to logical constructs which deserve that term, and "wrong" to assign the term "False" to those same constructs. In this way we have made one very shallow excursion into the realm of human morality. From this small beginning, many deeper excursions can be logically derived. And since we have now endorsed “morality,” what “ought to be” (instead of merely what “is”) has also becomes an endorsed part of our real world.

It is possible that 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 of human *reason* (never mind human morality). 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 here. Maybe there is some way that valid grounds for belief can be achieved, even in a mechanically caused world.

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 or real “random numbers.” These sequences *appear* to be random; but the sequences eventually repeat in a loop. 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 *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 like it might have great potential to produce various "creatively selected" designs for different creatures which are still *well optimized*.

Unfortunately, in this 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, sharks, dandelions, molds, cold virus, 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 form 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 a year's wages and a banana or a mackerel correctly. Even among humans, most of us seem to do at least as well (in regard to survival and reproductive fitness) with physical exercise as we do with a PhD. 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. This is, of course, a circular argument. It starts with the assumption that we do have logical reasoning capabilities; 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.

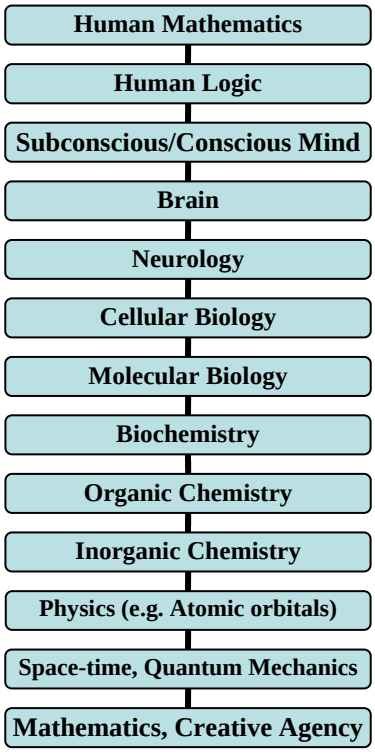
Evolution was not bound to produce logic or mathematics; yet somehow, both exist. If evolution *did* produce our logical minds, it was, at least, not, in any way, an inevitable result; at best it would have been an accident. More probably, logic is contrary to evolution's goals; "Physical victory" and "logical truth" usually seem to be at odds when they are encountered together. Evolution does not appear to be a very safe place to ground our trust.

Unfortunately, we still seem to be stuck with the need to break free from our foundation of causality – even though it leaves us with a whole chain of questions: How can we logically build from what merely "is" to what "ought to be?" or 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 we are finally ready for what I believe to be the answers.

Chapter 10:

Breaking the Loop

With the exception of having mathematics at both ends of our stack, everything else looks reasonably good just the way it is. Unfortunately, this doubling does indicate some kind of problem which might be just the tip of a very big 'iceberg."



Maybe we are wrong about the primordial sort of mathematics at the bottom of our stack being the same sort of thing as the kind of mathematics which resides in human minds. Is it possible that we are merely using the same word to identify two *very different* kinds of things?

Unfortunately, there are several clues which seem to suggest otherwise: First, we would need to convince ourselves that it is merely a coincidence that the two separate things that we just happened to have called "mathematics" are located at exactly the two opposite ends of our stack, where they suggest a loop. If we randomly chose two of these thirteen different causality levels to call "mathematics," we would have only one chance in 156 (or 12 x 13) of picking the two extreme ends. The placement of these two seems to be at least mildly suspicious.

Besides, we didn't pick the word "mathematics" arbitrarily; we really mean the same sort of thing at both ends of our stack. The "primordial mathematics," which is foundational to the observable events of the quantum-mechanical world, is functionally identical to the "mathematics" which men have dreamed up out of their minds. Both are represented by exactly the same equations; and both "predict" (although in slightly different senses) the results of the same physics experiments. Further, both seem to be of the "timeless" sort; we intuitively sense that "mathematics" of any kind would exist – even if the universe were to be removed. The two are too similar to chalk it up to a mere duplication in the terms we are using.

Perhaps human mathematics is just some kind of "echo" of the primordial sort – but what kind of Echo? They are certainly both very similar; but what would the *difference* be? What would separate human and primordial mathematics? Probably the most obvious difference is that the human mind's thoughts (which are foundational to human logic and mathematics) take place sequentially within time; so it would seem that human mathematics must also take place sequentially within time. Unfortunately, human thought it not really as sequential as it might, at first, seem to be.

When I was first learning how to write, I remember thinking that writing was very hard work. Now that I have written a few books, I *still* think writing is hard work; however, now that I have had some experience, I can understand *why* it so hard: The problem is that writing must be completely sequential – while our thoughts are anything but sequential.

A book is a single-file sequence of words. Every → word → has → its → exact → place → in → this → sequence. No two words can overlap. Sentence structure cannot branch out in multiple directions. In stark contrast to this, our thoughts connect together into a complex "web" which heads off in many directions at the same time. A writer wants to communicate a whole "web" of his thoughts; but writing them down forces him to arrange them into a single line. This involves cutting his "web" of connections apart into little pieces of "string," then connecting those "bits of string" together again end-to-end. Finally, the writer must repeatedly backtrack, to explain all of the now-missing connections – after the links are no longer fresh in either the writer's or the reader's mind. This can be a tedious and frustrating task.

Backtracking to my point, writing is difficult and unnatural because our thoughts are not naturally sequential. Even though our thoughts seem to

happen within time, they are not "shaped" anything like the single line of time which our minds experience. They are not really as "trapped" in time, as it might seem; *time* becomes a limitation to us when we try to communicate those non-sequential thoughts to other humans through a sequential medium like speech or written text.

In an earlier chapter, we saw the same thing in human mathematics: The equation, "N=N+1," may be written as a sequence of characters; but there is nothing sequential about the concept it conveys; both N's share the same instant of conceptual time. Computer programmers deal with temporal mathematics; they, quite naturally, write each mathematical command as a simple sequence of characters. By contrast, other mathematicians can be more comfortable spreading their equations out across the page in two different directions – as in the following mathematical definition of an "inverting matrix" called "**b**":

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

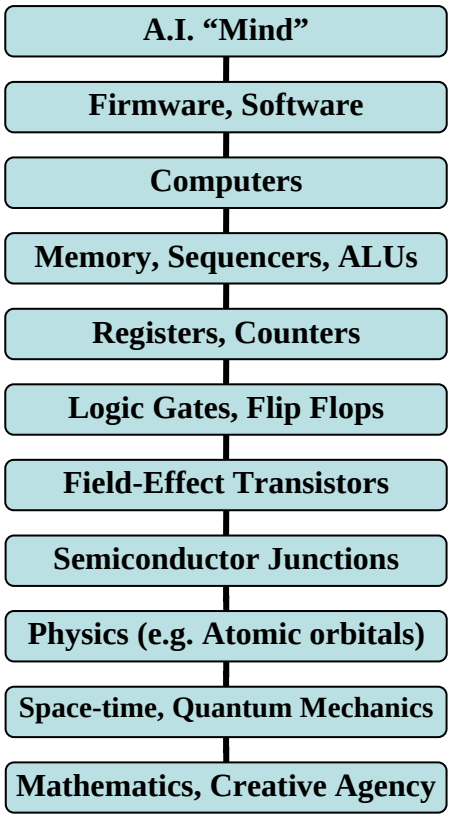
Converting this two-dimensional representation into a single sequence of characters (e.g. for a computer program) would require many times the amount of text; and the converted form would be much more difficult to understand. If we were to try to explain, here, what this two-dimensional representation means, it would take a very long sequence of English words. It might require an entire chapter (or more) of a mathematics textbook – depending upon where we might have to start. However, a trained mathematician can grasp the meaning of this definition with a single glance.

Now, to tie this little piece of "string" back into the earlier point that I was trying to make all along: If the difference between primordial mathematics and the human "echo" of the same thing, were that the echo was trapped in time, then our thoughts really ought to have been trapped in time. They aren't – at least not in any sense that would make life easier for a writer.

We might try to argue that human mathematics differs from the primordial form since it isn't sufficiently robust to *cause* an entire "world." However, it is a simple matter to demonstrate otherwise: Human mathematics, with the

aid of its supporting layers (human logic and human mind), has *already* nearly completed the replication an entire world of sorts:

By using human minds, human logic, and human mathematics (all three from the top of our stack), men have begun building up (from near the bottom of the stack), and have created a silicon replication of some very complex aspects of intelligent life – working *almost* all the way back up to the top for a second time. (They have even produced a "*third form" of mathematics* which operates in the computers which they have both dreamed up and constructed.)



By doing this, they have demonstrated that the power of human minds, logic, and mathematics, is sufficiently robust to direct the creation of a silicon version of a chain of causality – all the way up to some very robust forms of A.I. (if not quite yet to a conscious A.I. mind).

If we could ever create a real A.I. mind (remembering that we haven't quite done this yet), then it seems reasonable that subsequent A.I. minds could repeat the process – duplicating themselves for innumerable cycles.

Maybe we could also design a virtual world for those silicon minds to occupy. We could choose the "laws of physics" for their world; and we could interfere with it in any way that might amuse us. Perhaps we could give them the ability to explore every corner of their virtual world. Eventually, one of their scientists might even notice the mathematical nature of his world and speculate that his existence might rest on nothing more than operations on binary numbers. However, unless we were to grant those beings the ability, they would not be able to "see" outside of their own world – just like the circular inhabitant of Edwin Abbott's "Flatland" was unable to "see" outside of his limited world.

Of course those beings could create similar model worlds within their own – and so on. Such repetitions could continue until all of the resources which we originally granted them had became exhausted; but they could not replicate infinitely within a world having only finite resources.

This is a fascinating exercise, and it might even appear to provide an ultimate explanation – until we stop looking "up" the cycling stack of turtles and look back down. Then we remember the troublesome bottom "turtle." We may have modeled a series of causality cycles, but this system can't really sustain itself indefinitely; and it won't explain the bottom "turtle" either. We need a different explanation.

Our causality "loop" must have some kind of "very bottom end" to it. In order to arrange it back into a properly terminating line, we are going to need to "draw the line" somewhere and "cut" an "end" free from our "loop."

We needn't worry about promoting the flimsy "God of the gaps" sort of theology here (where we try to invoke God every time we can't explain some gap); in fact, we have, evidently, been guilty of the opposite mistake: We have been so willing to "explain away" the "unexplainable" that we have inadvertently constructed a *gapless "loop;"* we have carelessly tied up at least one loose end which should have remained loose!

At this point, we are ready to go looking for that bottom "turtle." Let's start at the "bottom" of our stack (at primordial mathematics) and start working our way around the "loop" in the "downward" direction.

Since the level immediately "below" "mathematics" is "logic," we would naturally expect to find "primordial logic" below "primordial mathematics." As we saw in a previous chapter, mathematics is obviously based, at least in part, on logic. Further, even "human logic" has a "primordial" quality about it – just like "human mathematics"; it appears to be something which would exist, even if the entire physical world were to be removed.

Of course "primordial logic" cannot be a "physical" thing any more than "primordial mathematics" can be. Instead, it must be some kind of "concept" or "idea;" but "concepts" and "ideas" are both "thoughts;" and "thoughts" exist within "minds" – which is the next level own on our causality stack.

When “mind” was safely at the top of our causality chain, it seemed plain to us that logic was a part of conscious thought, and that logic resulted directly from thought; but down here at the bottom, this same general idea may be starting to sound just a little bit spooky. Down here we seem to be dealing with some kind of “primordial mind,” which, somehow, exists separately from our own personal, individual minds.

Things are already starting to get strange here; but what happens if we try to go farther down? The next step down would be “brain.” Since the links in our causality chain are all *very solidly* established from “brain,” all the way down to “primordial mathematics,” we would either have to stop here, or continue all the way around our “loop” again. If there is a bottom “turtle” at all, *which there must be,* then that turtle would seem to be very close to this level.

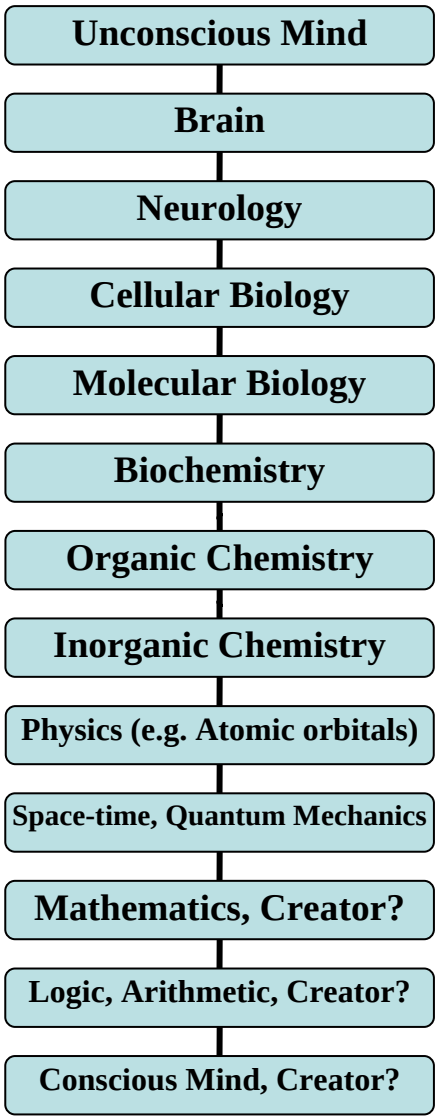
When we examined the workings of our human minds, in a previous chapter, we noticed that they were very poorly understood in terms of their supporting layers. Interestingly, this happened to be the *only link* in our “circular” chain which hadn’t been *very well tested*. In stark contrast to all of the other links, we had sort of been *taking it on faith* that there was any kind of causality link at all between “brain” and “conscious mind.” (The link between “brain” and “subconscious mind” is somewhat better understood.)

Furthermore, when men began simulating the biological path in silicon, they successfully duplicated every step of the way from the quantum mechanical level, right up the chain to a chess-playing machine that could *beat the best human players on earth* (playing more like an “expert” than like a “novice”); then, somewhat mysteriously, they were completely unable to take the next step. This happened within *the same general causality step* that the biologists had been unable to bridge successfully.

Focusing on the AI path (since we appear to understand it more precisely than the biological path) it looks like the “weakest link” in our circular “chain” of causality is likely to be at the same point *where AI failed*. As near as we can tell, that failure is located between what we call “subconscious mind” and “conscious mind.” What might the consequences be of severing our chain of causality between those two parts of our “minds?”

As we saw in a previous chapter, those two parts don’t seem to be so terribly mixed together that they would be overly difficult to separate; in fact, in

many respects they appear to be more like *opposites* than like aspects of the same thing. In one respect, they even appear to have their order *reversed*, (expert level operation being easier to simulate than novice. level).



It is a simple matter to try cutting the loop at this point to see what sort of consequences would follow. (See the illustration to the left.) Furthermore, as we have seen, *this is really the only reasonable place where we could cut the loop;* every other place we might try to make the necessary cut leads to one kind of *serious problem* or another.

Separating the "loop" at this point would put "subconscious mind" on the top of the causality stack, and would bring "conscious mind" down to the very bottom; it would also rotate logic and mathematics down to the two positions right above the bottom; and, of course, it would also bring the two levels labeled "mathematics" together, so we can combine them into a single layer.

The idea of cutting the loop at this point may take some getting used to; it might also require some adjustments to how we view our world: For one thing, the old term "subconscious mind" no longer sounds appropriate (since it is no longer "below" "conscious mind"). Instead, we will use the more generic term "unconscious mind" here.

Putting "conscious mind" *(including our own conscious minds)* at the bottom of the chain of causality is certainly a very strange idea; but it is really no stranger than what we have already encountered with relativity or quantum mechanics; in fact, as we will see in the next chapter, it actually has quite a few things going for it.

Chapter 11:

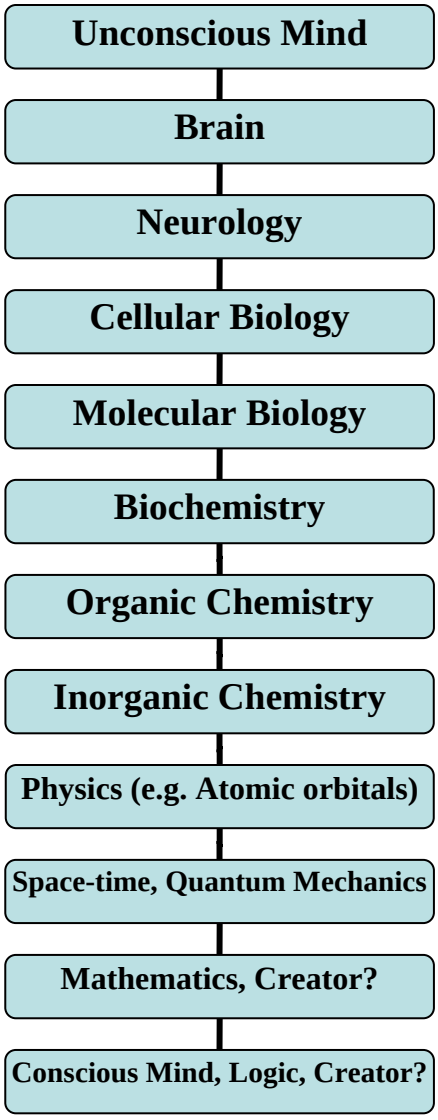
Theology of Observation and Reason

In the previous chapter we decided to try cutting our causality "loop" between the "unconscious mind" and "conscious mind" causality levels (this appearing to be the least unreasonable place to break the chain). Here we will consider the consequences of that choice, and see if we can also make some kind of sense out of everything we have examined up to this point.

"Conscious mind" may sound like a strange thing to put at the very bottom of the stack. However, *whatever* we put at the bottom of the stack, it has to be able to rest on nothing. The trick is to find something to put there that *needs* no support. When we *observe* our own conscious minds, we are left with the impression that there is something *very unnatural*, non-material, or even "spooky" about them. This suggests they might really have some kind of "primordial" type of existence. Further, when we attempted merely to simulate conscious mind electronically (never mind really creating it), we were unable to get anywhere. This particular "link" in our causality chain almost seems to be asking to be the point of separation.

However, logic's intrinsically un-provable nature might seem to locate *it* at the very bottom of the stack instead. It is on the very next level up, but, as we have seen in a previous chapter, it *can have nothing* foundational from which it might be derived. The very "bottom" seems to be where logic really belongs. We have already noticed (also in a previous chapter) that "human mind" and "human logic" seem to be inseparable in some enigmatic sense. If we simply combine the "conscious mind" and "logic" layers, both problems

disappear at once – leaving conscious mind and logic inseparable. When we had "human logic" near the top of the stack, it was difficult to understand how it could be so useful although it could not, even in theory, be shown to be valid. Here at the bottom, this is what is naturally expected.



This arrangement also eliminates the "is/ought" paradox. The concept of "what ought to be" seems to be grounded in logic or in conscious mind, instead of in matter, or in its derivative – unconscious mind. This would put "ought" at the bottom of the stack – below (and therefore in control of) all of the levels where "what is" dominates. This lower position for "ought" actually makes better sense than the conventional higher position:

Earlier, we had noticed that there seemed to be no way to build from what merely "is" to what "ought to be." On the other hand, it is a simple matter to build in the opposite direction – from what "ought to be" to what merely "is": When "mind" makes a choice, then acts on it, "what ought to be" can become "what is." (Interestingly, this also allows "what is" to assume the opposite state: "what *ought not* to be." What "minds," like our own, *choose* does not necessarily always have to be "good." This allows for worlds which contain "pain" and "suffering" – worlds like our own.)

Next, we noticed earlier that as long as we remain on the "A" path, our grounds for trusting logic *depend upon* a severing between human reason and causality; the goal of maintaining a hold on *observation and reason* requires this. With the present arrangement for the layers of causality, *this is not a problem at all;* instead, it becomes normal and expected. In fact, this arrangement eliminates all of the apparent paradoxes which had bothered us earlier. Instead of being difficult to resolve, they simply disappear.

Under this model, "mathematics" is a consequence of (or possibly a part of) "conscious mind" (whether human or primordial). As we noticed earlier, both "logic" and "mathematics" appear to transcend nature – to be "extra-natural" in some sense – to be something which would remain even if space and time were to be removed (especially since both are causally foundational to both time and space). Also the apparently "timeless" quality of human logic and mathematics (as opposed to the "time dependent" quality of their computer counterparts) seems more "at home" in the levels which are *outside* of time. It is true, for example, that neither "logic" nor "mathematics" (even "derived" mathematics) can ever "change;" the truths they express are "timeless."

"Quantum mechanics" would, of course, be controlled by these bottom levels (since it is above them). This allows for the mathematical nature of particle behavior; it even frees quantum mechanics from any need to behave according to any rules dictated by mechanical (or even relativistic) causality; it is bound only by the constraints of the underlying mathematics.

And, strangely, this also opens a window through which *uncaused* "conscious mind" might express itself. The myriad "uncaused causes" of quantum mechanics might turn out to be less random than has been presumed. In fact, this would seem to be the *only* way our minds could communicate with our brains (even if our brains weren't clear at the top of the causality stack). Nature's "leaky" quantum-mechanical "back door" appears to provide a path. This might involve the quantum-mechanics-to-neurology interface structure which Roger Penrose believes he has identified (as was mentioned in an earlier chapter) – only now it becomes obvious why this structure might expedite the stranger manifestations of conscious mind; it doesn't have to generate them, it merely provides access between them and the physical world.

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

For 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 to be sure 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*.

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. This appears to suggest that there is *no way* "the *design* agency" could have modified "the *creative* agency" in *"time"* to influence the initial creation; this is because *change requires time*. Unless the "designer" is also the "creator," there is *nothing* it could have accomplished which might have had any bearing on the creation's original design! The designer must also be the creator. (We didn't want to add any unnecessary "turtles" to our stack in any case.)

Although we are still uncertain where on our causality stack to put this agency, we know that it must be able to reside outside of time and space (probably putting it somewhere within the bottom two layers). This means that conscious mind, logic, and mathematics are the likely candidates for the "substance" from which this agency might be comprised. These all exist in "timeless" levels (or possibly in one unitary "timeless level," singular) where *change is impossible* – (change being possible only within the context of *"time"* and the creation). We already know that this agency does not (at least not exclusively) occupy the "quantum mechanics" and higher layers; those layers suffer the same fate as "giant pink bunnies" – they depend on space and time to operate.

Stephen Hawking has proposed that mathematics might be the underlying cause of all that exists; however this idea has prompted him to ask what might have put the "*fire* into the equations" that enabled them to express themselves in the form that we experience as the universe. If we are on the right track here, Hawking's "fire" would appear to be "primordial conscious mind" (identifying "mind" as part of the creator). This could certainly provide the equations with the "spark" necessary to initiate existence.

The fact that we ourselves are made, in part, from "conscious mind, allows us to determine whether the creative agency accomplished the design and construction of our "minds" directly or indirectly (through other agencies, such as mutations and survival fitness): *Higher levels of causality cannot modify the causal actions of 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 – identifying them as being a *direct* result.

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; this restriction limits (although it does not eliminate) the amount of logical and physical damage we can cause.

In summary, here is what we have *reasoned* out: Our unitary "design/creation" agency is probably comprised, at least in part, of "conscious mind." "Logic" shares its causality level *with* this agency and *is certainly* a part of it; 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.) Like "logic," this agency would inhabit a world of black and white, of truth and falsity. "Mathematics" is also a probable part of this agency's composition. Its native environment is independent of space and time, so the concept of "change" is foreign to it – except within the creation (a construct of time, space, matter, and energy).

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 mathematical derivations – 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 a previous chapter, the creative agency certainly has access to *lots* of energy). This agency completely surrounds us at the farthest reaches of the universe; it is likely to be closer to us as well. These attributes follow from what we have explored with our powers *of observation and reason* (a few of these attributes are partly speculative, others are reasonably certain).

At this point, we might be starting to wonder if this designer/creator is still hanging around – and whether it is able to meddle with our lives. The same quantum-mechanical "back door" (through which we apparently control our

own actions) could also serve as a portal through which this agency could operate. In fact, *the "act" of creation requires "action;"* this means this agency *does have* a portal through which it *can and did act*. Assuming this agency's "mind" is anything like our own, it is virtually certain that it has retained at least as much access to the creation as it has granted us – probably enough to fine-tune the universe in any manner it chooses (including the *potential to meddle* with DNA strands as desired).

Once again, our answers multiply our questions: In what other roles might this agency have been involved? Is this how the extreme improbability of the first living cell was overcome? Might its actions resolve the apparent contradictions between the competing evolutionary theories of "punctuated equilibria" and of "population genetics?" Has it communicated with men? Might our senses of "morality" or "truth" be part of such a communication? Might we be held accountable? Might it 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 able to "outlive" our brains? Does the fact that our *physical brains* contain no memories of any *previous existence* mean anything? These are all *very interesting questions*, but they don't really need to be answered here. (Besides, we have enough information by now that the answers may already be suggesting themselves.)

The final question which we *do* need to address is: Can this agency be trusted? This could be very important to us since we have reason to believe that this agency was responsible for the design of our conscious minds (and maybe, at least partly, of our unconscious minds and of our brains as well). This is critical if we intend to make our 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 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.

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 choice; 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 readers may have noticed, the attributes of the designer/creator which we have sketched out here, using *observation and reason* as our guides, appear to be quite similar to those spelled out in a couple of the world's more 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.

Even so, 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, Krishna, Allah, the Easter bunny, or in any other foolishness we might choose; and, of course, we must accept, without excuse, the consequences of our choices.

About the Author:

Don Stoner is nobody in particular.

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