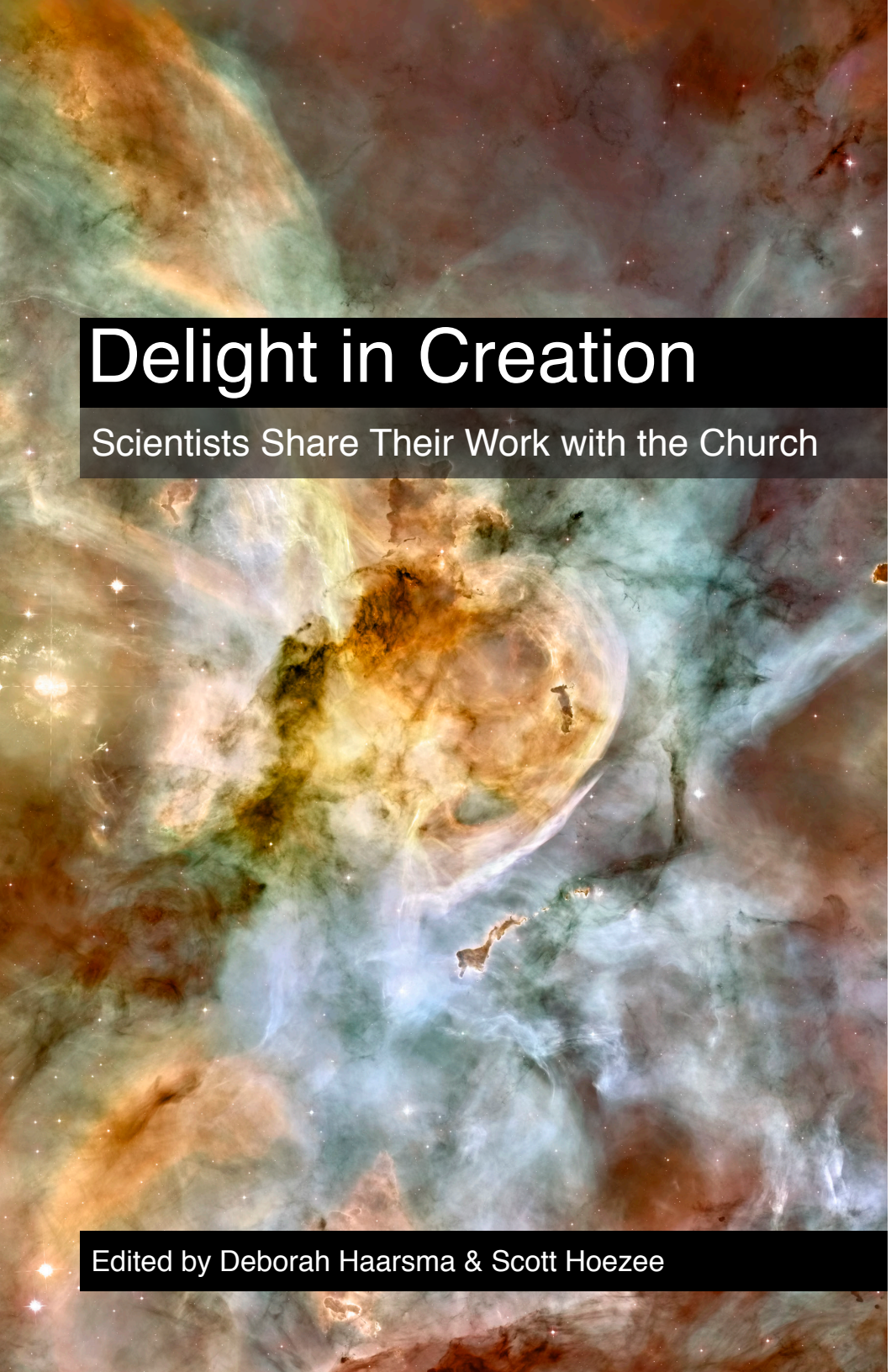

9 Randomness and God's Governance

by Randall Pruim

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I've enjoyed playing games as long as I can remember. Among my earliest memories are playing Candy Land, Chutes and Ladders, Don't Break the Ice, and Don't Spill the Beans. When I was a child, whenever someone did not know what to get me for a birthday or Christmas present, a game was always a good choice. Today, in the back room of our house, we have a closet filled with games that my children and I have accumulated over the years. The rest of our games are either in a closet upstairs or in one of several large boxes in the attic. Periodically we rotate the location of the games for variety.

Many of the games I enjoyed playing involve a combination of strategy and randomness: card games of various sorts, backgammon, and board games like Monopoly and Parcheesi. Some games, like Candy Land, Sorry, and War, which rely exclusively on chance (War, Candy Land) or too heavily on chance (Sorry) quickly became uninteresting to me. In fact, for Sorry, War, and several other games, I introduced additional rules to change the balance of strategy and luck—for example, by allowing each player to hold a hand of cards rather than merely flip a card and follow its bidding.

When my children were young, I played many games with them, especially those involving some amount of chance. I always play to win, so games of pure strategy like chess gave me too great an advantage—at least when they were still young. I still remember the first time I played the German game *Mitternachtspartie* with my children and some of their cousins. The game uses a die on which the number 5 has been replaced with the image of Hugo the ghost. Each player rolls the die and moves one of his figures the specified number of squares, unless Hugo is rolled, in which case Hugo moves instead. I quickly worked out the expected distance Hugo would move for each of my turns and the expected number of squares I would get to move my own figures each turn. Using that information, I could strategically place my figures in the opening portion of the game. I fully expected to win this first game, since my young children were going to have to learn from experience what I already know by the mathematics of probability. I lost—badly. As it turned out, the die had two Hugos on it. So compared to my expectations, Hugo moved twice as often, and my figures moved slightly less far. That combination turned the carefully calculated positioning of my figures into a disaster.

From Fun and Games to Science

I still enjoy playing games, including games that involve chance. But these days I encounter randomness even more often in my profession. Trained as a mathematician and now working at the intersection of mathematics, statistics, and computer science, many scientists and I use randomness on a daily basis as part of our toolkit for modeling and investigating all sorts of phenomena. Models known as *stochastic models*, which explicitly incorporate random components, often via simulation in computer software, are used to model everything from diffusion to genetics to quantum mechanics. Insurance companies and financial institutions use stochastic models to manage risk. If we include all the applications of statistics, then almost no area of science is untouched by the use of randomness.

Most of the time, scientists and game players alike don't devote much thought to just what makes randomness tick. But they both know that the better they understand the probabilities, the more successful they are. Nevertheless, if you ask many of them what it means for something to be random, they may struggle to put it into words. I won't try to give a precise definition either, but it is important that we have some idea what we are talking about, so let's consider one of the prototypical examples of randomness: the tossing of a fair coin.

If I flip a coin, the result could be heads or tails. Until I flip the coin, I don't know which it will be. In this sense, the coin toss is unpredictable. If the coin is fair, each result is equally likely, so while I cannot say in advance whether a particular result will be heads or tails, I can say something about a large number of flips: approximately half should be heads and the other half tails.

A little mathematics even allows me to determine a range around 50% in which the percentage will almost surely lie. For example, if I flip a fair coin 1,000 times, the percentage of heads will most likely be between 45% and 55% (where "most likely" means a 99% chance). If the percentage of heads lies outside this range—especially if it is quite far outside this

range—I am going to be suspicious that the coin flipping process is not fair. That's one of the key ideas in statistics: not only can we calculate the frequency with which an event occurs, but we can compare data to a stochastic model to see if they are compatible or incompatible.

There are several interesting things we can learn by considering a coin toss. First, probability calculations rely on assumptions. If the assumptions are incorrect, then the probability calculations will also be incorrect. For example, if the coin is biased (such as one that is heads 60% of the time), but we assume it is fair, then the probability calculations given above will be wrong. Of course, if the assumptions are not too far from correct, the results may still be sufficiently accurate for scientific conclusions. If we have an appropriate way to collect data, then we can test our assumptions by comparing data to projections made based on the assumptions.

Second, "random" does not imply "equally likely." A fair coin should have equal probabilities of heads or tails, but a biased coin is no less random. It's just different. It is not as simple to handle arithmetically as a situation in which all outcomes are equally likely, but it is not otherwise special. It is a common mistake to assume random events are equally likely when they are not (or when that assumption is not justified).

Third, randomness is about the process. It is a fun experiment to flip a penny 100 times, then spin a penny 100 times and record the side that is showing when it finally tips over, then to stand the penny on end (this takes a steady hand and a little practice) and record which side is showing after pounding the table. These are three different processes, and they do not yield the same results.

Fourth, random processes produce patterns. I sometimes ask my students to mentally flip a coin and record the results as a sequence of letters (e.g., "HTTHHTHT"). Then I have them actually flip a coin and record the results. If the sequences are long enough, I can almost always tell them which is which. The sequences imagined by the students tend to have too few runs of consecutive heads or tails. The sequences based on real coin flips usually include several heads in a row. People not familiar with randomness are often surprised at the patterns that result and assume that the process must not have been random when they perceive a pattern. Our eyes and minds are drawn to similarities and patterns—even those that

are produced purely randomly. This can lead us to draw false conclusions from coincidences of all sorts. Consider the image in Figure 1. It was constructed using a computer to randomly throw 300 darts at a square board. Every position on the board was equally likely to be hit by a dart. This does not, however, mean that the dots are evenly spaced. There are 100 smaller squares. The average is three dots per square. But your eye is likely drawn to some clusters and voids. My eye also catches a graceful downward swoop in the lower part of the upper left quarter. All of this is exactly what we should expect from this random process. If we repeated this experiment, we should expect similar results. Several of the smaller squares would be empty and some others would have two or three times the average number of dots, but these clusters and voids would appear in different places.

FIGURE 1. *A simulation of random darts thrown at a square dart board.*

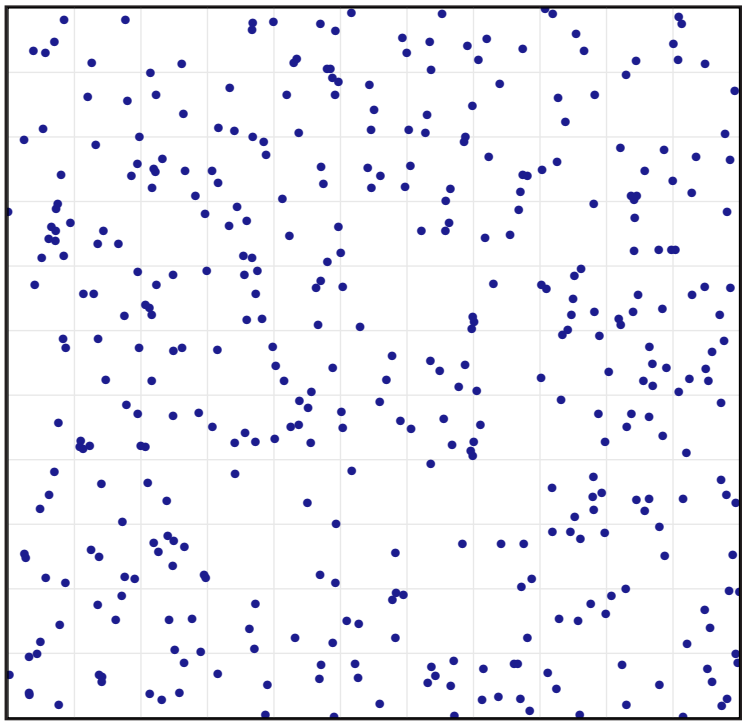

IMAGE CREDIT: RANDALL PRUIM

Finally, randomness can be used to produce patterns intentionally. Consider the two pictures in Figure 2. You may think the two pictures are identical, but they are not. However, they were each constructed using the same random process:

1. Start at the lower left corner of the big triangle.
2. Randomly choose one of the three corners of the big triangle.
3. Move half way to that corner, placing a dot at the new location.
4. Repeat steps 2 and 3 50,000 times.

The first few steps of this process for each image are illustrated in Figure 3. Although the final images look very similar, the route taken to get there is very different. In fact, the only point the two images have in common is the starting point. As the creator of the program that generated these images, I knew full well that the result would resemble a fractal image known to mathematicians as Sierpinski's Triangle, even though I did not know or exercise any control over how the individual points would be selected.

Divine Role? Divine Roll? Divine Rule?

Despite our familiarity with children's games and the importance of stochastic models throughout the sciences, many Christians have a reaction to randomness that falls somewhere between uneasy and antagonistic. And yet, those same Christians may well watch the evening news to learn about public opinion polls forecasting upcoming elections, take prescription drugs approved by the FDA based on statistics found in clinical trials, obtain electrical power from a nuclear power plant that uses random fission reactions, and insure their cars with companies that rely on stochastic models to set the rates. The foundation of each of these activities is a thorough understanding of randomness that begins with the simple description above.

So where does the uneasiness come from? Likely it comes from the feeling that taking randomness seriously means not taking God seriously. Or put more strongly, it comes from a fear that believing in randomness means not believing in God.

FIGURE 2. *Two randomly generated images.*

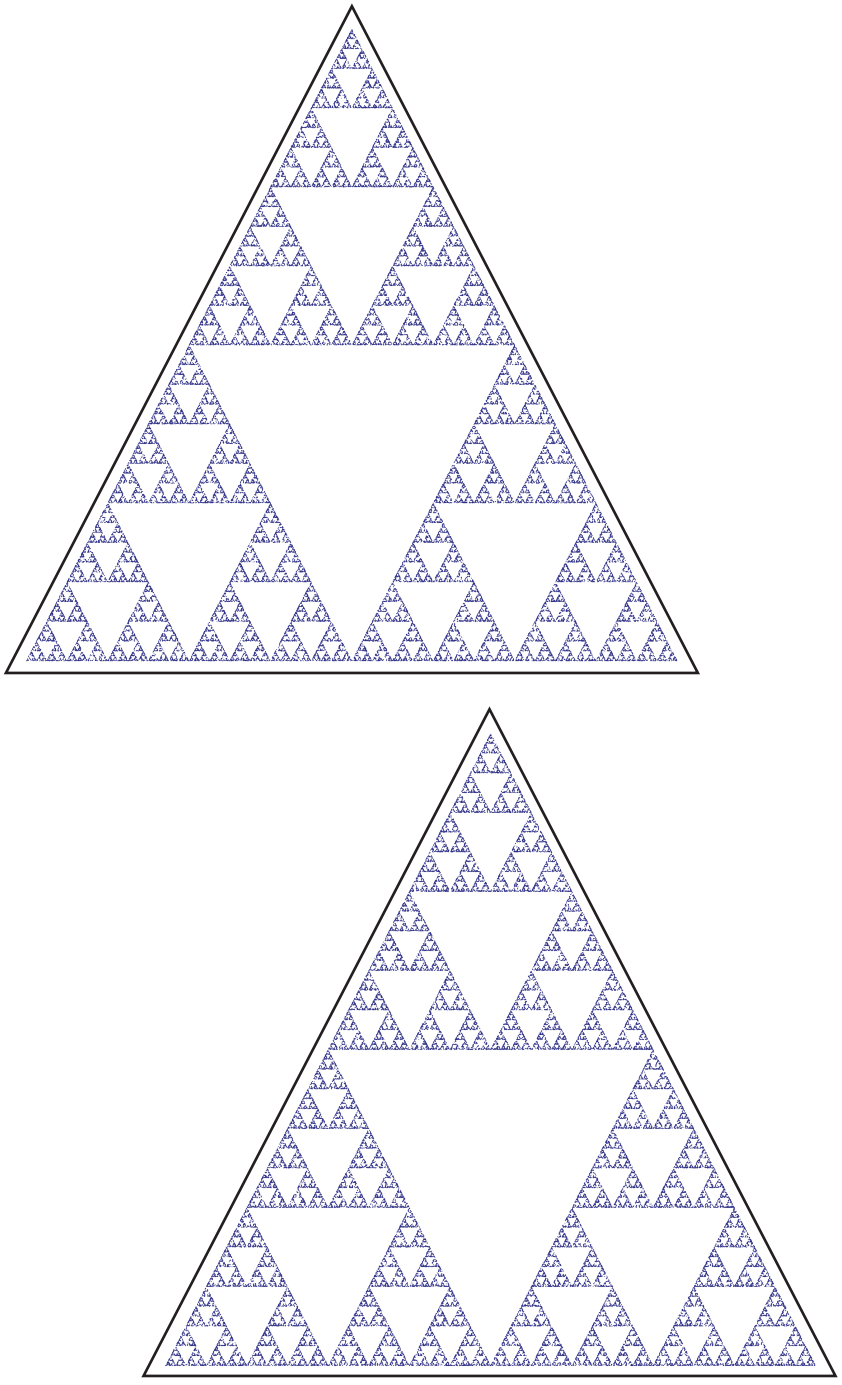

IMAGE CREDIT: RANDALL PRUIM

FIGURE 3. *The first few steps in generating random Sierpinski Triangles.*

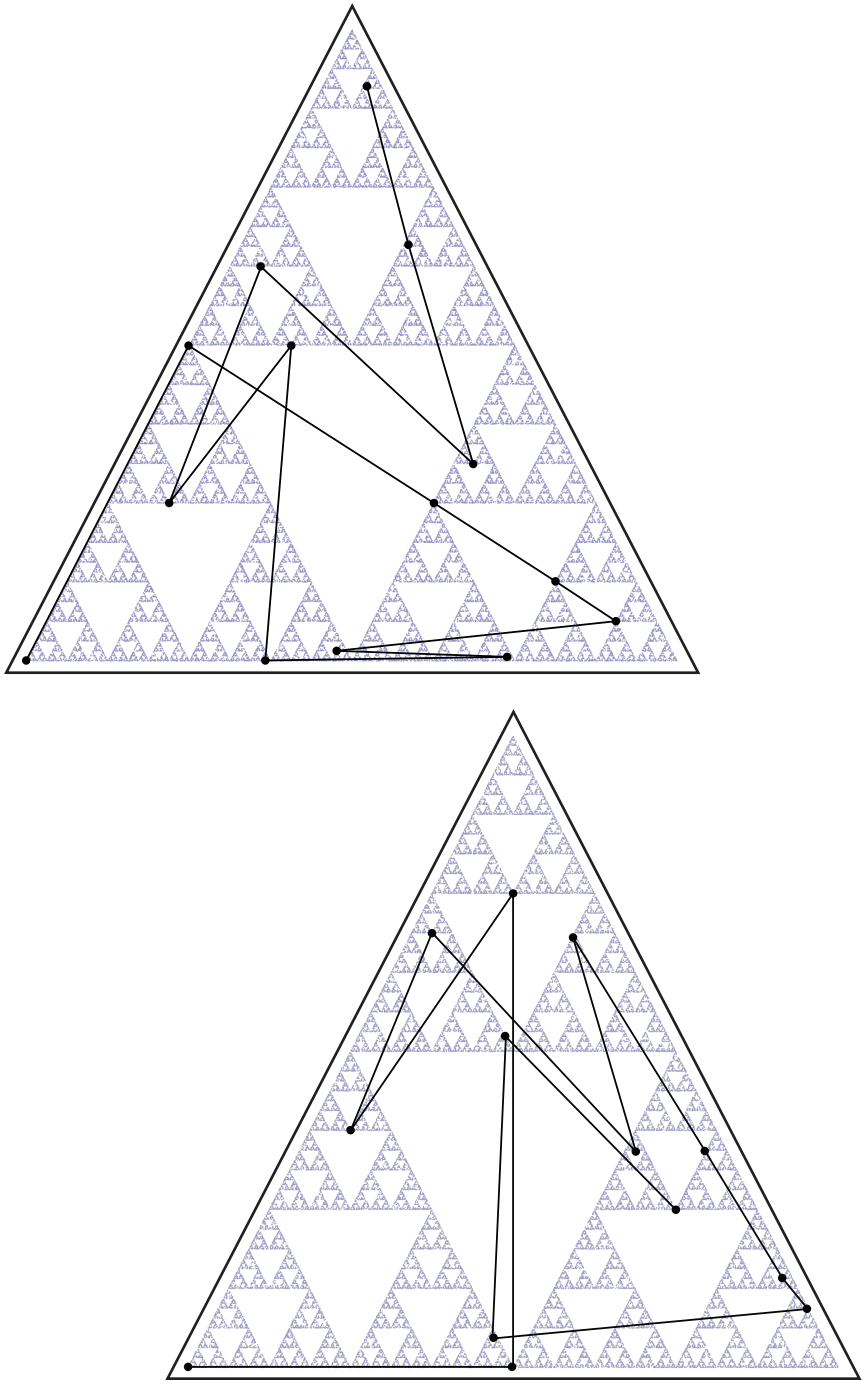

IMAGE CREDIT: RANDALL PRUIM

Does God Use Randomness to Achieve His Purposes?

Whether and how God uses randomness is difficult to tell, but randomness may not be as incompatible with a creating and sustaining God as some Christians fear. Too often, arguments make claims about randomness that are not warranted and therefore set up the false dichotomy of God (exclusive) *or* randomness.

One common issue is terminology. Randomness is often associated with words like "blind," "chaotic," and "uncontrolled," but as the examples above show, randomness can also be designed, purposeful, and creative. When mathematicians and scientists use the word "random," they are using it in a technical sense to refer to the unpredictability of individual events, not in the common sense of "purposeless." Randomness does not in itself preclude divine action or control.

To further complicate things, in the 1970s mathematicians borrowed the word "chaos," which originally indicated an abyss or emptiness, but had been used at least since the Vulgate to describe the void at the beginning of creation, and eventually came to be associated with anything disorderly or disordered. Mathematicians use "chaos" to describe a particular type of deterministic process that is so sensitive to its initial conditions, that *any* amount of imprecision in the knowledge of the initial state renders the long-term state of the process unpredictable. In fact, the situation is even worse, since for a chaotic system, improving the accuracy of the initial measurements will not necessarily improve the accuracy of the projections into the future, so the only practical models of these situations are stochastic models.

Passages like Genesis 1 are sometimes taught as a battle between "cosmos" (order) and "chaos" (disorder), in which the God of order wins over the gods of disorder. While this makes sense in the context of ancient near east cultures, it ignores the possibility that God could bring about order using processes that are random in a mathematical sense.

The Sierpinski Triangle example shows how randomness can be used to obtain highly predictable, desired results. This same principle applies in more practical settings as well. Stochastic screening, for example, is a printing technique that places small dots of ink randomly according to

rules that control the overall impression of color. Stochastic screening gives a more natural appearance than older methods that place dots of ink (of varying size) at predetermined locations.

When I began graduate work in mathematics at the University of Wisconsin, I lived in the apartment below Joe Wergin. Joe was in his late seventies at the time and also loved games. When he was younger, he had been a high school football coach. When I met him, his games of choice were Cribbage and Skat (a popular card game in Germany). He had written books about both games and loved to tell a story about a time he played Cribbage against an opponent who had an inflated estimation of his own ability. While his opponent was out of the room, Joe removed all of the 5's from the deck of cards they were using. Aided by his knowledge that there were no fives in the deck, Joe won their game handily. His opponent didn't even notice.

It is important to note that the Cribbage game did not become less random when the 5's were removed. Joe neither controlled nor knew which cards he and his opponent would receive. But he knew there would be no 5's and that the other cards were equally likely. This was more than enough to ensure victory. Perhaps part of God's creating and sustaining work is similar to these examples. What if God set up the conditions and random processes to achieve desired ends? To be fair, considering this possibility may mean expanding the definition of what it means to achieve one's purposes. My two randomly generated triangles are not identical, but they both equally suit my purposes (along with a large number of other triangles).

Lest one object that this is too small a role for God, I should mention that generating "true" randomness is not at all easy to do. Entire research agendas center on producing reasonably good pseudo-random number generators, in verifying their properties, and determining whether physical phenomena like atmospheric noise or radioactive decay provide sufficiently random results. (For a random number generator that uses atmospheric noise, visit http://random.org, or for one that uses radioactive decay, visit http://www.fourmilab.ch/hotbits.) Mathematicians have created an entire hierarchy of definitions of random, so that it is possible to talk about things being more random or less random in a technical, mathematical sense.

Statisticians and computer scientists discuss the best procedures for testing purported random data. Physicists search for the best physical sources from which randomness can be retrieved and harnessed. A God who can create randomness, determine the parameters in which it operates, and use it to achieve certain purposes is not a weak and powerless God. The idea is clever and elegant; the implementation, challenging.

This is not to say it really works this way. God's use of randomness is a challenging metaphysical issue for philosophers, theologians, and scientists to think about together. But before we claim to know both how the world works and how God works in it, we should at least consider this option carefully, weighing how it fits with our best scientific, philosophical, and theological theories. And we must not too readily dismiss it as incompatible with a God who exercises creative and sustaining influence over our lives and the world around us.

If God Doesn't Use Randomness, Why Does It Look That Way to Us?

Perhaps, as Einstein famously claimed, "God doesn't throw dice." Some may find the view in which God utterly controls all the minutia of everyday life—each coin toss, each radioactively decaying particle—simple and comforting. In this context, randomness only reflects our lack of knowledge and represents our best coping strategy for things we cannot understand any other way.

This belief alone doesn't answer everything, however. In particular, it doesn't explain why things look so random. As I already mentioned, making things appear random is non-trivial—and constraining. So does God choose all of the outcomes of all of the things scientists model with randomness, but then just happen to do so in a way that all the laws of probability are satisfied?

Even supposing this scenario is true, scientists—including Christian scientists—will not abandon their stochastic models and probabilistic explanations for the simple reason that they are the best thing we have going. For the most part, we do this without considering any deep philosophical or theological implications. We do it because it works. When pressed, most of

us would probably admit that the world feels random to us, not because we deny God his proper role, but because the random models fit the available data. In some cases, like quantum mechanics, it is difficult to even describe the phenomena without the language of probability. Randomness in this context isn't so scary. It helps make sense of the world around us.

One must be careful not to retreat to the position that randomness is incompatible with faith out of a sense that science is the antithesis of faith and that anything scientists believe must be misguided. At the height of the Enlightenment, scientists like Pierre Simon Laplace were convinced that mathematics could describe the deterministic workings of the world without the need for a "God hypothesis." In *A Philosophical Essay on Probabilities*, he wrote:

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

At the time, many felt that this mathematical determinism left no room for God. At best, it relegated God to the clockmaker of a clockwork universe that now runs without any divine intervention. As the discovery of systems with sensitive dependence on their initial conditions and especially quantum mechanics made it clear to scientists that the deterministic perspective was insufficient, they turned to random models. Now, some fear that randomness leaves no room for God and must be rejected.

Does It Matter?

At a practical level, it probably does not matter how we think God relates to randomness. It is an interesting question why stochastic models work so

well, but there is no denying that stochastic models have been incredibly effective in a wide range of situations, and there is no reason to expect that this will change any time soon.

However, how we interpret seemingly random events can matter at a personal, subjective level. In churches, where lots are cast to select leaders, do we imagine that God is picking individual people for these positions—and rejecting others? Or do we think it is merely the luck of the draw? Our answer might affect how we draw up the initial slate of candidates, and it certainly can make a difference in the feelings of those selected or not selected in the process.

When "coincidences" occur in our daily lives, do we see them as evidence of God directly intervening to achieve some purpose? If so, are we as willing to do so when the immediate impact is negative as when the immediate impact is positive? Or do things "just happen?" Do we interpret these events in a broader context in which, given enough opportunities, unlikely things are sure to happen to someone, or in a narrower context in which things are very unlikely to happen *to me*?

"The lot is cast into the lap, but its every decision is from the Lord," writes the author of Proverbs (16:33). How broadly does this verse apply, and when is it appropriate to cast lots to make decisions? Should we flip a coin to decide what house to buy, what job offer to accept, what college to attend, whom to marry, or which dessert to order? If not, why not? Does God treat a casually tossed coin or a decaying atom differently from a prayerfully cast lot?

Some Christian communities are opposed to insurance, but most of the Christians I know insure their homes, vehicles, health, and lives—at least to the extent they can afford to do so. Where do we draw the line between putting God to the test and trusting?

These challenging questions do not have simple answers. The contemporary scientific way of treating these situations is by modeling the randomness and using the resulting models to gather information and make effective decisions. Regardless of how we resolve the theological issues, it is a mistake to think that scientists use stochastic models because they are atheists and leave no room for God, or that this approach represents an attack on our faith—even though there are some scientists who would

like to make these claims. One way or another, this approach works, and scientists of every religious persuasion are using it to make sense of the world around them. I choose to view this as part of God's care for us and his preparation of us to care for his creation.

Further Reading

For a more thorough treatment of probability aimed at the educated layperson, see *The Drunkard's Walk* by Leonard Mlodinow. Several scientists have explored ways in which God could make use of randomness in creating and sustaining the cosmos. Among them are John Polkinghorne (a physicist and priest), David Bartholomew (a statistician), and Richard Colling (a biologist). The Biologos Forum, which seeks to be "a trusted source of excellent and accessible resources on contemporary issues at the science/faith interface," also includes a short article on this topic on its web site.

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