Finding God:
Reconciling faith and science

Robert Chadsworth

To my wife, who has shown me the light in all things

Acknowledgement

I have never thought of myself as an evangelist. I have been many other things – a husband, a father, a physicist. A mathematician, and a computer scientist. An options trader on Wall Street, a playwright and a stunt pilot. But never an evangelist.

Even now, as I set pen to paper (fingers to keyboard, actually), it is a role with which I am uncomfortable. I find it difficult to image that my relationship with God will be of interest to anyone other than myself and perhaps a few of my closest friends. It isn't something that I would normally have thought to share with others.

To the extent that my sharing it helps you, dear Reader, with *your* relationship with God, I am grateful. Not only grateful, but indebted to my friend and former paster, for it was he who encouraged me to take up the mantle of a very gentle evangelism in the first place. Bruce pointed out that I believed that my relationship with God was the single most important thing in my life. He noted that I believe that I have somehow come to a strong and intimate relationship with God in an unusual way. And he, to whom evangelism is no stranger at all, concluded that I had a real obligation to share that relationship with others, to allow their lives to be enriched by God in the same way that mine has been so often.

It was an argument I found compelling. So I say: if it's a good thing, give my paster the credit. But to the extent that what I have to say is incoherent, implausible, or simply uninteresting, blame me.

Robert Chadsworth
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Chapter 1

Reconciliation, and the need for it

Long ago, when man attempted to come to his first, partial understanding of how the world around him worked, science and religion were bedfellows. Each was an attempt simply to understand; it was assumed that the gods provided the fundamental reasons behind everything. Understanding the world was equivalent to understanding the whims of the gods.

Somewhere along the line, the two disciplines separated. Overly simply put, science became identified with a commitment to evidence; religion, with a commitment to faith. And the two disciplines have been bitter enemies since, with theologians decrying the fact that scientists have no faith, and scientists remarking scornfully that organized religion has no respect for the evidence.

The argument between the two disciplines grows ever more shrill. Science may allow us to walk on the moon and clone sheep, but is generally a failure at providing the moral compass that each of us needs. Scientists typically recognize that their work itself is seen as without moral content; rather than try to fill the gap, it is often easier to ignore the moral issues and focus only on technical progress. Theology, with its focus on morality, undermines this.

Technical progress itself is a challenge to religion. The fossil record suggests fairly strongly that there is some truth to evolution, and evolution is not an easy pill for theology to swallow. As our engineering accomplishments become ever more impressive, it is easy to think that faith is unnecessary: knowledge and technology suffice. By providing such an easy escape, technology undercuts religion's ability to compel people to consider serious moral issues.

This is not the intent of the scientific enterprise, just as it is not the intent of religion to draw attention to the apparent moral emptiness of technology in isolation. My goal in these pages is to visit these differences from a more forgiving perspective, in the hope that the two fields can be reconciled. Here, as in so many areas, reconciliation is a matter primarily of understanding.

You will bear with me, I hope, as I try to recount for you the steps of my own journey on this path, as I try to encapsulate what I understand – and how I have learned it – about science and about religion.

This will, of necessity, be something of a meandering journey; my personal experiences with both areas have been somewhat scattered. I was raised a Jew but now find myself more a Christian than anything else; only Christians, I think, have an appropriate focus on God's extraordinarily forgiving nature. From a scientific point of view, I was trained as a mathematician and a physicist but find myself a computer scientist. To the extent that insights from all of these areas bear on the eventual conclusions I hope to draw, I will need to spend time discussing the fields themselves. As I said, I hope that you will bear with me.

But let me begin by addressing the basic problem: That scientists lack faith and that the religious discount the evidence.

Scientists make progress by using something called the "scientific method." The idea, roughly speaking, is that a theoretical scientist makes a falsifiable claim. An experimental scientist (typically, although not always, different than the scientist making the claim) then tries to find experimental evidence that the claim is wrong. To the extent that the falsifiable claim explains the results of the experiment, it is accepted. If the experiment falsifies the theory, the theory is discarded.

As an example, Einstein's special theory of relativity implies, among other things, that time is relative. The faster you go, the more slowly time seems to pass for you.

This is a falsifiable claim. In principle, you could give someone a wristwatch, accelerate them to a very high speed, slow them back down again, and see if less time had elapsed for them than for you. It works: astronauts, over the course of a weeklong mission, typically lose about a second when compared to those of us remaining patiently on the planet.

A second over the course of a week isn't much, of course, and more direct experiments are possible. While atoms are small, there are many particles that are smaller still – the constituents of atoms (protons, electrons and neutrons), and other more exotic particles. These exotic particles are generally unstable, decaying into various byproducts while releasing energy. The rate of decay can be measured, and is seen to be an intrinsic property of the particle in question. A pi-meson will typically decay in about a millionth of a millionth of a second.

One of the nice things about subatomic particles is that their small size means that they can be accelerated to very high speeds in particle accelerators. So a more direct test of the special theory of relativity is to take some pi-mesons, speed them up to a significant fraction of the speed of light, and see how long it takes them to decay. If Einstein's theory is right, the "clock" on the pi-mesons should slow down and they should decay more slowly.

And so they do. Confirmations such as this (and many others) led to the reluctant acceptance of Einstein's theory in the early 1900s. After all, the notion that time is relative is not a terribly palatable one, unsupported as it is by our everyday experience.

But let's take a look not at the conclusion that time is relative, but at the scientific process itself. The basic idea is for someone like Einstein to come along and make a claim. The claim needs to be falsifiable; the more easily falsified, the better. One of the many reasons that relativity was such a remarkable – and eventually successful – theory is that it had so many ramifications, so many verifiable consequences.

Put somewhat more confrontationally, scientists divide into two groups. The theoreticians try to say things that are easily proven wrong, and the experimentalists try to then prove that they in fact *are* wrong. One of the things that isn't generally recognized is that the experimentalists are very good at what they do: most of the theories presented by the theoreticians are bunk, and demonstrated to be so in short order by the experimentalists. Almost all of the theoretical papers presented at scientific conferences are forgotten in a handful of years, as they turn out to be either wrong or uninteresting.

There are two amazing things about this. First, the theoreticians are willing to do it. Second, and more surprising still, the scientific method works. Virtually all (and perhaps absolutely all) of the remarkable technical progress of the past century is a result of theoreticians standing up in front of a roomful of people (friends and colleagues, supposedly), and trying to say something as confrontational as possible. Said friends and colleagues then go off and attempt, generally successfully, to show that the theoretician has just made a fool of himself in public. I can vouch for this description from personal experience.

Who would have imagined making progress in this way? You try to say something falsifiable, and then people try to falsify it. Yet most scientific advances have been discovered thusly, and the scientific community is utterly convinced that they will continue to progress in similar fashion. They have confidence that the past successes of the scientific method will be duplicated in the future.

In their mind, the scientific method has been "proven." The statement that, "The scientific method works," is, after all, a falsifiable claim that no one has managed to falsify. In other words, the scientific method has been validated by the scientific method!

This sort of circular argument bears a striking similarity to the religious arguments that scientists all too often ridicule. Faith is grounded not in evidence, but only in faith. In some sense, to believe in something that is grounded only in its own belief is a reasonable *definition* of faith.

What, then, can we say of the scientists? Their faith in the scientific method is just that: faith. It is neither better nor less well supported than the religious man's faith in God. Scientists' faith and belief in the scientific method is held just as deeply as the faith in God held by so many non-scientists.

The point I am hoping to make here is that the religious should not complain that the scientists have no faith, but rather that they have faith in the *wrong thing*. Now, this is no small matter, having faith in the scientific method as opposed to faith in God. But I would argue that recognizing the difference as one of faith makes it much smaller than viewing the religious as faithful and the scientists as faithless. The great leap is to have faith in anything. Having made the leap, reconciling the scientific method with God is a smaller step.

What about the other side of this coin, the scientists' claim that the religious have no respect for the evidence? Let us begin by examining the idea that scientists' respect for the evidence is absolute.

One of the most interesting transitions in the history of science is the emergence of chemistry from alchemy early in the eighteenth century. At the beginning of this transitional period, the alchemists had decided that turning lead into gold involved, at a minimum, heating it to extreme temperatures. This led them to study the properties of heat in general and combustion in particular.

One well-known piece of evidence surrounding combustion was that you can extinguish a candle by smothering it. The alchemists decided that when an object burned, it released a chemical called *phlogiston* into the air. When you put an inverted cup over a candle flame, the candle eventually goes out because the air in the cup fills up with phlogiston and becomes incapable of holding any more.

This conclusion led these early scientists to try to produce air from which all of the phlogiston had been removed. This "dephlogisticated" air did indeed allow things to burn much more fiercely than did normal air.

Of course, we know now that things burn not be emitting phlogiston, but by absorbing oxygen. The candle goes out not because the air is saturated with phlogiston, but because the oxygen is gone. And dephlogisticated air is, in fact, simply pure oxygen.

This idea (that burning is a matter of absorbing something, instead of releasing it) was suggested by the French scientist Lavoisier in the late 1700's, sparking an enormous debate within the alchemical community. The reason for the debate was that there was a fundamental piece of evidence on Lavoisier's side: when something burns, it typically gets heavier. This lent support to the oxygen theory. But it is also the case that burning things typically release smoke. This lent support to the phlogiston theory.

Eventually, the oxygen theory won out, as it was able to explain more and more of the available evidence. But the crucial point here is that the oxygen theory was generally accepted well before it was able to explain *all* of the available evidence. It was accepted when it was able to explain a preponderance of it. Since some things burn without smoking, it was eventually accepted that the evidence associated with smoking was less important than the evidence associated with weight gain. The oxygen theory couldn't explain *all* of the evidence, but it could explain the *important* evidence.

Suppose we now consider another scientific theory, evolution. Once again, there is a substantial body of evidence both for and against the theory. Evolution is capable of explaining fairly well the gradual modification of a particular species over the course of time, whether it's the artificial development of the navel orange or the natural change from Eohippus (a prehistoric horse standing about two feet tall) into the modern horses we see today.

What evolution has trouble with is the quantum jumps where entirely new physical features appear. It's hard to imagine eyes evolving gradually, for example. Larger and larger clusters of optically sensitive nerves, yes. But a lens capable of focusing light on a retina is either there or it isn't; a "partial" lens is hardly of much (if any) survival value.

In addition to evolution's difficulty with the details of quantum changes, it has trouble with the fact that an enormous *number* of such changes appear in the fossil record at about the same time (some three hundred million years ago). This introduction of a wealth of new life forms is generally known as the *pre-Cambrian explosion*, and there is no good scientific explanation for it.

Once again, there is a theory – evolution – and once again, there is evidence both supporting and undercutting it. The scientific community finds the evidence in support more compelling. They generally feel that the pre-Cambrian explosion is a consequence of some external event such as a nearby supernova. They have no detailed explanation of this event, but believe nevertheless that one will eventually be found and that evolution, as a theory, will come to explain more and more of the fossil record as we observe it.

For the religious camp, the situation is reversed. They feel that the pre-Cambrian explosion is in some ways the *only* important evidence regarding evolution, for it is this event that is the historical match for God's creation of plants and animals; it is this event that shows most clearly God's intervention in creation. The gradual changes by which a horse gets larger or an orange loses its seeds pale in comparison.

Who is right? It's not my place to say. The point I am hoping to make is not that one side is right and the other wrong, but that *both* sides respect the evidence. The difference is not that the religious don't care about the evidence, but that they care about a different *set* of evidence than does the scientific community. Just as the religious community's actual complaint is that the scientists have faith in the wrong thing, the scientific community's real complaint is that the religious attend to the wrong evidence. But the religious do clearly care about *some* evidence and this, I hope, makes the gap between the two camps much smaller than if they had no interest in the evidence at all.

Chapter 2

The fundamentals of science

Before turning to the boundary between science and religion, let me spend some time discussing each in isolation. In this chapter and the next, I would like to discuss what seem to me to be the key insights on which modern science and modern religion rest.

On the scientific side, let me begin with Heisenberg's uncertainty principle. Simply put, it says:

> To observe something is to disturb it.

Let me see if I can explain why this is so. The only way to examine something, roughly speaking, is to bounce things off of it.

When we look at something, we see it because our eyes are sensitive to the light reflecting off of it. Red things reflect only red light, absorbing the rest. White objects reflect all of the visible light that hits them; black things reflect none. When you turn a flashlight on in a dark room, and shine some light on something you are trying to see, you are bouncing light from the flashlight, off the object you're examining, and back into your eyes.

Our other senses are similar. When a violinist plays a note, his vibrating violin string causes the molecules in the surrounding air to vibrate as well, setting up a wave that moves through the air and eventually bounces off our eardrum. There is no sound in outer space because there are no air or other molecules to bounce off the object making the sound.

When we smell something, it is because small amounts of the object being smelled have become dislodged and drifted through the air into our nose; when we taste something, chemicals in our mouth interact with the food (or nonfood) in question. It is even reasonable to say that when we feel something, we are interacting with it by bouncing our finger off of it.

The point, of course, is that when you bounce one object off another, the second object is moved slightly by the interaction. As an example, suppose that you are in a dark room. Somewhere in the room is a small beanbag chair, and your job is to figure out where the chair is using a supply of bowling balls with which you have been provided.

The obvious solution is to roll the balling balls in all sorts of directions, listening for one of them to hit the chair. When it does, you'll know where the chair is – or more accurately, where it was before the bowling ball hit it, since it will presumably be in a somewhat different location after the bowling ball collides with it.

In this example, the bowling ball is heavy and the beanbag chair is light. When we shine a flashlight on something, the light beam is made up of many subatomic particles called *photons* (zillions is a reasonably accurate description of the number). Each photon is much lighter than the object being examined, but the basic idea is the same – each and every photon nudges the object being illuminated, albeit ever so slightly.

When you start thinking about things the size of photons, a physical principle known as *wave-particle duality* becomes important. Wave-particle duality means that photons are in some respects like particles, and in other respects like waves. They are like particles in that they are discrete; it makes sense to talk about a single photon as a single, coherent "blob" of light energy.

These individual photons, however, interact with things rather like waves. If you think about waves crashing into the pillars supporting a pier, for example, there are some very long (and typically fairly low) waves that would generally wash right past the pillars, and some very short (and usual fairly high) waves that would smash into the pillars and break up.

Photons are similar. Low energy photons have very long wavelengths, and often wash over things without being affected very much. High energy photons have shorter wavelengths, and are generally disturbed more by the objects they encounter.

So let's return to our flashlight example. Imagine that you're at home one night, and a short circuit in the toaster causes a circuit breaker to shut off the power in your house or apartment. You fetch a flashlight and head out to the garage, looking for the circuit breaker that needs to be reset to turn the lights back on.

If the wavelength of the photons emitted by your flashlight were much larger than the size of the circuit breaker, the wavelike photons would just drift on past it, instead of being reflected back into your eyes. To find the circuit breaker, you need to use photons with a wavelength no larger than the circuit breaker itself. For similar reasons, if you want to locate the circuit breaker with a certain precision (say within $\frac{1}{16}$ of an inch), you need to use photons with wavelength no greater than that precision.

In general, this isn't a problem. The wavelength of photons corresponding to visible light is incredibly short – perhaps ten millionths of a millionth of an inch. So they suffice for all normal purposes; we don't need to know where the circuit breaker is with anything like that accuracy in order to get the lights in the house back on.

But what if we were trying to use photons to locate another subatomic particle, like an electron? Now we may well want to know the location of the electron with an accuracy greater than ten millionths of a millionth of an inch – so we need photons with smaller wavelengths to do the job.

And there's the rub. If you think about waves breaking over a pier again, the long-wavelength waves are very low energy. They just cruise on by the pier without doing much damage. But the short-wavelength waves have much more energy; they smash into the pier and can affect it substantially.

Light is similar. The amount of energy carried by a single photon goes up as the wavelength of the photon goes down. In fact, the product of the energy and wavelength is a constant, exactly the same for all photons. It's called *Planck's constant*. As we try harder and harder to locate the electron precisely, we need to use photons of shorter and shorter wavelength, and thus of higher and higher energy. We can't tell where the electron is so much as we can tell where it was before the photon crashed into it. The overall situation is becoming more and more like the example of using a bowling ball to locate a beanbag chair (or worse still, a balloon) in a dark room.

This is a very general phenomenon. If we want to tell *exactly* where something is, we have to bounce very high-energy photons off it (or something else of equally high energy). That means that we can find out exactly where it is, but we start having very little idea of how fast it's moving because of the potential impact of the photons being used. In fact, however we measure something, it always turns out that:

$$\Delta x \cdot m\Delta v \geq \hbar \qquad (2.1)$$

where Δx is our uncertainty about the location of the object, Δv is our uncertainty about its velocity, m is the mass of the object (the same as the weight, give or take), and $\hbar$ is Planck's constant.

In practice, this isn't a big deal because $\hbar$ is very, very small. For a pencil weighing about an ounce, for example, we can know its location to within a millionth of a millionth of an inch while knowing its speed to within one inch every ten million years. Surely this is enough for all practical purposes!

For all practical purposes, it is. But now suppose that we are trying to balance that pencil on its point. To do that, we have to get the pencil *exactly* vertical, and *completely* still. If it's the slightest bit off vertical, it will fall – slowly at first, but faster and faster. If it's moving, ever so slightly, it will eventually fall – slowly at first, but faster and faster. Either way, the pencil will eventually fall over.

How long will it take? Not long at all, it turns out. Any realizable pencil will have some amount of deflection from the vertical or some speed; the best you can do is for the pencil to take about 20 seconds to fall over. The equation $\Delta x \cdot m\Delta v \geq \hbar$ is at the root of a branch of physics known as *quantum mechanics*, and it's reasonable to say that you can only balance a pencil on its tip for about 20 seconds before quantum mechanics knocks it over.

Before we move on to the implications of this, let me hasten to point out that examples where quantum mechanics impacts our normal lives are few and far between. As I type this, I'm looking at a bowl of fruit, wondering whether to stop and have some. In *theory*, fundamental uncertainty about the speed of a peach in the bowl could cause it to roll out of the bowl it's in and onto the table. In practice, that never happens. That's the reason people use bowls! Even in the pencil example, random air currents would knock the pencil over well before quantum mechanics got involved.

But although it doesn't matter much in practice, $\Delta x \cdot m\Delta v \geq \hbar$ is important in principle. It says something fundamental about our abilities:

> It is theoretically impossible to know both the position and the velocity of an object with arbitrary accuracy.

In many ways, this is just a restatement of Heisenberg's original uncertainty principle.

This is all well and good but hardly, I would think, merits the title of the "key insight" on which modern science rests. That depends on the following:

> It is meaningless to talk about an object that is at a precisely specified location and has a precisely specified velocity.

Compare this to the previous comment: the uncertainty principle says that we can never find such objects; the crucial jump of insight is the idea that it is meaningless to even discuss them.

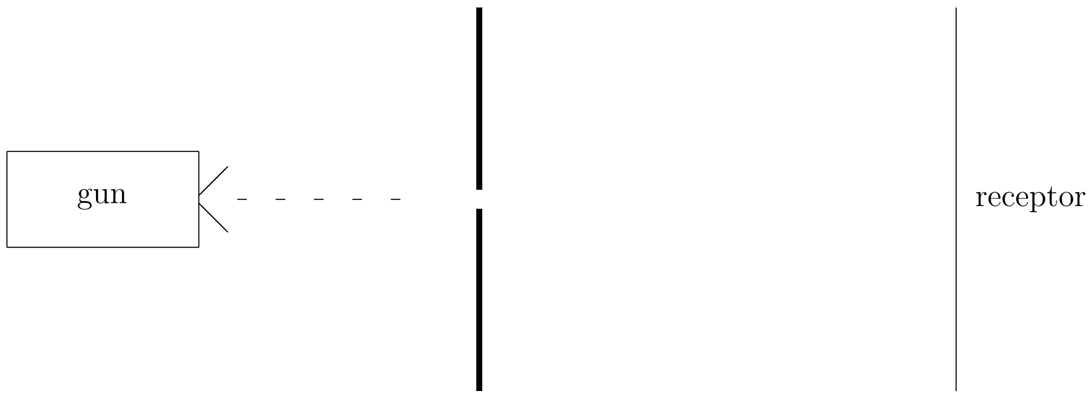
By "meaningless", I mean that a question referring to such things simply doesn't make sense. It's like asking, "Is the king of France bald?" Since France doesn't have a king, the question is ill-formed. If we want it to make sense, we have to somehow phrase it in a way that doesn't implicitly assume that France has a king. We might say, "There is a bald person who is the king of France," which is false. Or we might say, "Every person who is the king of France is bald," which is true because there are no such people to worry about.

In a similar way, the question, "Would a perfectly stationary pencil, balanced exactly upright, remain upright?" is also meaningless. There is no such pencil – and more importantly, there can't be.

Discussing hypothetical pencils seems a bit abstract, so let me spend some time discussing a somewhat more concrete example.

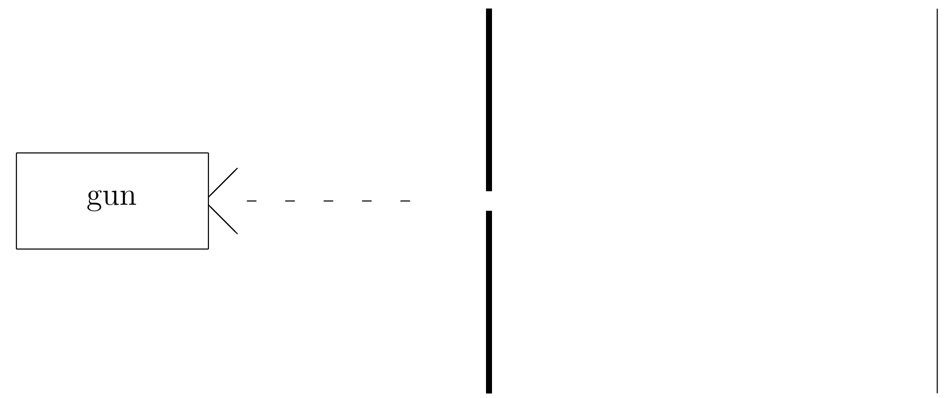
To start, suppose that you have a gun that fires electrons, one at a time. "One at a time" makes sense because electrons are particles – individual quanta. It's possible to measure the electric charge on a single electron, and no one has ever seen half of an electron (i.e., something carrying half the charge), or any other fractional value.

Our electron gun shoots the electrons at a wall with a small slit in it, something like this:



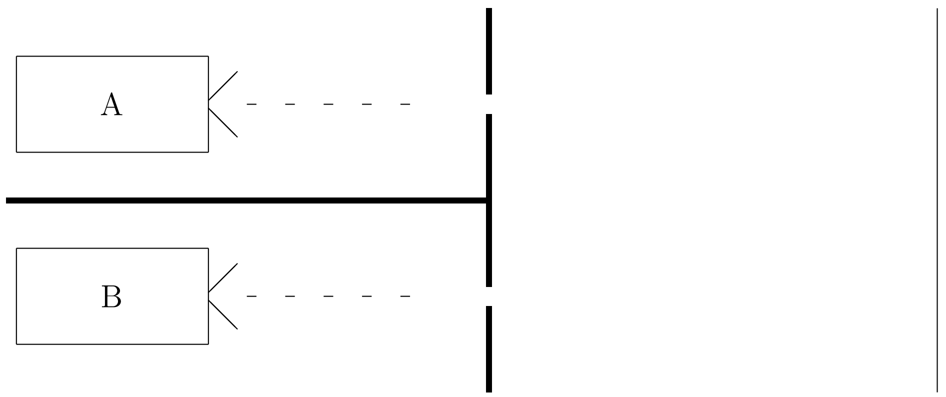
When the electrons go through the slit, they *scatter*. What that means is that they bounce out of the slit in arbitrary directions, not necessarily traveling straight through. On the other side of the slit is a receptor that is sensitive to the scattered electrons and detects the point at which each eventually collides with it. The electrons, as particles, come through and are detected one at a time.

On the face of it, we might expect the scattered electrons to appear uniformly on the surface of the receptor, but this is where the wavelike nature of the particles comes in. Just as water waves have peaks and troughs, so do the electron "waves". If we allow a large number of electrons to pass through the slit and get detected, we get a pattern that looks like this:

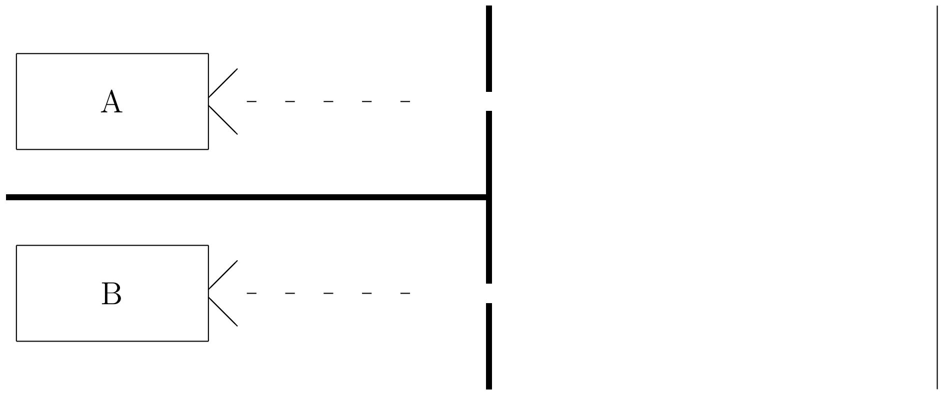


The figure we have drawn at the receptor is intended to indicate the probability that an electron is detected at any particular place; the further to the right the graph is, the more likely it is that we see an electron. Thus the figure as drawn corresponds (correctly) to the wavelike nature of the electrons; there are "peaks" where we are very likely to see electrons and troughs where we are unlikely to see them.

Now suppose that instead of one electron gun, we had two. Gun A on the top produces a pattern like the one above, as does gun B on the bottom. The patterns are offset a little bit because the guns are firing through different slits:

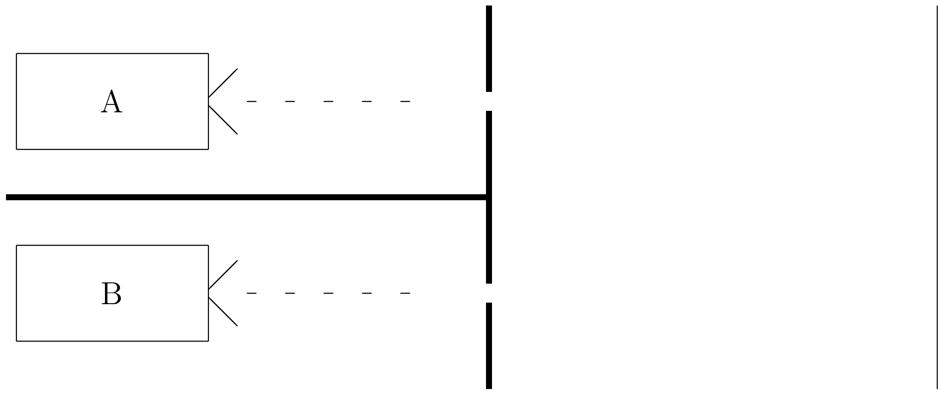


Assuming that we fire the guns one at a time, we can add up the offset patterns to get the overall pattern we would expect in this case. Here it is:



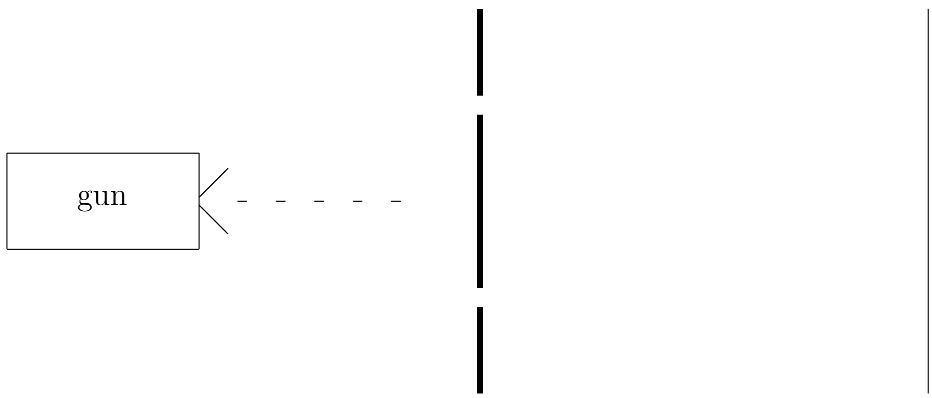
The peaks in the new diagram correspond to peaks in either of the two original figures, so there are twice as many of them.

If we fire the guns at the same time instead of individually, the picture looks like this:



The reason for the change is that the waves corresponding to the individual electrons *interfere*; if a peak in one wave aligns with a trough in another, the waves cancel out and there is no chance of observing an electron at that location. It turns out that number of peaks in the resulting figure is the same as the number of peaks observed from a single slit.

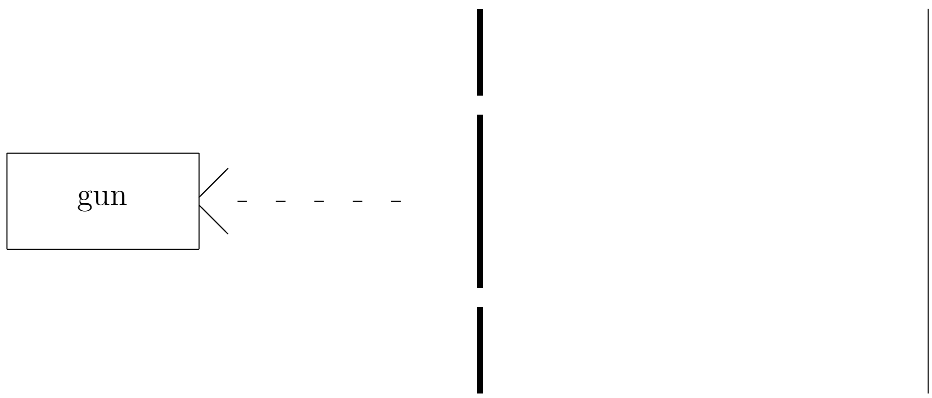
Now suppose that instead of two guns and two slits, we have *one* gun and two slits, like this:



How many peaks should we expect?

Remember that electrons are indivisible; the electrons going through the slits have to pass through either one slit or the other. We can confirm this by putting electron detectors at the two slits: each firing of the gun does indeed send an electron through just one slit or the other, and we get the same pattern as if we had two guns firing sequentially through the two slits: twice as many peaks as for a single slit.

What is surprising is what happens if we take the electron detectors away. Now it is impossible for us even *theoretically* to know which of the two slits the electron goes through. In analogy with the uncertainty principle, this suggests that it is *meaningless* to talk about "which slit" passes the electron. That suggests, remarkably, that we should think of the electron as going through *both* slits and should expect the single-slit wave pattern to reappear, even though there are two slits in the apparatus. And this is exactly what happens:



This is remarkable, and it is remarkable for many reasons. First, it is an extraordinary validation of the basic ideas underlying modern physics. Here, I would argue, is the key idea:

> **It is meaningless to attempt to draw a distinction that cannot, at least in theory, be validated experimentally.**

I cannot stress enough how important and far-reaching this idea is. It's not saying that you can't tell which slit the electron goes through; it's saying it's meaningless to even ask the question. The underlying assumption (that the electron goes through one and only one slit) simply doesn't make sense.

It's like asking if the king of France is bald. France doesn't have a king, so the question doesn't make sense. Asking which slit the electron passes through assumes that it passes through just one slit, which doesn't make sense because it's impossible to validate experimentally.

It's easy to think of this as, "Since the electron is indivisible, it goes through just one slit. But when we take the sensors away, strange things happen and it's as if the electron goes through both slits."

That's wrong. The natural behavior of the electron is the behavior that occurs when we leave it alone – and it goes through "both" slits. It's only when we add the sensors that things get strange – and the electron goes through one slit or the other. But the natural, undisturbed behavior of the electron is to go through both.

All of this, however, is beside the main point, which is that questions that can have no experimental answers are meaningless questions. Throughout the rest of this book, I will both accept this observation and rely on it. If a question cannot be tested experimentally, I will dismiss it and move on – often with surprising consequences.

This doesn't mean that the answer to such a question is "no." If I ask, "Does the electron go through the slit on the top?" the answer isn't "no." The question simply doesn't make sense.

Before I alienate half of my audience, however, let me hasten to point out that the existence of God is not a meaningless question by this definition. It is *emphatically* not: If someone were to show up on my doorstep this evening claiming to be God, there would be many questions I could ask and many tests I could make that would (presumably) disprove his claim. But if he managed to turn water into wine, cure my son's cold, restore my mother's health and (if need be) return my father to life or part an ocean, I would be hard pressed to argue that he *wasn't* some sort of deity.

So the fundamental question of God's existence is untouched by the guiding principle introduced in this chapter. As we will, see, though, many other questions are dramatically affected.

Chapter 3

The fundamentals of religion

In the last chapter, I discussed what seems to me to be the most fundamental observation of modern science: That questions without experimental answers are meaningless. In this chapter, I will discuss a similar conclusion on which most of religion (modern or otherwise) appears to be based.

Religion is older than science. The guiding scientific principle discussed in the previous chapter is perhaps a century old; to find a similarly pervasive notion in religion, we need to go back much further.

Nevertheless, there is a point at which religion seems to have taken an extraordinary turn. That point is the conclusion by the Jewish patriarch Abraham that there was only one God. This introduction of monotheism separates virtually all modern religions from their Greek and Roman predecessors.

In fact, monotheism is so universally accepted today that it might seem that there can be nothing for me to say about it. But that is not true: My aim in this chapter is to discuss monotheism from the standpoint of the observation in the last chapter. Claiming that there is only one god is to answer the question, "How many gods are there?" Does that question make sense?

In order for it to make sense, we must be able to imagine (although quite possibly not perform) an experiment that would tell us unambiguously if there were *more* than one god. What would such an experiment look like?

Well, let's go back to our god-on-the-doorstep example. This time, though, instead of one person showing up on my doorstep claiming to be God, two do. Is there any test I can do to challenge them?

The obvious thing is to ask each of them to perform miracles. But they each can do so: Oceans are parted, the dead resurrected, and so on. Does that mean that there are, in fact, at least two gods?

Maybe. But an obvious additional experiment I can perform is to set them off against one another. I can ask God #1 to turn water into wine, and ask God #2 to keep it water. If there is only one God, then the actual God will win and the impostor will lose. So in this case, I can indeed imagine an experiment that will determine whether there is one god or two, and the *question* of whether there is one god or two therefore makes sense.

But what if the two purported deities were incapable of interacting? Suppose that the world were divided into two regions, say A and B, with the first "god" operating only in Region A and the second only in Region B. Could I distinguish between this setup and one where there was only one god, operating in both regions?

I could not. Suppose first that I tried to show that there were two gods, God A operating in Region A and God B operating in Region B. This situation is clearly indistinguishable from the existence of a single god who behaves like God A and Region A and like God B in Region B. If he chooses, the single god can "simulate" two separate gods acting in two separate regions.

What if I tried to show that there weren't two gods, but only one? If the Region A god and Region B god both behave just like the one and only god, there will be nothing I can do to distinguish between the two possibilities. The two gods could, in principle, be two different "aspects" of just a single deity.

There are two points I would like to make here. The first is that this situation, where the different gods are constrained to each operate within their own limited domain of authority, is in fact *exactly* the situation as "understood" by the ancient Greeks and Romans. These societies believed in many gods – of earth, ocean, weather, love, and so on. The gods would fight when one wanted to control another's actions, but the local god would always win: Hermes had fundamental authority over war, Venus over love, and so on.

The second point is more profound. Given that there is no experiment we can perform to distinguish a reality with many separate gods from one with a single God, the discussion in the previous chapter suggests that the very question of how many gods there are is a meaningless one. Yet modern religion rests on monotheism. How can this be?

Let's look at our argument again. The reason we couldn't tell experimentally if there is one god or many is because it is impossible to distinguish between the situation where there are many gods (of earth, ocean, weather, etc.) and where there is one god that acts differently in different environments (earth, ocean, weather, etc.). In our context of only assigning meaning to differences with experimental consequences, we should perhaps describe Abraham's extraordinary insight as not so much that there is only one God, but that this God *acts the same* in all environments:

God's behavior is independent of the environment in which he is acting.

The question of how "many" Gods there are is still somewhat beside the point. There is no way to distinguish between one God, acting uniformly across all situations, and many Gods, all acting as if they were one. It's as if one were to try to say that I, as the author of this book, were actually two people: the Bob Chadsworth writing the book and the Bob Chadsworth not writing the book. It's a distinction one could make, but it really doesn't make any sense. They're the same Bob Chadsworth.

Talking about a person, of course, it makes sense to talk about there being only one: "Bob Chadsworth" is a specific person, in a specific location and living at a particular time.

But God is boundless, without scope in space or time. To say that there is only one God can never mean more than that God's behavior is uniform.

Let me add this, then, to the conclusion of the previous chapter. Everything I have to say in this book will, it turns out, be founded on four crucial principles, and we now have the first two:

1. **Questions that cannot, even in theory, be answered experimentally are meaningless.**

2. **God is not capricious.**

In keeping with the arguments we've made so far in this chapter, I've replaced, "There is only one God," with a statement suggesting that he behaves uniformly in all situations.

In all honesty, however, I should not let myself off so lightly. In addition to sanctioning the above two beliefs (which will, I hope, both be reasonably palatable to the scientific and the religious alike), I've also said something far more troubling:

> The claim that, "There is only one God," is meaningless.

Does this not fly in the face of accepted theology?

It does not. Let me consider first the most obvious argument that it does, and then suggest that there is in fact direct biblical support for the above claim.

The obvious argument that there is only one god is the first commandment: "Thou shalt have no other gods before me."

To say that there may be many gods is not to propose worshiping false deities: Whether there are many or one, they are all the same. I am proposing not that we worship false idols, but that God himself defies counting.

Let me return to the "Bob Chadsworth" example. One of the things my wife and I try to encourage in our children is respect of their parents. Now suppose that I spend so much time working on this book that my son actually comes to draw a distinction such as that mentioned earlier, distinguishing between "Daddy writing the book" (whom he is supposed to leave alone) and "Daddy not writing the book" (with whom he is encouraged to play). My son can honor his responsibility to respect me by respecting each of the two daddies "separately," or by simply respecting the one combined daddy.

In a similar way, we honor God equally well by honoring Him in all of His guises as if they were separate, or by honoring Him as a single combined deity. It doesn't matter whether we say that there is a single God. What matters is that we recognize that God's behavior is uniform throughout the universe, and that we honor that behavior.

In fact, I would go further. The arguments of the previous chapter suggest, for scientific reasons, that God defies counting. But the Bible itself, at least the New Testament, appears to *require* that God defy counting.

The New Testament describes the Holy Trinity: the Father (God), the Son (Jesus Christ) and the Holy Ghost (the resurrected Christ). I will have much more to say about Jesus later, but at this point let me only ask the following: We are clearly encouraged to worship all three members of the Trinity. Does that mean that we are encouraged to worship false gods? Does it mean that there is more than one god?

Of course not. The three members of the Holy Trinity are often described as both the same and different. In other words, God defies counting. I find it remarkable that this same conclusion can be reached both through extensive theological debate and through an application of the scientific principles of the previous chapter.

Before returning to scientific matters, however, let me discuss another of the principles on which religion appears to be founded. This one predates Abraham substantially, and says simply that God (or, in Greek or Roman terms, all of the gods) is *involved* in our lives. God is not distant and detached; He is here and tangible.

As with many things, I would like to endorse this idea but to cast it in a somewhat unusual fashion. Let me begin by assuming the existence of a Creator of some sort. God's presence now reflects the fact that he didn't just create the universe and then sit on the sidelines watching it tick; he remains involved in it as time passes. Put somewhat more colorfully, God is not a watchmaker.

It is more accurate to say that God is *more* than a watchmaker. Yes, he did the watchmaker's job, creating the universe and setting it going. But unlike the watchmaker, he remains involved.

Had God chosen to do the watchmaker's job only, it would be reasonable to say that His role would have been to provide the order underlying the universe. This is the watchmaker's task: make something, ensure that it has a smooth operating mechanism, and then walk away.

But God did not walk away. If the watchmaker's role is to provide order, God's role is to actually *be* the order underlying all things. And that is how I would like to look at it:

1. **Questions that cannot, even in theory, be answered experimentally are meaningless.**

2. **God is not capricious.**

3. **God is the order underlying the universe.**

The observation that God is involved with us in a tangible, personal way is reflected, I hope, in the last of the three basic beliefs: God did not just provide order to us, he *is* that order on a day-to-day basis. We will have much more to say about this point later, but let me stop here for now.

My overall goal here is to find a way to bridge the gap between theology and science; the scientists will be none too happy with the three conclusions given above. So let me begin by modifying those conclusions in a way that leaves their meaning intact but will placate the scientists somewhat:

1. **Questions that cannot, even in theory, be answered experimentally are meaningless.**

2. **The universe is not capricious.**

3. God is the order underlying the universe.

I have replaced "God" in the second assertion with "the universe."

Given the other two beliefs (especially the third), the beliefs themselves are unchanged. If God is capricious, then the order underlying the universe will be as well, making the universe itself unpredictable. If God is not capricious, the order underlying the universe will be solid, and the universe will be also. We see that given the third belief, the statements that God and that the universe are not capricious are completely equivalent. But a scientist will find the rewritten version a bit more palatable than its predecessor. (Although he will remain unhappy with the third claim.)

Armed with these three beliefs, then, let us return to the viewpoint of the scientist. As remarked above, we will find that he embraces the first two beliefs but challenges the third. The precise nature of his challenge, however, will be something of a surprise.

Chapter 4

Enter mathematics

Let me begin this chapter where I ended the last, with a summarization of our fundamental principles:

1. **Questions that cannot, even in theory, be answered experimentally are meaningless.**
2. **The universe is not capricious.**
3. **God is the order underlying the universe.**

What would a scientist make of these? Clearly the first would be acceptable, having as it does its root in science itself. As far as the second, let me instead add that other crucial belief that the scientific community takes on faith, getting:

1. **Questions that cannot, even in theory, be answered experimentally are meaningless.**
2. **The scientific method works.**

What does it mean to say that the scientific method "works"?

It means several things. On the face of it, it obviously means that the basic method of science, making falsifiable claims and then trying to validate them experimentally, will lead to progress. But just as the statement, "The king of France is bald," presupposes that France has a king, the statement that the scientific method works presupposes much about the world at large. So let me try to flesh out the claim itself a bit; instead of saying simply, "The scientific method works," we should perhaps say:

> **Making and testing falsifiable claims is a reasonable path to the discovery of scientific laws that will accurately predict the results of future experiments.**

And now the hidden assumption is obvious: the scientist assumes that the scientific *enterprise* is a possible one, that there *are* scientific laws that will accurately predict the results of future experiments. Let me break this belief into two somewhat simpler ones:

1. **It is possible to predict the results of future experiments.**

2. **Scientific laws can be used for this purpose.**

Saying that you can predict what will happen when you perform an experiment depends on an underlying conviction that things tend to be repeatable; given that the sun has come up every day we have ever seen, we believe that it will also come up tomorrow. If we hold a bowling ball in the air and let it go, it will fall. We believe this even if we've never tried it, since we've held so many other things in the air and let them go. With few exceptions (helium balloons come to mind), they all fall.

To see what happens when you let go of a bowling ball, you *try it*. You hold a bowling ball in the air, and let go. It falls. When you're done shouting and holding your toe, you predict with confidence that the next time you hold a bowling ball in the air and let go, it will fall again. And you've learned enough not to do it.

So that's the simplest way to predict the result of a future experiment: Do the experiment now, and see what happens. Assuming that the conditions of experimentation are unchanged later, we expect (with confidence) that the result will be the same as well. Put somewhat differently, it is possible to predict the results of future experiments because:

The universe is not capricious.

What about the second belief, that scientific laws have predictive value? Einstein put this belief very eloquently, saying that, "The most incomprehensible thing about the universe is that it is comprehensible at all."

Not only is the universe comprehensible, but it is comprehensible *using scientific laws*. Here is an oft-quoted one:

$$e = mc^2$$

In this equation, e is energy, m is mass, and c is the speed of light. What the equation says is that if you convert a certain amount of mass to energy, the amount of energy obtained can be computed by multiplying the amount of mass by the square of the speed of light. Since the speed of light is so large (roughly 186,000 miles per second), converting a small amount of mass produces a *lot* of energy. (In the above equation, c^2 means "c squared", or c multiplied by itself.)

Einstein's equation has *predictive* value. A hydrogen bomb works by converting mass (and not even very much mass, it turns out) into energy via a process known as fission (whereby a plutonium atom splits into a bunch of lighter fragments). A nuclear reactor works the same way. Even the sun generates energy by converting mass (using not fission, but fusion, where two hydrogen atoms are combined to get a – slightly lighter – helium atom). In all of these cases, the *amount* of energy produced is in keeping with Einstein's famous equation.

Here is another equation with a bit more commonsense applicability:

$$F = ma$$

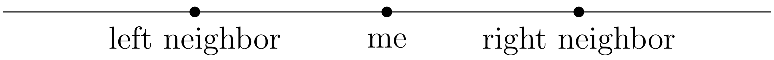


Figure 4.1: Life on a line

This law, due to Newton, says that if you apply a force F to an object of mass m, it will accelerate an amount a. When you let go of a bowling ball in midair, gravity provides a downward force, so the ball accelerates downward. It's harder to push a car than a tricycle because a car has so much more mass, so you need a lot more force to generate the same amount of acceleration. When you roll a marble across a table, there is no force on the marble after you let it go, hence no acceleration (if $F = 0$ in the above equation, then we must have $a = 0$ as well), and the marble keeps rolling.

Here's another common equation:

$$x^2 + y^2 = r^2 \tag{4.1}$$

This equation, due to the Greek mathematician Pythagoras, says that if you move the marble 3 inches to the right and 4 inches up on the table, it will wind up 5 inches from where it started, since

$$3^2 + 4^2 = 9 + 16 = 25 = 5^2.$$

The values for x and y are the "left-right" and "up-down" amounts of motion, while r is the overall distance from the starting point.

We can apply the rule on larger scales as well. If we drive 3 miles east and then 4 north, we wind up 5 miles from our starting point. But if we drive 300 miles east and then 400 miles north, the fact that the surface of the earth isn't flat starts to matter, and we have to use a modified version of the above equation that is appropriate for surfaces that are spherical instead of flat. (We really should have used the complicated version for the 3 mile/4 mile example as well, but the earth is so flat over distances of this size that it doesn't really matter.)

Once again, the rule has predictive value. After moving the marble three inches over and four up, the rule is *predicting* that the length of a string stretched between the marble's current position and its starting point will be exactly five inches. All scientific laws have similar form, even abstruse modern physics like string theory.

Our normal view is that space is three dimensional; it often makes sense to talk of time as a fourth dimension. In string theory, the universe is actually *ten* dimensional, with six extra spatial dimensions. But instead of extending off to infinity, the extra spatial dimensions are "rolled up" on a microscopic scale.

To get a better feel for this, imagine that instead of being three-dimensional, space were one dimensional so that we all lived on a line, as in Figure 4.1. (It wouldn't be terribly interesting, I admit – among other things, there would be something to our left on the line, something to the right on the line, and we'd never be able to interact with anything else. But bear with me for the purposes of the example.) We would think that the world was one-dimensional.

Now instead of living on a line, suppose that we lived on a cylinder, the shape of a flagpole. We would think that the world was two-dimensional. But what if the flagpole were skinnier, so that instead of a flagpole, we lived on a long piece of linguini? As the shape get narrower and narrower, we would eventually be unable to notice the extra spatial dimension, and would conclude once again that we were actually living on a line as in Figure 4.1. But in reality, we would be living in a two dimensional space, with one of the dimensions rolled up on a microscopic scale. String theory would have us believe the same about our world, with three "big" dimensions, a fourth dimension (time), and six rolled up ones. The mathematical structure of the six-dimensional rollup allows us to make predictions about experiments that we can actually perform in our apparently three-dimensional world.

It always comes down to mathematics. Scientific laws invariably work by providing a mathematical description of some aspect of our world, and then analyzing that description to predict the behavior of some experiment. In the soundbite version, mathematics is the order underlying the universe.

Putting all of this together gives us the scientist's view of the world:

1. **Questions that cannot, even in theory, be answered experimentally are meaningless.**
2. **The universe is not capricious.**
3. **Mathematics is the order underlying the universe.**

If I incorporate the religious view from the previous chapter, I get:

Religious view	**Scientific view**
1. Questions that cannot, even in theory, be answered experimentally are meaningless.	**1. Questions that cannot, even in theory, be answered experimentally are meaningless.**
2. The universe is not capricious.	**2. The universe is not capricious.**
3. God is the order underlying the universe.	**3. Mathematics is the order underlying the universe.**

No wonder they argue.

Chapter 5

Resolution

Setting religion and science off against one another, as I did at the end of the previous chapter, is perhaps too contentious. Let me combine the beliefs somewhat differently:

1. **Questions that cannot, even in theory, be answered experimentally are meaningless.**
2. **The universe is not capricious.**
3. **God is the order underlying the universe.**
4. **Mathematics is the order underlying the universe.**

Before going on, let me ask you, the reader: How many of the above statements do you believe?

If you count yourself in the religious camp, I imagine that you believe the second and third; the first is novel but you are, I hope, prepared to accept it. You find the fourth statement utterly unacceptable.

If you count yourself in the scientific camp, I imagine that you believe the first, second and fourth statements. The third, however, is unacceptable.

As further evidence that the four statements above capture the essential difference between the scientific and religious views, let me assume that you do indeed belong to one of the two camps as described above. If you are religious, I would imagine that what you think is fundamentally "wrong" with the scientist is that they believe in the fourth statement – they place their faith not in God, but in mathematics. If you are scientific, you likely feel that what is "wrong" with the religious community is that they place their faith not in mathematics' predictive ability, but in some ill-defined deity.

In many ways, we are back where we were at the end of the first chapter: each group's complaint about the other is that they have faith in the wrong thing. This is the fundamental difference, the rock on which previous attempts at resolution inevitably foundered: tension between the last two of the above four beliefs.

What about my own beliefs? I have tried to take a neutral tone throughout the previous chapters; is it not now time for me to get off the fence?

Strangely perhaps, it is not. As I have struggled over the years to understand the differences between the religious and scientific communities, I have indeed come to appreciate that they rest on the apparent incompatibility of the above four statements. But I remain squarely on the fence, for I find myself honestly believing all *four* of the above statements.

How is this possible? Before I tell you the answer (which is actually obvious) let me try to stress that it is not just *possible* to believe all four of the above statements. It is in some sense *essential* to believe them all. To do anything else is to discount either religion or science. But both religion and science have impressive credentials in terms of historical successes; both have the ring of truth, as well.

In any event, if you want to believe all four of the basic principles we've spent so much time developing, you also have to believe:

God and mathematics are the same.

I mean that as I have written it. I most emphatically do *not* mean something much weaker, like "Scientists feel about mathematics like religious people feel about God." That's true, but it's true *not* because scientists have faith in mathematics and the religious have faith in God. It's true because the entities themselves – mathematics and God – are the *same thing*.

One of the nice (or at least, balanced) things about this resolution is that it appears to be equally unpalatable to everyone. The scientific view mathematics as very real (albeit abstract); God is mystical. It is an affront to them to equate the elegant accessibility of mathematics with the mystical inaccessibility of God. The religious, meanwhile, view God as very real (albeit abstract); mathematics is distant. It is an affront to them to equate the constant accessibility of God with the sterile inaccessibility of mathematics.

I will return to this in a moment. Let me first address a more direct concern: how could mathematics and God possibly be the same when the words used to describe them (by scientists and by the religious) are so utterly different?

To answer this, let me use an analogy that was first given to me by a friend of fine. (He was talking about something completely different at the time, but no matter.) Imagine that nine blind men are trying to describe an elephant to one another. One grabs the tail and describes the elephant as ropelike. Another, examining the leg, reports that the elephant resembles a tree trunk. One describes the skin. Another describes the trunk as thick, muscled, and moist on the end. The tusks are smooth and cool. And so on. The descriptions are so different because none of the blind men has a view of the entire elephant; each sees only one element of the overall whole.

And so it is with us and God/mathematics. God is too big for us to understand completely; the scientific have a (reasonably good, I would argue) view of one aspect and the religious an (also reasonably accurate) view of another. Neither view is better or worse than the other; an elephant's tail is just as much a part of the elephant as is the trunk. More importantly, just as with the nine blind men, *our goals are the same*: to understand. Our differences in perspective are to be commended, not criticized; just as it is impossible to understand an elephant by examining only a small portion, so it is impossible to understand God by examining only one aspect. Each of us has much to teach the other.

As we discuss the consequences of this idea that God and mathematics are the same, language will be something of a problem. I don't want to write 'God/mathematics' all the time, as I did in the previous paragraph, so I'm going to use simply 'God' to describe the joint entity. When I talk about the "religious" God, I will often use the phrase "anthropomorphic view," because the religious view of God often ascribes to Him many humanlike qualities that he surely does not have (gender, for a start). As humans, it is difficult for us to personalize a relationship with anything as utterly different from us as God surely is. We often overcome this difficulty by ascribing humanlike qualities to the other entity; we *anthropomorphize* it. Hence my choice of phrase.

What about the "scientific" God? When a mathematician proves a new result or theorem, it is appropriate, I believe, to say that he has *discovered* the new result. The result (an aspect of God) was already there – the mathematician didn't create it. But it is all too easy to lose sight of this, and you will often find mathematicians or scientists talking about "inventing" their results. Just as it is incorrect (but understandable) for the religious to anthropomorphize God, it is also incorrect (but understandable) for the scientific to think that they have created Him. I'll call the "scientific" God (i.e., the mathematical perspective) the *synthetic* view.

With the linguistic issues out of the way, let me return to some of the more obvious objections to my overall approach. I'd like to spend the rest of this chapter discussing some beliefs held by the anthropomorphic approach that seem to be inconsistent in some way with both the synthetic view and the idea that God and mathematics are identical. The three that I will look at are:

- God is vibrant; mathematics is sterile,
- God hears us pray, and
- God wants us to be good.

God is vibrant; mathematics is sterile. Of all of the objections I will discuss, this is both the easiest to deal with and the most difficult. It is easy because to a scientist or a mathematician, mathematics is enormously vibrant. It's hard because this is a difficult thing to get across to a non-scientist.

Let me try by giving you a couple of brain teasers. For the first, imagine that I have two trains, 250 miles apart. The trains are moving toward one another, one traveling at 75 miles an hour and the other at 50 miles an hour.

On the front of the first train is a bumblebee. Just as the trains start moving, the bee takes off in the direction of the second train at a speed of 110 miles an hour. (It's a fast bee.) When it reaches it, it immediately turns around and heads back toward the first train. When it reaches *that* train, it heads back toward the other, and so on until it gets squashed. How far does the bee fly?

Here's the second problem. Consider the two checkerboards in Figure 5. Is it possible to the checkerboard on the left with 32 1×2 dominoes?

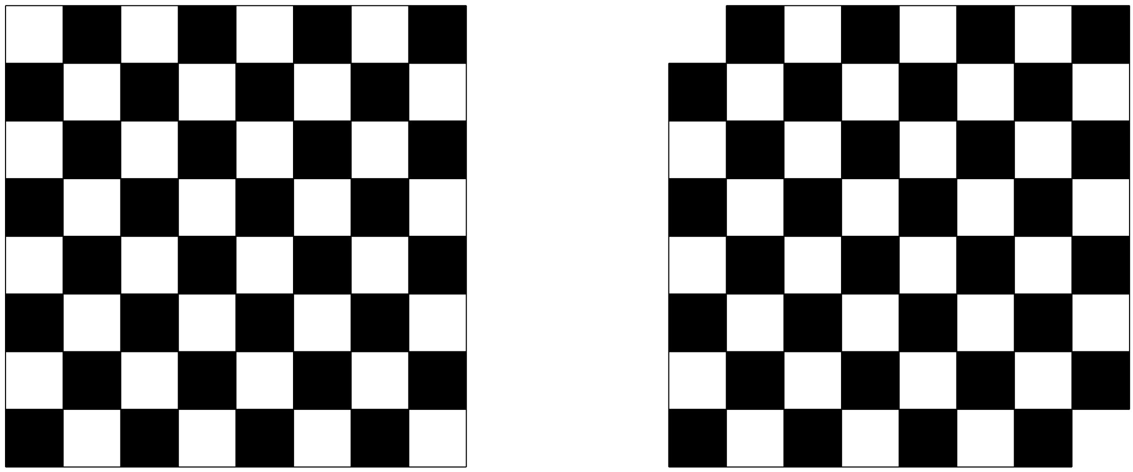


Figure 5.1: Two checkerboards

Of course it is. But what about the "mutilated" board on the right, which has had two corner squares removed? Is it possible to cover *that* checkerboard with one fewer domino?

Returning to the bumblebee problem, you can solve it with some fairly fancy mathematics. For the first trip, the bee and the 50 MPH train are closing at a rate of 160 MPH, so the bee reaches the train after $\frac{250}{160}$ hours, during which time it will have flown $110 \times \frac{250}{160}$ miles (about 171.9 miles). Now you have to figure out how far away the 75 MPH train is and repeat, then repeat again with the other train and so on. You get an infinite series of journeys, and it's possible to figure out how far the bee goes. It takes about two pages of algebra.

Alternatively, you can simply observe that the trains are approaching at 125 MPH, so the bee gets to fly for two hours before it gets squished. It goes 220 miles. The two pages of algebra are clumsy; the two-hour argument is elegant.

For the mutilated checkerboard, it's possible to use some fairly sophisticated mathematics (again, about two pages worth by the time that you're done) to prove that you can't tile the board on the right with 31 dominoes. Or, you can just notice that you took out two white squares, and each domino has to color one square of each color. After you've put down 30 dominoes, there will be two black squares left, and you'll be stuck. Once again, there is a clumsy proof and an elegant one.

In general, mathematics is elegant. The most insightful theorems almost always have short, elegant proofs.

It's also possible to get a "feel" for mathematics. When you're trying to prove a fairly complex result, it's often somehow clear when you're on the right track and when you aren't. The right track somehow feels right. And when you're stuck, you generally know that you're stuck. The problem is that you can't find an approach that feels right.

As an example, there is a famous theorem due to the French mathematician and jurist Pierre Fermat. It says that for any four positive whole numbers x, y, z and n with $n > 2$, you can never have

$$x^n + y^n = z^n$$

(contrast this with (4.1), if you'd like).

Fermat claimed to have proved this in the eighteenth century, although he refused to reveal the details of the proof (claiming that they were "truly wonderful, but too small to fit in the margin" of the book where the theorem first appears).

It is currently believed that there was probably a mistake in Fermat's proof, because the only known proof (due to Wiles in the 1990's) is hundreds of pages long. (This is an elegant result with no short proof, it seems.) How could Wiles have produced such a long proof? What kept him on track through the myriad steps involved?

His intuition did. Some things felt right; others, wrong. Surely there were many missteps along the way, but Wiles' intuition – his *feel* for mathematics – guided him sufficiently well that he was able to eventually assemble all the pieces into a single, coherent whole.

These two general properties – elegance and intuition – are what makes mathematics so vibrant. The better you understand mathematics, the more familiar you are with its details, the more vibrant it is. The same, of course, is true of God.

The study of mathematics is not fundamentally about adding long columns of numbers. It is about unraveling an unending series of beautifully crafted mysteries, each telling us something fundamental about mathematics, and through mathematics, about the world in which we live. The best mathematicians are more artists than engineers. Mathematics is simply their canvas, and a very vibrant canvas it is.

God hears us pray. There are two issues here. One is the idea that God "hears" us in some sense, and the other revolves around prayer generally.

It is presumably fairly clear that God doesn't hear us in anything resembling the way we hear one another. Here is the anthropomorphic view at its most pernicious; it isn't even clear what we could say instead. "God is aware that we pray?" That, too, anthropomorphizes the interaction.

God is everywhere in both space and time; in many ways, He is *outside* of space and time. He is without dimension; He is timeless. Our prayer (or lack thereof) is part of the framework of His universe. He is aware of it as He is aware of all things.

Perhaps that's not what is meant by "hear" in "God hears us pray." Perhaps the intention is that God will somehow *react* to our act of prayer or, more specifically, that God will reward prayer.

But that, too, is anthropomorphic. All we can really say is that, "Prayer is rewarded."

This brings us to the central issue of prayer. For whose benefit do we pray? Surely not God's; he doesn't need us to pray. He is what He is independent of our acknowledgment.

We pray for *ourselves*; not for God's benefit, but for our own. Perhaps what we should be saying is simply that praying is good for us.

But what is a prayer? It is, fundamentally, a recognition that God is in charge, that He is taking care of things. That God, as the order in the universe, has things under control and we can relax a bit and trust Him to deal with whatever troubles us. So instead of saying simply, “God hears us pray” (which is short and to the point, but confusing), I would say:

> At any point, it is always valuable to remember that God, as the order in the universe, is beneficial for all things.

Put thusly, there is no tension between this idea and the synthetic view. Indeed, mathematics supports it wholeheartedly: It is clearly only by virtue of the existence of an order to the universe that we can get by at all. What matter the particular name associated with the order itself?

God wants us to be good. Mathematics doesn't want much of anything.

While “wanting” is clearly an anthropomorphic quality, I don't want to dismiss the above statement for that reason alone. Instead, I'd like to ask what it *could* mean to say that God wants us to be good.

Non-anthropomorphically, we might just say that God *rewards* us for being good. Curiously enough, mathematics suggests the same thing.

People, by and large, are good.[1] We follow the Golden Rule, doing unto others as we would have them do unto us. The *fact* that we seem driven to follow the Golden Rule is often quoted (by C.S. Lewis in *Mere Christianity*, for example) as evidence of the existence of an absolute set of morals and, as the source of those morals, the existence of God.

To understand this from a mathematical point of view, I need to introduce a concept known as *Pareto optimality*. Let me describe it via an example.

Imagine that I have a basket full of toys. I've got video games, movies, sports equipment, and so on. I've also got a room full of kids, some of whom want one toy and some of whom want another. My job is to distribute the toys to the kids in some sort of optimal way.

Suppose that Fred wants a video game, and Rose wants a new baseball glove. If I give Fred the glove and Rose the game, I've obviously made a mistake; by switching the two items, I can make them both happier. This is the essence of Pareto optimality:

> A solution is called *Pareto optimal* if there is no way to make it better for one participant without making it worse for another.

Here's the surprising result: Imagine that we have a community of interacting agents, and that they need to pick some sort of protocol by which they will interact with one another. They can pick the Golden Rule, or “each man for himself,” or whatever. It's possible to show that if the goal is to maximize the expected well-being of each member of the community, the Golden Rule is a Pareto optimal protocol. “Each man for himself” isn't. A society that follows the Golden Rule will outperform (and eventually, outsurvive) a society that doesn't. Yes, God draws us to the Golden Rule as a recipe for living. Mathematics does the same.

[1] Not perfect, of course. Not without sin. Not godly. But we struggle to overcome our own frailties and failings, to honor what appear to be God's desires for us.

Perhaps, however, this evades the main question: God *wants* us to be good. It *pleases* God when we behave well. Mathematics simply doesn't support these anthropomorphic qualities, and they seem enormously difficult to give up.

But what does it mean for someone or something to want something, or to be pleased? In the case of a person, it may mean that a smile is evoked, that the person is happier, or that the person takes some specific action intended to cause the desired result.

God doesn't smile. What about the question of whether God is happy or sad? Surely God's behavior cannot be affected by such considerations; He would hardly wreak havoc on one person in a simple fit of pique over a third party's poor behavior. The story of Noah is typical; God saved Noah because he alone was a good man in a time of ubiquitous human failing.

Put somewhat differently, there is no way we could ever tell if God is happy or sad, no experiment we could conceivably do or measurement we could take that would resolve the issue. So according to the principle inroduced in Chapter 2, it makes no more sense to talk about God being happy than it does to talk about mathematics being happy. All that we can really say is that God, and mathematics, reward good behavior. The anthropomorphic and synthetic views are in complete accord.

Part II

Elements

Chapter 6

Where did God come from?

In the beginning of this book, I have argued (or tried to argue) that God and mathematics are the same. I have argued that they *must* be the same, because each is the (unique) order underlying the universe.

This argument only succeeds, however, if you believe that each of God and mathematics is indeed the order underlying the universe – if you believe that God is the order and that mathematics is secondary, there is no reason to equate the two. If you believe that mathematics is the order and that God is a fiction, there is similarly no reason to identify them.

In support of my argument, I have tried to suggest that the belief that God is the order underlying the universe is central to religion, just as the belief that mathematics is that order is central to science. Put somewhat differently, it is impossible to believe all three of:

1. God is the order underlying the universe.
2. Mathematics is the order underlying the universe.
3. God and mathematics are different.

All three of these beliefs are natural, but they are inconsistent.

My choice is to give up the third, jarring though that may be. My faith in the first two is simply too fundamental for me to consider a different course. But your choice may be different; perhaps you are unimpressed by technology and choose to abandon the second belief as opposed to accepting the counterintuitive abandonment of the third.

In this next part of this book, I hope to defuse this to some extent by making a bit more palatable the claim that God and mathematics are the same. I will do this in two ways: First, I'll examine some of the (non-anthropomorphic) properties that God has, noting in passing that mathematics has the same properties. I did this to some extent at the end of the last chapter, where I discussed the fact that – to a scientist, at least – mathematics has the same vibrancy that is normally attributed to God.

Somewhat more importantly, I would also like to address the counterintuitive nature of my fundamental conclusion by considering some well known religious elements, and seeing if mathematics can shed some light on them. Again as at the end of the previous chapter, it will turn out that the synthetic view of God is in remarkable alignment with the anthropomorphic view. It is my hope that all of these arguments and discussions, taken collectively, convince you to retain the first two of the crucial assumptions above, abandoning the third. God and mathematics truly are identical.

Discussing God's qualities from a mathematical perspective is a curious exercise; God has many qualities (e.g., His forgiving nature) that seem almost of necessity to doom our overall plan of understanding Him in this way. Let me set these godly qualities aside, just for a moment. I will return to them shortly, and ask only that you, as the reader, suspend your disbelief while we warm up with something simpler.

When my family joined a particular church in our town, one of the first sermons the pastor gave was about the first four words of the bible: "In the beginning, God." Before there was a universe, there was God. He existed before the Big Bang, and he will exist after the Big Crunch.[1] He is present at all times and at all places, everywhere and everywhen. In a very real sense, it is fair to think of God as *outside* of time and space.

God's atemporal nature is doctrinally recognizable in other ways as well. Consider Noah once again: When did God form the plan of flooding the earth and starting over?

The generally held biblical view is that God's plan here (as everywhere) is timeless. It's not as if God got up one morning, looked around, and said, "Things are a mess. I think I'll have a flood." We can please God by behaving well;[2] we can displease Him by behaving badly. But we can't surprise him. His plan for Noah existed before time began; as God is timeless, so are His plans.

It is God's atemporal nature that fundamentally undercuts any attempts we make to paint him in human terms. Human beings are born. We live, we die. Time is everything to us. It governs our lives, our actions, and our desires.

But time is nothing to God. It is not that He has so much of it that it means little; He is truly *outside* of time. It doesn't make sense to talk about God "living forever," because time does not pass for Him. I have a yesterday and a tomorrow. The Bob Chadsworth of yesterday may have a cold, while the Bob Chadsworth of tomorrow is healthy. But God does not get colds. There is no "God of yesterday" and no God of tomorrow. There is just God, for whom time matters not.

In all of man's universes, imagined and real, there are exactly two things that are outside of time in this way. God is one. And the other is mathematics.

There is a personal element that I should mention here. My tone throughout this book has been one of utter conviction in the fact that God and mathematics are identical; indeed, it is something that I believe utterly. But it is hardly something that I have always believed utterly.

I have believed in both science and religion for many years; they have both had the ring of truth for me. But for most of those years, I was content to simply believe, ignoring the intrinsic tension between the two disciplines. When I did start worrying about the tension,

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[1] Some physical theories suggest that the universe, although currently expanding, will eventually collapse back into itself. The point at which it collapses completely is colorfully referred to as the "Big Crunch."

[2] But remember the discussion in the last chapter about God wanting things.

the concerns were ill formed, nagging doubts that something was inconsistent in my belief set.

At some point, those nagging doubts became a specific hypothesis: Maybe God and mathematics were the same. “No,” was my first reaction, “That’s ridiculous. It can’t be.” And back the idea went into my subconscious murk.

While all of this subconscious muddling was going on, I was also struggling to better understand what God was *like*. Surely the image of an old man with a flowing grey beard, sitting on a throne of some sort and looking down on us, was no better than metaphorical. But what was he really like?

Well, one of his most striking features was his atemporality. How amazing, to be outside of time like that. Could I understand God by understanding that element of Him a bit better? What else was atemporal that I could use for comparison?

Unfortunately, nothing was atemporal. “Nothing lasts forever.”

Nothing except mathematics, that is. And there it was again, the suggestion that mathematics and God have something fundamental in common. Coming not from a direct attempt to reconcile science and religion, but from an attempt to simply understand God at all. And very slowly, I became convinced.

That conviction now rests on many things. It rests on the understanding of Grace that mathematics provides, on the insights it gives into free will, on what it has to say about the role of Jesus in God’s plan. But what first convinced me was the surprising fact that God and mathematics – and *only* God and mathematics – are outside of time, and the recognition that if science and faith are to both be valid, God and mathematics must be the same.

There are other consequences of the fact that God is outside of time. It’s often tempting to ask, “Where did God come from?” By this we often mean something like, “What was the universe like before God? What mechanism brought God into existence?”

These questions don’t make sense; since God is outside of time, you can’t really talk about the universe “before” God. That’s like asking about the part of this sheet of paper that’s to the left of Pluto. Pluto isn’t to the right or left of the paper; it’s in a different direction entirely. God isn’t a before or after thing; He’s in a different direction entirely.

It does make sense, though, to talk about what the universe itself would be like without God. Not before Him or after Him, just without Him. If God never had existed and never would. We know that God is just *there*, but can we say anything more? Where does God come from?

If we think about it in terms of mathematics, we can get something of a different slant on this question. Where does mathematics come from? Somewhat more specifically, where do numbers come from?

Well, it turns out that real numbers can be thought of in terms of series of fractional ones. So there is the number π, which is the ratio of the circumference of a circle to its diameter. Its decimal representation starts 3.1415926535...

The decimal representation of π never ends; there is no sequence of numbers you can write down that is *exactly* π. But you can write down a series of numbers that gets closer and closer. The series might start with 3, and then 3.1, and then 3.14, then 3.141 and so on. Each element of the series is a little bit closer to the actual value than its predecessor. And if I tell you I want a number that is within one part in a trillion of π, not only is there such a number in the series, but there's a point after which *every* number in the series is that close. A mathematician would say that π is the *limit* of the series, and it turns out that every number is the limit of a series of numbers that you can write down.

What about these numbers that you can write down? Where do they come from? Well, 3.14 is really just $\frac{314}{100}$, and so on. So the numbers that you can write down are just fractions, whole numbers divided by one another. The numbers you can write down come from the whole numbers. But where do the whole numbers come from?

It turns out that the whole numbers come from *sets.* A set is just a collection of things, like the set of glasses in my cupboard. I can think of the whole number "two" as the number of elements in that set (I don't have very many glasses!). "Three" might be the size of the next bigger set, and so on. *Zero* is the size of a special set called the *empty* set.

But where do sets come from? It turns out that sets come from a single operator that we might think of as "make a set out of." That's not much of an operator; once we say what sets are, it's pretty obvious that you can make sets out of the objects they contain.

But what about the objects themselves? Don't we need some objects to get started?

Amazingly, we don't. If we don't have anything at all, we at least have the empty set. And now we can make the set *containing* the empty set to get a set of one object! If we call the empty set $\emptyset$ and the set containing it S_1, now we can make a set with two objects – $\emptyset$ and S_1. This is S_2, and so on. Starting with just the idea of making a set, we get the whole numbers. We can talk about combining two sets to get the idea of addition, and multiplication from that. Division is the opposite of multiplication. Once we have division, we get the numbers that we can write down, and then all of the real numbers, and we're off. We have all of mathematics.

How can that be? Where did mathematics come from? All we started with was the idea of a set of things, and all of mathematics reappeared.

The way I like to think of this is that mathematics comes from *itself.* Somewhat more eloquently, the answer to the question, "From what wellspring did mathematics come?" is that mathematics is its *own* wellspring. You can't have a "little bit" of mathematics. As soon as you allow anything – even the idea of a set of things – all of mathematics comes tumbling out.

And so it is with God. God comes from *Himself.* His existence needs no justification. The universe is either completely godless, or God is everywhere. There are no half measures.

The anthropomorphic view makes it sound funny to say that God is His own wellspring, since this view makes it so hard to remember that God is outside of time. But it is easy, almost inevitable, to say that mathematics is its own wellspring. And so it is with God.

Chapter 7

Grace

There is a well known saying in politics: "You may forgive your enemies, but you never forget their names."

Human forgiveness is all too often like this. Someone transgresses against us (in our opinion, at least). Most of us struggle against the urge to strike back, to get even. On a good day, we overcome those desires and "forgive" them.

But have we really forgiven them? It may be true that we no longer wish them ill, but that is far different from truly forgiving – in Jesus' words, from offering them the other cheek to strike. The suggestion that we offer them the other cheek is not because we want to prove our ability to suffer, but because if we really do forgive them, we will trust them as well. To *truly* forgive someone is to treat them as if the original transgression or other problem had never even occurred.

And so it is with God and us. We transgress against Him constantly and in more ways than can generally be counted. On a bad day, we come to work grumpy and treat a coworker unkindly, or speak harshly to a troublesome child. On a good day, we forgive the coworker who treated *us* badly the day before – but our forgiveness is only partial. We fall far short every day, every minute, and in almost every way.

But God forgives us. Christian doctrine has it that he forgives us completely – so completely that it is as if our sins never occurred. How can this be? We have done nothing to merit that forgiveness.

God's forgiveness is the essence of grace. Grace is *undeserved* reward. We are completely and utterly forgiven, although we have done (and will continue to do) nothing to deserve it. God's forgiveness is as undeserved as it is complete. Such is grace.

Grace is a complicated issue. Some things about it seem easy to understand, others hard. Perhaps it varies from person to person. But there are certainly many issues involved; the two that typically are focused on the most closely are:

1. *How* is it that God manages to forgive us so completely?

2. Is there a price that must be paid for our forgiveness?

Let me deal with only the first question here. I will return to the second, but only after laying a good bit of groundwork first.

The question of how God can forgive us completely is curious for many reasons. In one sense, it seems *obvious* that God can forgive us completely: his power, after all, is without bound.

In another sense, however, it seems *impossible* that God can forgive us completely. He surely cannot forget our sins, after all. Isn't it a contradiction for God to treat us as if the sins had never occurred when He cannot forget that they did?

I'll attempt to argue shortly that there is no contradiction here, since God's actions, His treatment of us, need not reflect his memory and knowledge of our fallibilities. Before turning to this, however, let me spend just a moment discussing an apparent contradiction in the previous two paragraphs: How can a God with unbounded powers be incapable of forgetting?

It is clear that God's powers are not completely unrestricted. He cannot, for example, cause Himself to cease existing. So *some* restrictions on His powers exist. (And I'll suggest in Chapter 8 that these restrictions are profound indeed.) How can there be restrictions on unbounded power?

Let me answer this with an analogy. Consider the sequence of integers

$$1, 2, 3, \ldots$$

It is reasonable to say that this sequence is *unbounded* in that if I name any particular number, such as $1{,}320{,}097\frac{1}{4}$, there is a number in the sequence that's bigger. But it's also reasonable to say that the sequence is restricted in that every element satisfies some particular property – in this case, every element is a whole number, with no fractional part. $1{,}320{,}097\frac{1}{4}$ is simply not part of the sequence. The sequence is unbounded, but hardly unrestricted. God's power is similarly unbounded, and similarly restricted – there are things that He cannot do, but nothing so large that His abilities are not larger still.

What about grace from the perspective of mathematics? I'd like to look at this in terms of four separate questions:

1. What is a "sin" from a mathematical point of view?
2. What is the consequence of a sin?
3. Is sinning part of human nature?
4. How (and how completely) is a sin forgiven?

Sin from the point of view of mathematics What, then, is a sin?

The bible answers this in many ways. A sin is a violation of one of the ten commandments. Perhaps more generally, it is any action taken against the will of God. But as we discussed earlier, to say that God has a will is to anthropomorphize him. In a less anthropomorphic way, perhaps we might describe as a sin anything that diminishes God, either by contravening

His specific instructions (be it disobeying a commandment or eating forbidden fruit) or by diminishing Him directly (worshiping idols, propounding atheism, and so on).

How does one diminish mathematics? The answer, I would argue, is simply by making a mistake. Adding a long column of big numbers, if the answer is 1,452,227, that's what you're supposed to come up with. To produce a different answer (say 1,451,227) is to diminish mathematics.

The man who says that God does not exist may well not be lying. But even if his mistake is an honest one, it is still a mistake that diminishes God. It is still a sin.

In a similar – albeit far less dramatic – way, to proclaim that $2 + 2 = 3$ is to diminish mathematics. The mistake may be an honest one (although presumably not in this simple a case!), but it is a sin nonetheless. Mathematics "wants" the answer to be four; when we write something else, we diminish mathematics.

The consequences of sin In spite of this, it certainly feels like getting a single digit wrong when adding a whole page of numbers is less of a sin than standing on the rooftop and glorifying the devil. Are there big sins and little sins, with mathematical transgressions somehow being less important than spiritual ones?

There is no scriptural distinction between a big sin and a small one. We all sin, all the time. And all of those sins are forgiven, independent of their size. In fact, it is inevitable that sins that are small in our perception lead to "larger" ones. A minor transgression today, be it a harsh word or an apple eaten, only sets us up for more serious mistakes tomorrow.

Mathematics supports this view completely, also drawing no distinction between a big sin and a small one. The idea that small mistakes lead to larger ones pervades mathematics as well, where one false statement generally leads you to conclude many others.

In fact, a single false statement will in general allow you to conclude *all* others; in mathematics, "Falsehood implies anything." In fact, one of mathematics' urban legends involves a philosopher – supposedly Bertrand Russell – attempting to explain this idea to a dinner companion who refused to accept it. Russell's colleague challenged him with, "If falsehood implies anything, suppose that $2 = 1$. Now prove that Tom over there is the pope."

Without hesitation, Russell replied, "Tom and the pope are two, therefore Tom and the pope are one." The speed of Russell's response impresses me as much as its clarity.

In both systems of belief, then, there are obvious sins and non-obvious sins, but the "size" of a sin is an illusion – in God's eyes, none is larger or smaller than any other. And in both systems, apparently small sins lead almost inevitably to sins that seem more substantial.

The inevitability of sin As both the anthropomorphic and non-anthropomorphic views agree that all sins are equal, they similarly agree that sin is inevitable for us – part of our essential nature.

In the anthropomorphic view, this is simple doctrine. We sin because we are imperfect.

In the synthetic view, this is simple statement of fact. We sin because we are imperfect: who among us has never made a mistake of the sort that causes a checkbook not to balance?

It is also the case in both views that just as sin is inevitable for us, it is *impossible* for God. In both views, to sin is to do something that is against God's nature – something that is impossible by definition.

Redemption from sin Let's have another look at the example of the unbalanced checkbook from a few paragraphs above. You make a mistake computing the balance after check #1137, which then propagates (as sins do!) to a mistake in the balance after check #1138, #1139 and so on.

But now suppose that you find the original error; you were off by $1. So you add a dollar to the balances after each subsequent entry, and your checkbook now balances.

It is as if the mistake had never been made. Mathematics (i.e., God) has forgiven you.

It is all too easy to be deceived by the apparently trivial nature of this example. Of course mathematics forgives you. But "of course" in what sense? If you make a mistake and stick a fishhook into your finger, it's not a simple matter to remove it. Nature is not in general nearly so forgiving as is mathematics.

It is in the nature of mathematics to be forgiving. Mathematics is so *completely* forgiving that it one cannot imagine it being otherwise. And so it is with God – which is, after all, the same thing. I find it curious that from a commonsense point of view, people often have trouble coming to grips with the fact that God is forgiving while simultaneously being unable to imagine mathematics being otherwise.

Before we turn to other matters, there is one additional point that I would like to make. In order to have our checkbook sin erased, we need to recognize it, and repair both it and its consequences (the subsequent entries in the checkbook). Conventional religious doctrine does not require recognition or reparation in order for a sin to be forgiven.

When we say in the anthropomorphic view that God forgives us completely, we do not mean that sin is without consequence. We mean that *God* bears us no ill will because of the sin, although the sin itself may well have distasteful (and hence educational) ramifications.

Mathematics is, as usual, exactly the same. Mathematics doesn't hold it "against us" when we make a mistake. The laws of arithmetic don't make it harder to balance a checkbook one month if we've made a mistake in the previous month. There are consequences, which we can typically repair, but mathematics itself bears no grudge. Once again, the two approaches lead to identical conclusions.

Chapter 8

Free Will

Religious doctrine is typically very concerned with issues surrounding free will. The idea, basically, is that the choice of whether or not to believe (in God, in Jesus, in little green men, whatever) is ours. God, for all His power, does not control whether or not we believe. That choice, and the consequences that go with it, is up to us.

I would like to spend this chapter discussing free will and related issues. In fact, I would like to broaden the discussion somewhat, discussing not only questions involved in whether or not whether *we* have free will, but also the question of whether or not *God* has free will.

8.1 What is free will?

Before approaching any of these matters, let me examine the question that underlies them: What is free will in the first place?

On the face of it, "free will" is any choice that some entity (us, God, little green men, etc.) makes in an uncontrolled way. So it seems as if free will refers to any choice that is not controlled by an outside influence.

There is another, somewhat different definition, however. It might make sense to speak of free will as a choice that, in addition to being outside the control of some third party, cannot even be *predicted* by that third party. This definition appears to be somewhat less inclusive than the previous one, since presumably if the third party can *control* our choice in some area, then that third party can *predict* our choice as well.

As mentioned previously, I would like to examine the difference between these two types of free will in two separate settings:

1. The question of whether or not we have free will, in that God can either control or predict our choices.

2. The question of whether God has free will, in that we can either control or predict His choices.

Let's look at the first of these. What would it mean for God to "control" a choice of ours?

One thing that it *wouldn't* mean is that we would be about to choose one thing, and then God comes along and makes us choose something else. God is outside of time. If He is going to force us to do "something else," then we were *always* going to do that something else; it was inevitable. It doesn't make sense to talk of our being "about to" make a different choice; we were inevitably going to choose as God decided.

Put somewhat differently, God is the order underlying the universe. If we make a choice, and that choice could be predicted in any way, then that choice is a consequence of the universal order underlying the predictive method. *This* is what it means for God to "control" our choice – that the choice is a consequence of God's universal order. In other words, that the choice is predictable.

There is thus *no difference* between God being able to predict our choices, and His being able to control them. It might seem that God, outside of time, would have no trouble predicting our choices at all. But as we will see, especially in Part **??**, things are not so simple.

Before turning to this, however, let me touch on the question of whether God has free will.

In this case, it is (or at least should be!) clear that we can't *control* what God does; the best we can hope to do is to predict it in some cases. So while the question of our having free will was unchanged in the "control" as opposed to "predict" sense, the question of God's having free will is interesting only in the "predict" case. So that's the interpretation I'll be using throughout this chapter: When we say that an entity has *free will*, we'll mean nothing more or less than the fact that the entity's choice cannot be predicted.

8.2 Free will for us

When we ask, then, whether or not we have free will, we are really asking whether or not our actions and beliefs can be predicted. I'd like to look at this in some depth, since the observations we make here will bear on a variety of issues in Part **??**.

One way in which our actions might be predictable would be if *everything* were predictable, in the sense that if we only knew enough about the details of the universe at the current time, we could predict its behavior with arbitrary accuracy at any point in the future. If this were true, we would say that the universe was *deterministic* since its current state would unequivocally *determine* all future states.

Is the universe deterministic? There is certainly nothing in our basic belief set that says that it isn't; God could still be the underlying order and meaningless questions would still be meaningless.

In fact, the universe was believed to be deterministic in Newton's day, and this belief continued until the early twentieth century. It was as if the world were a giant pool table, with balls moving along and bouncing off one another according to predefined rules. Small inaccuracies in our knowledge about the position of any particular ball might eventually magnify, since the future path of that ball would become more and more uncertain, but in principle at least, we could know the current state of the universe to arbitrary accuracy and predict from that state what the universe would be like at any given point. (Of course, *we* would never have the resources to conduct such a computation, but in theory it would be possible. God – or mathematics in the abstract – could certainly do it.)

With the advent of quantum mechanics, however, things become much murkier. Now we realize that it is impossible to know the position of any of the pool balls with arbitrary accuracy; indeed, it doesn't even make sense to *talk* about arbitrarily precise positional information. Quantum mechanics is *non*deterministic. There are some things that you just can't know.

As an example, suppose that I have a uranium atom. Uranium atoms go through a process known as *fission*, where they spontaneously break into smaller pieces.

The half life of a uranium atom is about 47 minutes. That means that if you take a uranium atom, half the time it will split in less than 47 minutes, and the other half of the time is will split in more. But there is *no way* to tell in advance just how long it's going to take. All uranium atoms are the same; it's just that some of them split quickly and some split slowly. You can't tell how long it's going to take; all you can do is wait and see.

Uranium's unpredictability has all manner of interesting consequences. It turns out that while a uranium atom just sitting there takes about 47 minutes to decay, you can cause it to decay much more quickly by hitting it with something – like a fragment from the decay of another uranium atom.

So suppose that I have a whole pile of uranium atoms. One of them decays, emitting some atomic fragments. Some of those fragments just go flying off, and nothing interesting happens. But if some of those fragments hit other uranium atoms, then they decay, emitting still more fragments.

It's like a room containing some mousetraps. On each mousetrap are two ping-pong balls. When one mousetrap goes off, the ping pong balls fly around the room. Maybe they hit nothing. But sometimes they hit two other mousetraps, and now there are four ping pong balls flying. Then eight, and so on – a chain reaction.

And so it is with uranium. If you have enough uranium, and it's in a small enough space, then all of the particles cause more decays, and pretty soon you have particles flying everywhere. An atom bomb.

If you don't have quite that much uranium, a lot of the particles escape. They hit other things, and can make those other things hot. You can use that heat to produce steam, and then use the steam to turn turbines. The reaction doesn't get out of hand (you hope!). That's how a nuclear reactor works. It's tricky because you can't predict the behavior of each individual uranium atom. All you can do is hope that you have enough such atoms that they behave, on average, about like you'd expect.

But let me return to the case of a single uranium atom. If we watch it, we'll know after 36 minutes (or whatever) whether it's decayed or not. But what if we don't watch it?

It's a lot like the electron traveling through two slits that we discussed in Chapter 2. When we didn't disturb the electron by looking at it, it went through *both* slits.

And so it is with the uranium atom. It isn't in a state of "decayed" or "not decayed." Until we make the observation, it's in both states.

The German physicist Kurt Schrödinger made this example even more bizarre. Imagine, Schrödinger suggested, that we build an apparatus that detects the decay of the uranium atom. Also included is a cat, and the whole device is constructed with a mechanism that gives the cat a fatal injection when the uranium atom decays. We put a black box around the cat-uranium setup and don't look inside.

Since we haven't observed the uranium atom after 47 minutes, it is presumably in a half-decayed, half-not-decayed state. But what about the cat? Is it half dead and half alive?

Questions such as those surrounding Schrödinger's cat have made quantum mechanics a philosophical quagmire for the last century. We will return to these questions as well in Part **??**, but let me leave them unaddressed for the moment.

Instead, I'd like to return to a comment from earlier in this section. I've suggested that the question of whether or not we have free will is intimately connected to the question of whether or not our actions can, at least in a theoretical sense, be predicted. If our actions can be predicted, then God, as the order underlying the universe, is controlling them as well. We have no free will.

But what if our actions can't be predicted? What if they are somehow tied up with quantum mechanics (for example), and simply outside the domain of the predictable? Would it be fair to say that we have free will in this case?

Maybe it would. But – and here is the crucial point – *it wouldn't matter.* Those of our actions that were outside of God's control, outside of His ability to predict, would necessarily be outside of *our* control as well. It wouldn't make sense to say that we "chose" to believe in God; it wouldn't be our choice to make. Maybe the state of our belief is predictable; maybe it's quantum mechanical. But we certainly can't control it in a way that God cannot.

This appears to fly in the face of conventional religious doctrine. The usual view is that we choose whether or not to believe, and that God rewards those who choose to believe and punishes those who choose not to. If the choice is out of our hands, so that we cannot control whether we believe or not, the situation seems unfair.

If we were somehow divided arbitrarily into believers, who would be saved, and unbelievers, who would be punished, it would perhaps be unfair. But just as one piece of good news is that believers are indeed saved, let me give you another: Sooner or later, everyone will believe.

This is not a guess. It's not speculation. It's a necessary consequence of the two observations we have made in this section:

1. We can never be better able to predict our own beliefs than God is, and hence can never have more control of them than He does.

2. Any scenario in which some souls are arbitrarily selected for salvation and others are not is inherently unfair.

To these two we must only adjoin the fact that God's plan is fair to conclude that everyone must be saved – sooner or later. We'll come back the this in Part **??**, where I'll try to explain just how it is that everyone has time to believe, why it's impossible to die first. But even without this explanation, I would argue, we would know that everyone will indeed believe and be saved eventually.[1]

8.3 Free will for God

But what about that third assumption above, that God's plan is fair? Granted, it would certainly be comforting to know that God's plan is fair, but what if God is cantankerous? Can His plan be unfair? Does He have free will in that He can choose to have an unfair plan?

I would argue that He cannot. God is hamstrung by His own perfection. At many levels, he *defines* perfection; nothing truly godlike can be imperfect. While quantum mechanics may (or may not!) render us unpredictable in fundamental ways, God *is* predictable. Any quality of His is dictated by the simple requirement that He be absolutely perfect.

There is, needless to say, a mathematical analog. To understand this, let me turn to a famous mathematical result, the fact that every map can be colored using at most four colors without coloring two neighboring countries the same color.

The fact is interesting for two reasons. First, it's pretty obvious what the claim means. You don't have to be a mathematician to understand that some maps can be colored using just three colors, while others need four. (A map of the United States needs just three.)

Second, although you can draw a lot of maps, and color all of them with just four colors, that doesn't mean that *all* maps can be colored in this way. You haven't proved that you can *never* make a map that needs five colors.

It turns out that you can't. But the proof that you can't is extraordinarily complex, and lay undiscovered for over a century before finally being found by a team of mathematicians and computer programmers from the University of Illinois in 1976. The proof is *so* complicated, and involves so many different cases, that a computer had to be used to check them all out.

But let's go back to a point in time before 1981, when people suspected that the "four color theorem" was true, but couldn't prove it. Even during this period, it was recognized that there *was* an answer – either every map could be colored with four colors, or it would eventually be possible to produce one for which no 4-coloring existed. Unlike our quantum mechanical universe, mathematics (and therefore God) are deterministic.

... But in the case of mathematics, not quite. Let me see if I can explain an exception.[2]

It is clear that if I have a flower with three leaves and two blossoms, it has more leaves than blossoms. But what about the even numbers? Are there properly fewer of them than there are whole numbers generally?

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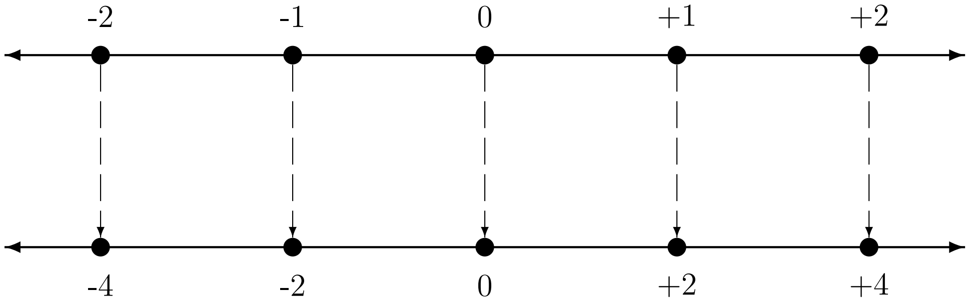
[1] I am very much aware that my comments here appear to contradict biblical references where Jesus says that those who believe in him will surely be saved, and those who do not believe will surely die. Does this not imply that some die without coming to believe? Please bear with me until I can resolve this in Chapter **??**.

[2] This is going to get reasonably tricky, for which I apologize. Feel free to skip on to the next chapter if you're so inclined, although you might want to read the last paragraph or so of this one first.

At first, it seems like there are. But now consider a way to associate each whole number with an even whole number – just double it. It's pretty clear that no two whole numbers get associated with the same even number, and that every even number is associated with something. This is what mathematicians call a "one to one" mapping:



If you can construct a mapping like this, then it seems reasonable to think of the two sets in question as being of the same size.

Now suppose that I have some set S of objects. I can construct a new set S' that contains all of the *subsets* of the original set S. So if my original set S consists of the four members of my family, the new set S' consists of all of the groups of people *within* my family. Examples might be the set consisting of just me, or my wife and me together, or the two kids, or all four of us (the whole set S is an element of S'), or maybe none of us at all (the so-called "empty set" that we saw earlier in Chapter 6).

Now I can make the following claim: *For any set S, the set S' is bigger than the set S.* This is actually two claims: First that the set S' is at least as big as S is, and second, that there can never be a one-to-one mapping between S and S'.

The first claim is obvious. Each element of S is itself an element of S', so S' is at least as big as S is. What's surprising is that there is some way to prove that there can *never* be a one-to-one mapping between S and S'.

Suppose that there were such a mapping. Than for any particular element e in S, suppose that e is mapped to some e' that is in S', so that e' is a set of elements of S. Now there are two possibilities: either the original element e is in e' or it isn't.

Now here's the trick. Consider the set of *all* of the elements e in S that are *not* in the associated e' is itself a subset of S. I'll call this set T. Since T is an element of S', there must be some element f in S that is mapped to T.

Now suppose that f is in T. That means that f is in the associated f', which means that f is *not* in T because of the way that T itself was set up. Alternatively, if f is not in T, then f is not in the associated f', so f is in T after all.

So it turns out that f can't be in T, and f can't not be in T. This is obviously impossible, so our original assumption (that there was a one-to-one mapping between S and S') must have been wrong. In other words, S' is properly bigger than S.

Whew. Now it gets easier.

Consider the set of whole numbers. Now suppose that I have a particular subset, say $\{2, 3, 5, 6\}$. I'm going to write this like this:

$$.0110110000\ldots$$

where the way it works is as follows: The first number after the decimal point is 0 because 1 is not in the set. The next number is 1 because 2 *is* in the set. Then 3 is in the set, 4 is not, 5 and 6 are, and then nothing else is.

The number above can actually be thought of as a real number, just like the number

$$0.25$$

corresponds to $\frac{1}{4}$. Of course, numbers like the .011011 above will consist of only 0's and 1's, so it makes sense to think of them as "binary" decimals – instead of the first place counting the numbers of $\frac{1}{10}$'s, the second the number of $\frac{1}{100}$'s, and so on, the first number counts the number of $\frac{1}{2}$'s, the second the number of $\frac{1}{4}$'s, etc. Thus the above real number is

$$\frac{1}{4}+\frac{1}{8}+\frac{1}{32}+\frac{1}{64}=\frac{27}{64}$$

This construction gives us a mapping between the set of real numbers between 0 and 1 and the set of *subsets* of the whole numbers. It follows from this that there are *more* real numbers than whole numbers.

So here's the question: Given that there are indeed more real numbers than whole numbers, is there any other set that is properly between the two? Is there a set that's bigger than the set of whole numbers, but smaller than the set of real numbers?

Since no one was able to produce such a set, it was generally believed that there wasn't one. The suggestion that there wasn't was called the *continuum hypothesis.*

One of the most remarkable developments in mathematics occurred in 1963 when it was shown that the continuum hypothesis was independent of the axioms of arithmetic. In other words, *the continuum hypothesis can come out either way.* Mathematics remains consistent if it's true, and mathematics remains consistent if it's false.

Yes, mathematics is generally constrained by its own perfection, by its own rigor and constraints. But every now and then, there are two possibilites that are *equally* perfect. And then mathematics – and God – finally has a choice.

In mathematics, these choices are incredibly rare. In addition to the continuum hypothesis, only one other is known (it's called the "axiom of choice," and it's even more confusing). God and mathematics aren't completely constrained by their own perfection, but it's awfully close.

Chapter 9

Jesus

In discussing Jesus, the position I am taking reconciling religion and science becomes more difficult still. To Jews, Jesus is a rabbi. To Moslems, a prophet. And to Christians, the son of God. Science and religion have done little more than bicker (since the inquisition, at least). Religions have been at war for millennia.

I hope that what I have to say about Jesus is consistent with the views of all of the major religions. This is not because I'm trying to straddle the fence and to avoid committing; it's because I believe that the *essence* of what Jesus was is, in fact, consistent with the major religious beliefs.

The question that I will try to address here is not that of who Jesus *was* (where religions do indeed differ, and I will decline to choose sides), but the question of what *role* Jesus played in God's plan.

Let me begin by describing a few things that Jesus' role is *not*.

First, Jesus' role is not a causal one. It's common to hear Christians say that humans in general are saved *because* of the facts surrounding Jesus' death on the cross. The implication is that if Jesus had not died as he did, the rest of us would be beyond salvation.

Whoever or whatever Jesus was, it is clear that he plays an important role in God's relationship with us. This means that God had no choice about the facts surrounding Jesus' life and death. Jesus *had* to die as he did. Jesus' death was an inevitable part of God's perfect plan for us. God's plan itself, as God, is outside of time. The inevitability of Jesus' death was as true ten thousand years before he lived as it is true today.

Given that Jesus *had* to die as he did, statements about "If Jesus had not died on the cross ..." simply don't make sense. To imagine a world where Jesus died in some other fashion is to imagine a world where God's plan (and thus God himself) is imperfect. It doesn't make any sense.

If we can't talk about the causal consequences of Jesus' life and death, what can we talk about? The answer, I would argue, is that we can seek to understand in more detail the role that Jesus plays in God's plan. Given that God's plan is fixed, perfect, and outside of time, Jesus' role can't be causal. But it still can be – and obviously is – important.

Whether you think of Jesus as a rabbi, a prophet, or the son of God himself, one thing is, I think, clear: Jesus' role is to help bring mankind closer to God.

There are two specific ways in which Christians expand on this overall view. In the first, they suggest that God, being perfect, was incapable of having a relationship with humans, who were inevitably imperfect. Jesus bridged this gap by allowing God to walk among us, to share our imperfections and thus come to have a direct relationship with us.

The second element of Christian doctrine here is that Jesus' death was a payment. The basic idea is that our sins incur a debt on our part; justice requires retribution of some sort. Jesus' death pays a price that we ourselves could never pay.

Jesus as a bridge Let me deal with these suggestions in this order, beginning with the idea that Jesus is a "bridge" that allows God to interact with us when He otherwise could not.

We touched on a similar notion in Chapter 5, when we discussed prayer. Prayer, we pointed out, is not for God's sake. It is for our sake. God doesn't need us to pray to Him; rather, we need to pray because it is we ourselves who benefit when we do so.

And so it must be with Jesus. God does not need Jesus. *We* need Jesus. God is everywhere, at all times and in all places. He is the order underlying the universe. He will interact with us come what will. In the anthropomorphic view, he will understand us whatever our failings. Always and forever.

Jesus *is* a bridge between us and God. But it is we who must cross the bridge, not God. God does not move.[1] As I said a few paragraphs ago, Jesus' role is to bring mankind closer to God, not to bring God closer to mankind. If the mountain will not come to Mohammed, Mohammed must go to the mountain. God is a mountain that does not move.

Jesus as a payment The other conventional Christian role for Jesus is that of a savior. The idea is that a price must be paid for our sins (or other indiscretions), and that it is Jesus who pays the price.

Implicit in this is the notion that God's justice is *retributive.* You break the rules, you pay the price.

Justice need not be like that. When my son breaks the rules, my response is whatever will help him grow into the best man. Sometimes, he gets punished. But other times, he doesn't. Maybe he has already tried his best to make things right. Maybe he's confessed the mistake, and it's better to reward the honesty than to punish the crime. My goal in the interaction is not to punish my son, but to help him.

Surely it is the same with God. Indeed, the bible encourages us to think of God not as a judge, but as a father. God's desire appears to always be simply that we be close to Him. It is never that we suffer for suffering's sake.

We can go further. We *know* that God's plan for us does not involve retributive justice. We can argue that this is "because" of Jesus or not, but it is clear that retribution is simply not part of God's overall plan.

[1] In fact, God *cannot* move. His perfection constrains Him.

There is no retribution in God's plan. Not now, not ever. Not in the future, and not in the past. God doesn't "need" Jesus to sidestep retribution and more than He needs Jesus to be involved in our lives. God's involvement with us is inevitable. Since God's justice is not retributive, it, too, is inevitably that way.

What role for Jesus? I suggested earlier in this chapter that while Jesus was not a bridge in the sense that he allowed God to move closer to us, he *was* a bridge in that he allowed us to move closer to God. I suggested above that Jesus was not our savior in that he allowed God to forgive us when He previously could not. Is Jesus our savior in some other sense?

Absolutely. The bible says it clearly in Acts Chapter 13, verse 38: "Therefore, my brothers, I want you to know that through Jesus the forgiveness of sin is proclaimed to you."

The verse does not say that through Jesus, sin is forgiven. It says that through Jesus, the (preordained and inevitable) forgiveness of sin *is proclaimed to us.* As always, Jesus' role is for us, not for God. God doesn't need help forgiving us. We need help understanding the nature and depth of his forgiveness.

Before moving on, let me acknowledge that the suggestion I am making here – that Jesus' death was a proclamation as opposed to a payment – is at odds with conventional biblical interpretation. While I believe that it follows from God's basic nature that Jesus' death must be a proclamation (which we need) as opposed to a payment (which God cannot need), let me try to explain why I believe that this view is, in fact, completely in accord with what the bible actually *says*, although not perhaps with how it is typically interpreted.

Early translations of the bible describe Jesus' death as a "propitiation", a word that means appeasement. But more recent translations, such as the NIV (New International Version) describe it as a "reconciliation", a word that is far more forgiving.

I find the "appeasement" translation unrealistic. You cannot appease a timeless entity; appeasement itself makes no sense in that context. Appeasement is a *process* wherein the feelings of the appeased individual change. Appeasement *is* the change. But God, outside of time as He is, cannot change. To appease God is a contradiction in terms.

That said, here are the first eight verses of Romans 5:

> Therefore, since we have been justified through faith, we have peace with God through our Lord Jesus Christ, [2]through whom we have gained access by faith into this grace in which we now stand. And we rejoice in the hope of the glory of God. [3]Not only so, but we also rejoice in our sufferings, because we know that suffering produces perseverance; [4]perseverance, character; and character, hope. [5]And hope does not disappoint us, because God has poured out his love into our hearts by the Holy Spirit, whom he has given us.
>
> [6]You see, at just the right time, when we were still powerless, Christ died for the ungodly. [7]Very rarely will anyone die for a righteous man, though for a good man someone might possibly dare to die. [8]But God demonstrates his own love for us in this: While we were still sinners, Christ died for us.

The beginning of the passage makes it clear that it is our faith that justifies us, as opposed, perhaps, to Christ's sacrifice directly. It is clear that Christ's sacrifice has an important role to play, but it is our faith that is the source of the justification.

This is born out in earlier chapters in Romans. In Romans 4:5, for example, we are told, "... to the man who does not work but trusts God who justifies the wicked, his faith is credited to righteousness." Romans 4:9 goes on to ask, "Is this righteousness only for the circumcised [Jews], or also for the uncircumcised [Gentiles]?" This passage goes on to repeat that it is faith that matters, not circumcision or the lack thereof.

Continuing with Romans 5, we see in verse 6 that Christ died for the unrighteous, for the faithless. This is how God *demonstrates* his love for us (verse 8).

The consequence of this demonstration is to bring us closer to God. The recognition of God's love for us has allowed millions of us to find our way toward trusting in God generally – in other words, to find faith. Christ's blood *has* saved us. But not by appeasing God. Instead, it has saved us by allowing us to discover faith. If there is a causal relationship here, that is it: Christ's death has caused us to have faith. It reconciles us with God by changing *us*, not by changing God.

I find this reading, that Christ's death changes us and helps us to deal with our own shortcomings, far more natural than a reading that implies that Christ's death somehow changes God by allowing Him to forgive us when He previously could not. There is, however, another way in which this reading conflicts with the standard Christian beliefs. If you interpret the bible as I have suggested, then a person of faith who came to that faith *without* the intercession of Christ would be as thoroughly saved as someone who came to faith only because of the demonstration that Christ's death provides.

I think that the bible supports this view. First, Romans itself says this explicitly. Chapter 4 is entitled, "Abraham justified by Faith." It is faith that brings Abraham to God, not Christ specifically. But this seems at odds with Jesus' statement reported in John 14: "I am the way and the truth and the life. No one comes to the Father except through me." The NIV bible itself suggests that a more careful translation would be, "I am the way (to the Father) *in that* I am the truth and the life."

Jesus' life and death are a path to salvation for many of us, but it is Jesus' unflagging commitment to his faith that is the path that we must *all* follow. It is in that way that Jesus is the truth and the life, and it is surely true that faith is the only path to God.

Jesus' fundamental message is always that it is faith in *God* that is crucial. Perhaps this faith is to be found through Jesus; certainly many have. But the Jews who preceded Jesus could be justified through their own faith, perhaps found in other ways. Others have found faith in the Koran, or in mathematics. Jesus is the unique path to God in that he and his life are a testimony to faith, and a lack of faith is the gap that each of us must cross if we are to draw closer to God. But it is important only that we find God, and not whether we find him in the New or Old Testament, the Koran, mathematics, in a rainbow or under a rock. It matters only that we find him. The path is faith itself. And in that light, there is indeed only one path.