DOES GOD PLAY DICE? INSIGHTS FROM THE FRACTAL GEOMETRY OF NATURE

by Paul H. Carr

Abstract. Albert Einstein and Huston Smith reflect the old metaphor that chaos and randomness are bad. Scientists recently have discovered that many phenomena, from the fluctuations of the stock market to variations in our weather, have the same underlying order. Natural beauty from plants to snowflakes is described by fractal geometry; tree branching from trunks to twigs has the same fractal scaling as our lungs, from trachea to bronchi. Algorithms for drawing fractals have both randomness and global determinism. Fractal statistics is like picking a card from a stacked deck rather than from one that is shuffled to be truly random. The polarity of randomness (or freedom) and law characterizes the self-creating natural world. Polarity is in consonance with Taoism and contemporary theologians such as Paul Tillich, Alfred North Whitehead, Gordon Kaufman, Philip Hefner, and Pierre Teilhard de Chardin. Joseph Ford's new metaphor is replacing the old: "God plays dice with the universe, but they're loaded dice."

Keywords: chaos and complexity; contemporary theologians; evolution; fractal geometry; fractals; genetic algorithms; loaded dice; polarity; randomness and law; science and religion.

Albert Einstein once said, "I am convinced the Old One [God] does not play dice" (Jammer 1999, 222). Huston Smith, whose book *The World Religions* (1991) has sold over a million copies, stated, "I do not believe that God could have created us in his image by the mutations of the genes" (Smith 2000). New findings about the fractal geometry of nature, chaos, and complexity challenge these negative statements about the statistical nature of the physical world (Gleick 1987). Einstein and Smith reflect the

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old metaphor: chaos and randomness are bad. Scientists have recently discovered that many phenomena, from the fluctuations of the stock market to variations in our weather, have the same underlying order. Natural beauty in mountains, plants, and snowflakes reveals a new fractal geometry characterized by the complex interplay between randomness (symbolized by dice) and global determinism (which loads the dice) (Mandelbrot 1983). Darwin's theory of evolution is similar to fractal analysis: the randomness of mutations and global natural selection. We shall see how old metaphors are being replaced by the new, such as one by chaos theorist Joseph Ford: "God plays dice with the universe, but they're loaded dice" (in Gleick 1987, 314).

"Noise is good," says Robert Hilborn (2000; 2001). Random noise added to a signal can increase its detectability in a system having a threshold. A familiar example is a hearing test in which one is asked to press a button as soon as the sound is loud enough to be heard. The noisy hiss added to the coherent sound signal enables it to trigger the hearing threshold. Thus, a lower-level signal with noise can be detected better than one without noise. Of course, the noisy hiss can not be so large as to drown out the signal. "A little noise is good" is a more precise statement.

THE FRACTAL GEOMETRY OF NATURE

What might appear as random noise has in some cases been discovered to have an underlying order. For example, the fluctuations of the stock market obey fractal statistics (Peters 1994). A number of physicists are using this analysis as an investment strategy to make money on the market (Bass 1999). Nature offers many examples of fractal statistics: branching in our lungs and in plants; variations in the flooding of the Nile river, of rainfall, and of tree-rings (Peters 1994).

Fractals have the property of self-similarity in that the parts are in some way related to the whole. In the fractal, or Sierpinski, triangle (Figure 1), the one central triangle has sides that are 1/2 that of the large one in which it is enclosed. The three second-generation triangles have sides that are 1/4 of the large one, the nine third-generation triangles have sides 1/8 of the large triangle, and so on. The scaling factor between generations is 1/2.

We will now play the Chaos Game to generate the fractal triangle. First, we *randomly* draw a point, as shown in the left triangle in Figure 2. Next, we roll a die to find the direction of the next point. In the triangle on the right, the roll of a die gave a 5 or a 6, which corresponds to vortex C. Then we apply the *global* rule and draw a point halfway to C (5,6). This algorithm is repeated again at each new point.

A computer was programmed to apply this rule 10,000 times. The first 50 points were discarded as "transients," and the remaining 9,950 points formed the black granular background inside the orderly fractal (Sierpinski) triangle. The Chaos Game shows that local randomness and global determination can coexist to create an orderly, self-similar structure called a fractal (Peters 1994, 10–17).

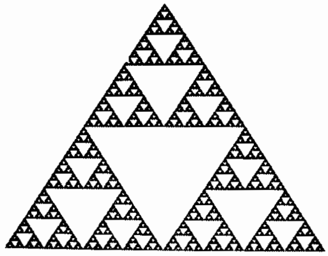

Fig. 1. A fractal (Sierpinski) triangle.

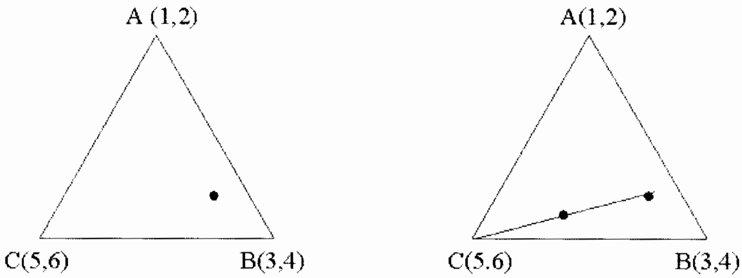

Fig. 2. Illustration of the Chaos Game.

The branching of the tubes in our lungs as well as that of plants is described by fractal scaling. For example, the diameter D(G) of our bronchial tubes is related to the diameter of our main trachea D(0) by

$$D(G) = D(0)\ 2\ \exp\ (-G/3)$$

where *exp* means that 2 is raised to the fractional power -G/3. G represents the generation number 1, 2, 3, ... Each generation or set of smaller tubes is scaled down by this factor (Peters 1994, 13). Of course, not all of the smaller tubes are the same size, but they have a statistical distribution about the mean value given by the global equation above. Fractals have global determinism (average tube size) and local randomness (diameter of individual branches). The fractal structure is more stable and error-tolerant than the more deterministic, Euclidean geometry. This is why fractals are so common in nature from tree trunks and branches to the intricate vein structure of leaves.

The variations in natural phenomena such as the flooding of the Nile River, rainfall, tree rings, and noise-caused errors in electronic transmission lines also can be characterized by fractal statistics. H. E. Hurst (1900–

1978) worked on the Nile River Dam Project. Most hydrologists had assumed that water inflow was a random process. Hurst, however, studied the 847-year record that the Egyptians had kept of the Nile River's overflows, from 622 to 1469 A.D. The record did not appear random to Hurst. Larger-than-average overflows were likely to be followed by more large overflows. Suddenly, the process would change to a lower-than-average overflow (the Joseph Effect: seven years of great plenty in the land of Egypt were followed by seven years of famine). Overall there appeared to be cycles, but their length was nonperiodic. Hurst's mathematical analysis revealed that the Nile river's overflows were described by fractal statistics, which is more like picking a card from a stacked deck than from one that has been shuffled to be truly random. The stacking algorithm is the global rule that characterizes fractal statistics.

EVOLUTION AND GENETIC ALGORITHMS

Charles Darwin's theory of evolution is similar to fractal analysis in that it includes the individual randomness of mutations and the global determinism of natural selection. After reading Darwin's *Origin of Species* in 1859, Henry D. Thoreau wrote, "The development theory [evolution] implies a greater vital force in nature, because it is more flexible and accommodating, and equivalent to a sort of constant *new creation*" (1993, 102; emphasis added).

Darwinian evolution does not have design built in as a premise, but the design emerges as variations occur and some organisms get naturally selected over others (Ruse 2003). It is analogous to the algorithm for generating the fractal triangle, whose intricate design containing smaller triangles emerges as a result of applying randomness with the global law.

The engineering community has discovered that computer simulations of Darwin's evolution, called genetic algorithms, are very effective for optimizing physical devices. Edward Altshuler of the Air Force Research Laboratory discovered a genetic algorithm that enabled him to design antennas having much better performance than he would have been able to conceive of based on his many years of conventional design experience (Altshuler and Linden 1999). The genetic algorithm starts with millions of randomized antenna dimensions. Each antenna's performance is then calculated, and the best are selected as being closest to that desired. The next generation of antennas is made by "sexually mating" the best antennas: half the dimensions of each new generation are chosen from the old generation. These theoretical design predictions are in close agreement with experimental performance. Darwin's theory of evolution, discovered from nature, is very effective at optimizing the man-made world.

The development of a baby's neural system is a good example of natural selection. A baby has a number of neurons in parallel. The nerve that is dominant and used is the one that survives. The other nerves atrophy and die—a good example of "Use it or lose it."

Biochemist Arthur Peacocke, winner of the 2001 Templeton Prize for Progress in Religion, states, "Instead of being daunted by the role of chance in genetic mutations as being the manifestation of irrationality in the universe, it would be more consistent with the observations to assert that the full gamut of the potentialities of living matter could be explored only through the agency of rapid and frequent randomization. This is possible at the level of DNA" (1998; see also Peacocke 1995). Chance operating within a lawlike framework is the basis of the inherent creativity of the natural order in its ability to generate new forms of matter and life. As in many games, the consequences of the fall of the dice depend on the rules of the game.

Biologist Stuart Kauffman of the Santa Fe Institute writes, "Self-organization mingles with natural selection in barely understood ways to yield the magnificence of our teeming biosphere" (2000, 2).

Steven Wolfram's best-selling book *A New Kind of Science* (2002) shows that randomness can evolve into order and vice versa. Wolfram uses a rule or recursion relation called "cellular automaton" to show that there are conditions under which a random set of cells can evolve into an ordered set. Starting with a row of randomly ordered black and white cells, he applies the simple cellular automaton rule that a lower cell becomes black if either of its upper neighbors is black. The row of random cells then evolves into an orderly pattern. Conversely, there are other local recursion rules, or cellular automatons, that cause an ordered set to evolve into a random pattern. Cellular automata can be used to generate the hexagonal patterns seen in snowflakes (Wolfram 2002, chap. 8) as well as pigmentation patterns in mollusk shells. The latter, like a one-dimensional cellar automaton, grow one line at a time, with new shell material being produced by a lip of soft tissue at the edge of the mollusk. The simple local rule of a cellular automaton can lead to the large-scale complexity observed in nature.

Does God Play Dice?

Einstein, having published a paper on random Brownian motion, would, I think, be fascinated by the discovery of fractal statistics if he were alive today. And Huston Smith might want to reconsider his doubt that God creates through the random mutations of evolution. He overlooked the global determinism of natural selection.

Does God play dice? Yes and no. Yes, if one considers the random nature of evolution and fractal statistics. No, if one considers their globally deterministic laws and rules. "God plays dice with the universe, but they're loaded dice" (Gleick 1987, 314). Like Hindu's Shiva, God plays.

THEOLOGICAL REFLECTIONS

The yes/no answer of this metaphor represents the polarity of randomness and law that characterizes the self-creating natural world. This polarity is in consonance with Taoism and contemporary theology. Theologian Paul Tillich believes that we have freedom only in polar interdependence with destiny and nature has spontaneity in polar interdependence with natural law. This interdependence is seen by theologian Gordon Kaufman (1993) as the serendipitous creativity of God. Continuing creativity is a common theme for multipolar process theology and such theologians as Philip Hefner and Pierre Teilhard de Chardin. Hefner believes that we are "created co-creators" (1993), and Teilhard holds that evolution is converging toward an Omega Point (1961, 287). Polarity is an intrinsic part of Taoism: good/evil, male/female, light/dark, and so on. Thus, Taoism would accept randomness and deterministic rules as complementing and balancing each other in creative tension.

Tillich believed that religious truth is expressed by symbol and metaphor, which should not be interpreted literally. Thus, "God plays dice, but the dice are loaded" should be understood as metaphor. Tillich emphasized that God is not *a* being, who would be finite and limited, but the ground of all being. Being is all-encompassing and includes both deterministic (law) as well as statistical (dice) reality. Evolution is a manifestation of New Being (Haught 2002). Tillich believed that God's creativity works though spontaneity of creatures and human freedom. This should *not* be understood as God's miraculous interference (Tillich 1963). Humans have freedom in polar interdependence with destiny, which are analogues of randomness (spontaneity) and law.

The polar interdependence between chance and law is seen by Kaufman as serendipitous (fortunate) creativity, which is manifest throughout the universe from the Big Bang on in trajectories. These directional movements emerge in the evolutionary development of the cosmos and of life (including human life) on planet Earth. Serendipitous creativity is a manifestation of God.

Mathematician Alfred North Whitehead's *Process Philosophy and Reality* (1929) is multipolar in that events occur as the joint product of the entity's past, including its genetic inheritance (law); its own action, self-creativity, and freedom (chance); and divine purpose. Creativity, the principle of novelty, is a universal of process theology. Our freedom eliminates a preordained determinism. God does not coerce but lures and guides the universe in the continuing process of evolution. God does not intervene in discrete events but is present in all events in a role different from natural causes. God "acts" with and through other entities rather than acting alone (Barbour 1997, 296). The Creator has a vision for the future rather than a deterministic plan (Haught 2000). God has both a primordial and a consequent nature. In the latter, the creative process affects God. Divine purpose is a part of the evolutionary process.

We are created co-creators, according to Hefner (1993). God through the process of evolution created us with the freedom and responsibility to contribute to the ongoing process of creation. We are to "birth a future that is most wholesome for nature and the human community that birthed us" (1993, 27).

Global laws and randomness have analogues in Christianity. Global laws are similar to liturgy, such as the tradition of the Lord's Supper. The whisper of God's grace is beyond our ability to predict and thus has an element of surprise akin to serendipitous randomness. Grace is different from Hinduism's karma or cause and effect. "Grace is when God gives you something you do not deserve, in contrast to: Mercy in which God keeps you from getting what you deserve" (Hedrick 1986).[1]

Teilhard sees evolution occurring in the spiritual as well as the biological realm and converging toward the Omega Point, the final culmination of the continuing creation in God. The evolution of the earth from geosphere to hydrosphere, atmosphere, and biosphere is emerging toward a world-encircling "noosphere," created by human hearts and minds:

> The end of the world: the wholesale internal introversion upon itself of the noosphere, which has simultaneously reached the uttermost limit of its complexity and centrality. The end of the world: the overthrow of equilibrium (Heat Death), detaching the mind, fulfilled at last from its material matrix, so that it will henceforth rest with all its weight on God-Omega. (Teilhard 1961, 287)

CONCLUSION

Does God play dice? The yes/no insight from fractal geometry is symbolized in the self-similar patterns of the Sierpinski triangle, which can be generated with an algorithm that has both a random and a lawful element. Nature's spontaneity and our freedom result in a universe that has beauty and harmony. This self-creating universe with both randomness and law is for me a manifestation of divine creativity. Process theology reminds us that the universe is not static but an evolving and continuing creation, whose intricacies result in continuing scientific discoveries. I pray that we will have the wisdom to use the power of scientific knowledge as responsible created co-creators and not as destroyers of our earth through the unintended consequences of our technology. As created and creating creatures, we can profit from religious wisdom. In it, I find hope that the continuing creation is converging toward its ultimate consummation.

NOTES

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1. Samuel Hedrick discovered this saying at Christ Church, Oxford, U.K., where John Wesley was educated.

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