The Benevolence of Chaos and Uncertainty

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Abstract

At the dawn of the 21st Century we seem to be further than ever from the promise of harmony, unity and peace for mankind. If anything, the world appears to be more chaotic, complex and disordered than ever. A close examination of Nature suggests that disorder and chaos are universal and characteristic of naturally occurring physical and biological systems. Why then should we expect that human society would ever display systematic order and stability? In this paper, an attempt is made to show that chaos and complexity are integral components of highly sophisticated systems and that one need not fear this. Indeed, complexity is essential for self-organization; without it, life, indeed the universe, could not exist. It will also be argued that complexity is merciful, allowing a toleration of errors in our lives, as long as these errors are within the bounds of moderation.

Inscribed upon the Gate of Hell are the words: "Through me is the way into the suffering city; through me the way into grief eternal; through me the way among lost humanity… Abandon every hope ye who enter." [1] Related to a fearful humanity some 700 hundred years ago, the words of Alighieri Dante may well have been describing the terrorized state of humanity in the early 21st century, rather than the condition of Hell. For it is quite reasonable for those who do not share the Bahá'í vision for the future to share instead a sad pessimism for those unfortunate enough to be born in this age. And great vision is indeed what is needed if one is to remain optimistic; an informed and well-educated mind could be forgiven for coming to the conclusion that humanity is doomed to extinction at the best, or an endless masquerade of "peace in our time" superlatives at the worst. Life, it seems, has become far too complex and uncertain for most to truly enjoy. And how can one make sense of such a complex and chaotic world?

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The observation that life is extremely complex is not a new one, nor is it something that can be denied. A close examination of anything – be it from the raging bulls of the stock market to the lifecycle of a humble moth – reveals layers of complexity that are only just being understood. This complexity must not be ignored and we cannot run away from it. No matter how much we might like to think that in essence all things are simple to understand, the evidence that Nature herself provides suggests otherwise. Just because Nature is complex does not imply that we cannot make great strides in understanding her deeply and thereby gain a more profound knowledge of ourselves and our purpose in life. Bahá'u'lláh, in the Kitáb-i-Íqán, recounts an Islámic tradition from Sádiq, son of Muhammad, which says: "Knowledge is twenty and seven letters. All that the Prophets have revealed are two letters thereof. No man thus far hath known more than these two letters. But when the Qá'im shall arise, He will cause the remaining twenty and five letters to be made manifest [2]." While the Guardian has stated that this should not be taken literally[1], it does suggest that from the moment the Báb was made manifest, whatever was hidden from the intellect of Man was also *potentially* manifest. It means that we have made, and will continue to make, discoveries the likes of which no previous age could ever have even imagined, let alone accomplished. The history of science and art in the 20th century provides spectacular proof of this, and whatever discoveries lie ahead of us are likely to be at least as marvellous.

Our predisposition to simplify life as a sequence of identifiable cause-and-effect relationships has its roots deeply embedded in our psyches and is echoed in the language of ancient Scriptures. In these texts God 'speaks' to Man and says in simple language: "Do this and I shall reward you. Do that and feel my wrath." More often than not, Man does the wrong thing and, behold, he is indeed chastised, plagues of locusts, rivers of blood and so on. The Scriptures may at times read like epic novels, and in some respects that is their purpose: to teach men and women by dramatic stories, couched in simple terms, the most abstruse of all concepts: the meaning of their lives, the purpose of existence, and their relationship with a God that they will never be able to see, feel, touch, hear or smell. The Scriptures were never intended to encapsulate the totality or magnitude of the intricate relationship that exists between the Creator and His creatures, or to reveal the full extent of just how limitless this universe is, in every level of its outward manifestations. While the language was suitable for the largely uneducated people of ancient times, it is no longer appropriate in an era of mass education. We are therefore fortunate to live in an era in which it is possible to learn more about those extra "twenty and five letters" that have been revealed through the Revelation of the Báb, but are yet to be fully explored.

[1] See *Lights of Guidance*, Bahá'í Publishing Trust, New Delhi, India (1988), 483.

We would like to believe that Nature reflects God's virtues in a simple, albeit naïve, way: that all God's creatures live harmoniously with each other, that all mothers care for their young, that all mates are faithful to each other, and so on. This is what a good number of pre-Darwinian naturalists and theologists believed: that God is good, and all natural things that have been uncorrupted by satanic influences (i.e., anything not touched by mankind's inherent predisposition to evil) are also good, and this sometimes involved elaborate rationalizations of cruelties apparent in Nature.[2] They did not closely examine the facts that Nature openly presents, as did Darwin and his contemporaries. Modern science has now discovered many of those facts, and the truth is not as comforting as many would like. The fact is that not all creatures do live harmoniously with each other. In fact, it is in the nature of some to be downright hostile or predatory to others (literal wolves and literal lambs shall *never* dwell together, unless one happens to be in the belly of the other). Nor do all mothers care for their young; there are instances when mothers *will* abandon at least one child either to preserve itself or its other offspring, or siblings will kill fellow siblings in order to gain a competitive advantage (this is true amongst both animals and man). Mates are *not* always faithful to each other.[3] These are just a few examples that represent scientific fact. All seekers of religious truth must also acknowledge the validity of scientific truth, for all truth must, by definition, lead to the same common conclusions.[4] 'Abdu'l-Bahá stoutly defended the application of science and its methods to religious belief by these words: "I say unto you: weigh carefully in the balance of reason and science everything that is presented to you as religion. If it passes this test, then accept it, for it is truth! If, however, it does not conform, then reject it, for it is ignorance! [3]" This is not to say that Nature does not reflect the virtues of God, or is not 'good'. It does, and it is. But God's Divinity is unfathomable, and its expression in Creation can appear on occasion as cruel and insensitive. In the same way, what we may regard as 'good' may not in fact be in accord with Divine law.

Such simple models of Nature were based, either consciously or unconsciously, upon an exclusively deterministic[5] causal mind-set. Condition A leads categorically to outcome B, which in turn leads to outcome C, which in

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2 A good source of examples is contained in the Editor's Introduction to Darwin's *Origin of Species*, by Prof. John Burrow (Charles Darwin, *The Origin of Species*, Penguin Books, London, 1968).

3 Perhaps the most bizarre example being that of the female preying mantis who, after copulation with its mate, will, if she gets the chance, bite off his head as an appetiser, before proceeding to devour his body as the main course.

4 The Oxford dictionary defines truth as "Quality or state of being true or accurate…" where true is defined to be "In accordance with fact or reality, not false or erroneous." If both science and religion have a particular view about a particular issue and if there is contradiction in these views, the only conclusion can be that either one or both views are false.

5 A deterministic process is one that is strictly causal in nature: A leads to B, which leads to C, etc, is a deterministic process. A leading to B1 or B2 or B3, etc, is also a deterministic process. A non-deterministic process is one in which it is impossible to define rules about how a process *exactly* evolves in time.

turn leads to outcome D, and which in turn leads to… etc. An example of this might be: God is good; therefore all things that emanate from God are good; therefore Nature is good because Nature emanates from God; therefore all things that are encompassed by Nature must be good, because Nature is good; therefore all animal mates are good to each other (because animals are encompassed by Nature, which is good) and, as they are good, shall never deceive. Such logic is flawed (especially for male preying mantises) for it fails to take into account this possibility: Condition A may well lead to outcome B, but *under certain circumstances* it may also lead to outcome B2. Under a slightly different set of circumstances it may lead to outcome B3, or B4 or B5, etc. And these possibilities, in their totality, lead in turn to a plethora of outcomes, C or C2, or C3, or C4… *ad infinitum*. The failure in the logical sequence that goes: "God is good; therefore Nature is good; therefore …" is, first, that we have not allowed for all possibilities of outcomes from a single origin, and, second, that we have not even defined what we mean by the word 'good'.

The saying: 'One man's meat is another man's poison' is an apt one in this instance. In a very real sense, what is 'good' to one of God's creatures is not necessarily 'good' to another, when measured on the same scale of 'goodness'. Yet when measured in accord with Divine law (and by this is meant measured in the totality wherein *all* things are considered) all things that proceed from God are indeed good, for they all have a purpose, even if that purpose seems senseless to the finite mind of man. This does not mean that evil does not exist, for it does. It is unique to man and exists because man is free to use his rational faculties for acts that can either benefit or harm others. The Bahá'í teachings inform us that it is the absence of good, rather than a force in its own right, in the same way that darkness is the absence of light. With this perspective it is apparent that evil cannot exist in the animal kingdom because there is no meaning in 'good' for an animal. The practice of 'good' implies a conscious definition of what is *good*, and a clear conscious differentiation to its antithesis, what we call 'bad', or evil. Man has the ability to define what is good and what is not; sometimes God through His Manifestations reveals these definitions, and sometimes they are purely man-made. Animals have no such consciousness, no such definitions, and no such language. There is nothing good or bad about a blackheaded gull swallowing a neighbour's chick, or female preying mantises devouring their mates, from the perspective, that is, of *these* creatures. We are shocked by such horrific actions, only because they are horrific according to our rules, our definitions, and our standards.

To understand how it is that from one beginning a plethora of outcomes may result, we can again look to Nature as our guide, for she has draped herself with innumerable ornaments that testify to the immensity of her

diversity. Wrapped within the core of each of these ornaments is a distinction that differentiates between a world whose potential is limited and doomed to rapid extinction, and one of infinite potential and self-perpetuating existence. In the language of mathematics, this distinction is one between systems that are linear, and those that are not.

A linear system is, simply stated, a system that is *entirely* the sum of its parts, no greater and no less. A clear example of this is what happens when ocean waves intersect or collide with each other.[6] If one wave has a height of say 1 metre, and another has a height of 2 metres, then when their paths cross one finds that at the instant their peaks align the new combined wave will have a height of 3 metres.

A nonlinear system is one that defies such simple arithmetic. Examples of nonlinear phenomena also occur in the ocean. The fact that waves break on a shore is just such an example. In shallow water, the top of the wave travels faster than the base because the friction between the base and the ocean floor slows down the bottom of the wave with respect to the top. The wave's centre of mass[7] thus shifts and it becomes inherently unstable (or 'top-heavy'), eventually rolling in on itself and breaking onto the shore. If one could find two such superposing waves, one might find that the height of the combined wave was not just the simple linear sum of both separate waves (in this case 1 metre plus 2 metres does not equal 3 metres!).

Nonlinear systems are ubiquitous in Nature. Almost everything in our universe is nonlinear. Simple linear systems are largely an abstraction, an idealization of a far more complex reality. We go through a dozen or so years of schooling with the erroneous notion that our universe can be understood by simple relationships, and (whether we know the terminology or not) that linear laws govern these. Our minds are still developing as children and teenagers, and so, perhaps justifiably, we have been misled into believing that Nature is linear and simple so that we may more easily understand her. Students of university physics and mathematics realize how misleading this simplification is by the time they complete their second year of study.

In the 1970s and 1980s great progress was made in the understanding of nonlinear systems, and the term 'chaos' was coined to describe them. This is perhaps an unfortunate choice of words, for beneath this apparent level of 'chaos' lies an underpinning dynamics that is not at all chaotic, but is in fact fully deterministic. Fully deterministic, that is, only if we have a complete knowledge of all possibilities. We will return to this shortly.

There is a considerable amount of material published in the popular literature that tries to apply chaos theory to the modern world, much of which

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6 In technical jargon, this is referred to as superposition.

7 The centre of mass of a body is that point on it that moves in exactly the same way as a single point-particle with the same mass would if it were subjected to the same forces. One may think of it as the point on the body that represents the location of its spatially averaged mass.

is folly based upon a misunderstanding of what scientific chaos really means. From a rigorous scientific perspective, a system is chaotic if it has a sensitive dependence on its initial conditions. Take for example a spinning top. No matter how accurately one may try to spin it each time in exactly the same way, one finds that on some occasions the top is stable, and spins for a long time, and on other occasions it is catastrophically unstable, spins out of control, and collapses almost immediately. This, despite the fact that one has been very careful in how and where the top has been spun. In fact, unless one was able to perform each spin in *exactly* the same way (and by 'exact' one means just that: 100% certainty) one would *never* be able to guarantee a perfectly spinning top. This is because the top is an example of a nonlinear, chaotic system.

Assume an idealized situation: one has two trials at spinning the top.[8] On both trials one is able to impart *exactly* the same force on the top. In this respect, one has perfect knowledge. One is unable, however, to have perfect knowledge of the top's base-position at the start of the trials, except that it is known that this location in trial 2 is within some distance (say, *d*) to that of trial 1. If one then measures the trajectory of the top in both trials one would find that *d* increases in time *exponentially*. In other words, the value of *d* increases by the same factor after some characteristic time *t*. This is what is meant mathematically by something growing exponentially: a doubling (or tripling, or quadrupling, etc.) of some quantity (be it the separation *d* of top trajectories, or the population of *E-coli* bacteria in a Petri dish) in equal periods of time.[9] If one were able to give the top sufficient force to enable it to spin for a very long time, one would find that the top in trial 2 is very far from the top in trial 1, even though they were initially separated by only a very tiny distance, *d*. This is a simple example of a chaotic system. Imagine then the complexity of trying to figure out what is happening to a group of thousands of tops, each separated by some minute distance *d* from an idealized starting point, each of which diverges exponentially as time advances, and each of which interacts and collides with neighbouring tops, thus setting them off in new trajectories! And these are just tops. Imagine the enormity of trying to understand the population dynamics of animal species as they interact with each other, or how the billions of stars in our galaxy interact with – and influence - each other, or most of all, how human society organizes and regulates itself.

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[8] This is indeed a highly idealized example and the assumptions made here are not elaborated on. What causes the chaos in the motion of the top is complex and depends on a number of physical factors, including the friction between the top and the surface it spins on, as well as the force at which it is spun.

[9] This geometrical factor does not have to be an integer. It could be a fractional number. In general, exponential dependence can involve both positive and negative factors, where a positive factor implies the quantity increases in time, and a negative factor implies it decreases in time. Exponential divergence implies a positive factor, which means that the quantity (in this case a difference in trajectories, *d*) increases with time.

We can now have a better appreciation of why a single possibility may lead to a number of equally likely outcomes. For a system that is nonlinear (and as we have seen, this means most of the universe) if the initial condition A is *exactly* known and there is absolutely no uncertainty in its knowledge, then yes, outcome B is the *only* possibility. But if there is even the *slightest* uncertainty in the knowledge of A, then *any* of B, B2, B3… B∞ may result. This makes the business of predicting the future at best very difficult, and more practically impossible to determine precisely with existing knowledge, because there is always some uncertainty – no matter how small – in *anything* that we can know.[10] Even the most precise atomic measuring devices can only specify an object's position and time to within some inherent uncertainty based upon the physical limitations of the instrument. And while such uncertainties may be minute (billionths of a metre or billionths of a second), the fact that they grow *exponentially in time* is what makes prediction of the future so fraught with danger.[11] And this too is why Melburnian weather prediction is not always right, especially the notorious "7 day forecast". Small uncertainties in atmospheric conditions can bring about huge variations in climate over a relatively short period of time.[12]

In the above discussion, reference has continually been made to physical or natural (including biological) systems. It would suggest that the only way to gain a complete knowledge of the future is to somehow transcend the very dynamics of those processes that lead to the future! As such transcendence is unphysical, presumably it can only be exercised by spiritual experiences, such as those experienced by the Prophets of God and other inspired souls. 'Abdu'l-Bahá describes this type of knowledge as the "bounty of the Holy Spirit" which, He says, is the only kind of condition "in which certainty can alone be attained [4]". This in itself is another topic of vast richness, but which will not be pursued further in this article.

The prospect of an unpredictable future is indeed frightening. Precisely this kind of fear prevails in our uncertain world today. No one can take his or her individual or collective future entirely for granted. While the Bahá'í Writings attest to the ultimate acceptance and adoption of the Bahá'í Faith throughout the globe (for this knowledge indeed *does* transcend the dynamics that leads it there), we know little or nothing about the path we will tread to get

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10 By 'know' here is implied knowledge gained through the senses, through reason, or though acquired learning. It does not refer to the only type of infallible knowledge possible, that which 'Abdu'l-Bahá describes as the 'bounty of the Holy Spirit' ('Abdu'l-Bahá , *Some Answered Questions*, Part 5, section 83).

11 As an example of exponential growth, consider a bacterium that divides in two every hour. If there was only one such bacterium to start with, after one hour there would be two such bacteria; in two hours there would be four; in three hours there would be eight; after twelve hours there would be four thousand and ninety six; in twenty four hours there would be over sixteen million; and after thirty six hours there would be almost seventy billion!

12 This is the famous "butterfly effect" example often quoted in popular accounts of chaos.

there, or how long it will take. It may be fraught with many tests and calamities. Bahá'u'lláh even anticipated that should He be slain "God will assuredly raise up one who will fill the seat made vacant through my death," and if His enemies "attempt to conceal His light on the continent, He will assuredly rear His head in the midmost heart of the ocean and, raising His voice, proclaim: 'I am the lifegiver of the world!'" [5].

The science of chaos has brought about an emergence of a probabilistic view of Nature. While some theories may go too far in this interpretation, the best of them are those that tie in the determinism of the fundamental laws of Nature with a probabilistic interpretation of those things we are unable to know with 100% certainty. An interesting consequence of this is the notion of what has been termed an 'attractor'. An attractor is a set of possibilities that any dynamical system[13] may ultimately evolve towards. In physical systems, these 'possibilities' might be the coordinates and velocities of some complex system, like the planets in our solar system, or the molecules of a gas flowing down a pipe. For microbial systems, they may be the location of sources of nutrients and warmth from which bacteria might be able to thrive.

It turns out that attractors can exist for both linear and nonlinear systems. An attractor for a linear system is generally simple: it consists of only a single set of possibilities that can never be violated. It is entirely predictable and leaves no surprises or tantalising new possibilities. It is, alas, rather boring, both in its structure and its consequences.

Attractors for real non-idealised systems are actually impossible to draw because they have more than 3 dimensions, and therefore cannot be visualized in our 3-dimensional world. They are essentially mathematical constructs. But for certain 'low dimensional' systems, they can be visualised.[14] An example of an idealized low dimensional linear system is a pendulum swinging in a plane. The attractor can be drawn by plotting its velocity on one axis and its position on another axis (it is thus a 2-dimensional diagram), resulting in a perfect circle. The idealization in this example is the absence of friction, and hence no energy dissipation.[15] Without loss of energy via friction, the pendulum has exactly the same energy at all times, so will continue swinging in its up-down motion forever. So, for this simple example, the attractor is a circle in what is known technically as 'phase space', i.e., the set of all allowable coordinates specifying the location and velocity of the pendulum. This is shown in the figure below.

[13] A dynamical system is one which evolves as time increases, as opposed to a static system, which remains constant in time.
[14] In particular, a low dimensional system with three or fewer dimensions.
[15] By dissipation is meant the conversion of mechanical energy into heat that is then lost to the system.

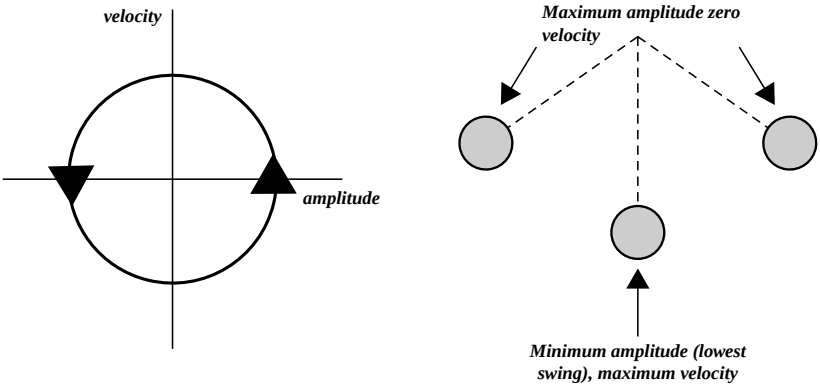

Diagram of an attractor (left) for a frictionless, non-dissipative pendulum (right).
Velocity is plotted as a function of amplitude (left). Maximum velocity corresponds to the point at which the pendulum is at its lowest swing amplitude, whereas zero velocity corresponds to the point where the pendulum is at its maximum swing amplitude. The intersection of the two axes represents the point (0, 0), i.e. zero velocity and zero amplitude. The pendulum is shown (right) at three different positions in its swing cycle.

If one now considers the real world, then friction comes into play, and because this means dissipation of energy, the idealised circle will in fact become a spiral, spiralling inwards until it reaches a point with the coordinates that correspond to zero velocity and the rest position of the pendulum (i.e. the pendulum comes to a complete stop). This is because the energy of the pendulum is lost to friction, diminishing both the amplitude and velocity of the pendulum in time. Friction in the real world invariably results in nonlinearity.

For a highly nonlinear system the attractor is much more richly structured than that of a linear system, with many more possible paths of evolution available to it. Because a nonlinear chaotic attractor usually has an unusual and complex 'shape'[16] it is termed a 'strange attractor'. A low-dimensional strange attractor, one that can be completely visualized in three or fewer dimensions, often has a wispy, hair-like structure, wherein each strand represents a set of possible paths along which a system might evolve. Each strand

[16] 'Shape' is parenthesised because for dimensions greater than three it is impossible to draw an attractor (we can only draw one, two or three dimensional objects). Its structure is complex and exists in a multidimensional abstract hyperspace that can only be analysed mathematically.

in turn can be fractal (see below), constructed of finer self-similar strands, which are themselves constructed of finer self-similar strands, *ad infinitum*. In between these strands and sub-strands are voids that represent forbidden zones, pockets of phase space not allowed by the laws that govern the behaviour of the system. However, no matter which evolutionary path the system takes, it remains in the domain (known as the 'basin') of the strange attractor, as long as it is stable in time. This means that even if something, some modest perturbation, knocks the system off its phase space trajectory, as long as the perturbation is not catastrophic and not sustained, then the system will return back to its stable attractor. This is why they are called attractors: because they 'attract' a phase space trajectory back onto its allowable evolutionary course.[17] And this is true, *despite* the exponential divergence of neighbouring trajectories that are characteristic of chaotic systems.[18] A stable strange attractor *guarantees* that there are in fact boundaries to evolution. While there may be an infinite number of possible paths within the attractor, the attractor is nonetheless finite in its extent.

An example of this 'finite contains the infinite' relationship may be found in the fractal nature of certain objects, such as a snowflake. Fractal objects, according to physicist Leo Kadanoff "contain structures nested within one another like Chinese boxes or Russian dolls [6]." A snowflake is just such an object, and while there are many forms of snowflakes, one nice idealized model is known as the Koch snowflake. One can construct a Koch snowflake oneself. Simply draw a triangle of equal side lengths of 1. Then, in the middle of each side insert a new triangle of equal size lengths of one third. Do the same for all the new triangles created and one will find an object that is self-similar, in that each section of the boundary resembles a smaller microcosm of it, and so forth. If one was able to do this forever one would find this snowflake in fact has a boundary whose length is infinite, despite it having a finite area! In an analogous way, a stable strange attractor can allow for a limitless range of possible evolutionary paths, while yet ensuring that the entire system is bounded within some finite range of total possibilities.

The comforting thing about this is that no matter how chaotic a system may get, no matter how uncertain its initial conditions or its eventual evolutionary path, the determinism of the dynamics that governs its evolution ensures that it will, in time, move along its unique strange attractor. In this sense then, there *is* order in chaos; there *is* certainty in uncertainty. The universe is not out of control and things are not free to do whatever they like! Natural law allows for chaos, yes, but this chaos has reigns that keep it under control.

[17] It is important to appreciate that 'attract' here implies a tendency for a trajectory to evolve along its attractor. There is no actual force of attraction, unlike, for example, the gravitational force of attraction between the earth and the moon.

[18] Why this is the case is interesting and has to do with the stretching and folding of chaotic trajectories in phase space. It is however beyond the scope of this article and will not be discussed any further.

When contemplating this, one is actually amazed how, out of such uncertainty and chaos, the universe and life emerged at all. Despite the complicated interactions that exist between all things, some as simple as the fundamental particles that constitute all matter, others as complex as human beings trying to organize their society on this planet, there is a glue that unites each component into a whole, a glue that guarantees their cooperation. How then can we rationalise such a contradiction? On the one hand deterministic dynamics leads to chaos, yet on the other it is *precisely* this complicated chaotic behaviour that in turn leads to the cooperativity that underpins the universe's existence and the existence of life itself!

Examples of this paradoxical behaviour abound; all we need do is look for them. Consider a fluid in a cup. Let us suppose that the fluid is at equilibrium, which means it is not being in any way stirred or shaken, and is thus at rest relative to us. At the molecular level we find molecules interacting with each other by two processes: the exchange of interaction forces, and by collisions. We consciously experience an interaction force every day, namely gravity. Though we cannot see it, we feel its influence all around us. It is the glue that binds us and everything else to our world, and the glue that binds the constituents of the universe together. Similarly, atoms and molecules also have interaction forces associated with them. This is not gravitational, but rather electromagnetic in nature: the attraction of positive charge with negative charge, or the repulsion of like charges (in the same way that like poles of a magnet repel each other, whereas unlike poles attract). Such forces are sometimes termed *configurational* forces, because they depend on *where* one atom is in relation to another. These forces act at a distance, just like the earth and the sun are attracted to each other, though they are over a hundred million kilometres apart. The other type of force is collisional, which is easier to visualise. Think of billiard balls colliding on a pool table, and one has a simple but effective model of how atoms and molecules collide. In these collisions kinetic energy (the energy of motion) is transferred between atoms and molecules.

Now, these interactions – both configurational and kinetic – result in the redistribution of mass, energy and momentum[19] in the fluid. They are governed by precise laws of motion and are fully deterministic. And yet, the system is chaotic because it is highly nonlinear. It is thus impossible to predict with constant accuracy the trajectory of any one molecule, let alone the collective system of the billions upon billions of molecules that comprise the fluid. So, on the fundamental level of the laws that govern the interactions and motion of each molecule, there is complete determinism. On the next level up, that of the collective system, there is chaos. But there is yet another

[19] Momentum is mathematically defined as the product of mass with velocity. The change in momentum of a body as time progresses is a measure of the force experienced by that body during that time.

level beyond that, the *macroscale*, in which our senses have direct experience. On this scale we see the fluid as a collective whole, a mass of fluid, in which we have no knowledge or awareness of its atomic or molecular constituents. We can characterize it fully only by its density, its pressure, its temperature and other physical and chemical properties readily accessible to observational measurement. Despite the underlying chaos of the microscopic world, in the macroscopic world all is calm and perfectly predictable. We can measure the pressure of the fluid to very high precision, and measure the same pressure again and again with almost perfect consistency in the results. No chaos there. We can similarly measure its temperature over and over again, always with the same predictable value. Somehow in going from the chaotic microscale to the macroscale we have crossed the barrier again, this time from chaos into order.

So here we have three levels: on the first, there is inherent predictability based on the determinism of the laws that govern the dynamics of atoms and molecules; on the next, there is chaos, where the determinism of the laws of motion lead to unpredictable outcomes due to the exponential divergence of nearby molecular trajectories; and in the final, there is again order, in which macroscopic quantities can be measured (and predicted) with high precision. Interestingly, if we were now to stir the fluid vigorously with a teaspoon, order would again be transmuted into chaos, this time manifested as turbulence within the fluid *on the macroscale*. But at the fundamental level of the laws that govern the dynamics of the motion of atoms and molecules, there is still complete determinism. On this level, nothing has really changed.

There are no simple explanations of these types of conundrums, but it is patronising and unedifying to rationalize our lack of understanding as another of God's mysteries. Certainly, these processes *are* mysterious, but written into the twenty-and-five remaining letters of Knowledge revealed through the Revelations of the Báb and Bahá'u'lláh is the means to a greater understanding of them. There are, for instance, some instructive examples we might consider, from both the material and spiritual realms of existence, which could shed light onto our sometimes dimly lit minds. On the level of material phenomena, we realize now that complexity results from interactions that are nonlinear in nature. Linear phenomena are not 'complex', and for this reason they are devoid of the potentialities that make an intricate universe stable, or life possible. In terms of spiritual phenomena, we need to appreciate that there is an almost unimaginable wisdom in the necessary inter-relationships that exist between what we naively term 'good' and 'bad'. Good and bad are a little like white and black. They are extreme opposites and idealized abstractions. Nothing is only 'good', nor is anything completely 'bad'. The universe is a far more palatable place to live in because of the reds and greens and blues and yellows that abound in it. A black and white universe would be somewhat boring and lacking in imagination and combinatorial beauty.

Let us first look at an example of how material complexity is good for us. This example is actually wrapped within us. It is our genes. Genes are, of course, composed of that remarkable molecule known as deoxyribonucleic acid, more familiarly known as DNA. DNA is an immensely large molecule comprised of millions of atoms. DNA in fact consists of a double-stranded helical molecule: two strands of DNA intertwined together in a helix. In turn, each DNA molecule is composed of four different types of sub-molecules, known as bases (adenine, thymine, guanine and cytosine, commonly known by their first letters: A, T, G and C), and each base is paired with another base on the adjacent strand. What DNA does is that it sends messages to other biological molecules, and these messages tell them what they should do and what they should make. The result is life. Furthermore, the order in which these base pairs are arranged is critical. Within this order is encrypted the unique message to be imparted to other molecules.

But this is not the end of the story. Recall that DNA is what genes are comprised of. Genes are much larger, far more complex structures consisting of *sequences* of DNA bases. Genes are, again, the imparters of messages, this time to a class of biological molecules known as proteins. And it is proteins that manufacture and control the engines of life: the cells of which we are all composed. A gene for brown skin, for example, gives instructions to skin cells to produce brown pigmentation, and so-forth for all other genes. Relatively simple creatures, such as viruses, exist with only a few genes. While 'simple', each virus gene is still hundreds of thousands of DNA bases long. Something as small as yeast consists of a colossal 15 million bases. And when we consider more than single-celled organisms we are faced with a complexity that has never been known to the human mind before. The human genome (the collective word for the whole family of genes that together make us what we are) itself consists of some 30000 genes!

The point is this: we humans, and life itself, can only exist due to the enormous complexity of biochemistry. At its core, this involves billions upon billions of interactions between billions and billions of molecules, each molecule in turn may be composed of millions of atoms. Anything simpler, anything smaller, and life could not exist. And, yes, these interactions are nonlinear, and hence chaotic. Life *could not exist* without this crazy and complex world of chaos occurring within our every cell! We should not therefore curse a universe that is complex; rather should we embrace and marvel at it.

As an example of how something spiritually complex is beneficial to us, consider the following. We accept as a matter of faith that all things spiritual are good for us, and that by some mysterious process all these spiritual realities must be essentially 'simple'. If they were so simple it should be asked (but seldom is), how is it that so few people are gifted with what we might term a divine nature? How is it that most people, even those who profess allegiance to one of the world's great Faiths, still struggle with their daily

temptations, fight their own demons and struggle to maintain their own sense of purpose? Why is it that so many of us fail so many times in our spiritual challenges, rather than enjoy an endless string of successes? Perhaps it is because the acquisition of spiritual virtues is not at all easy, and we deceive ourselves by claiming anything other. Perhaps also because we do not understand that spiritual evolution, like the evolution of biological creatures or the evolution of planetary trajectories, involves a type of deterministic dynamics.

There is in fact a dynamics of spiritual evolution. Its laws are contained in our Writings and indeed the Writings of all other Faiths, but we have to look for them. This is another topic in its own right, but in summary the dynamics goes something like this: God creates man to know Him and to love Him. But as it is impossible to know the Nature or Essence of God, what is meant is the attainment of His attributes *as they are reflected* in His creation. And since Man is the pinnacle of God's creation[20], then knowledge of our own selves is equivalent to gaining the highest *possible* knowledge of God. The path that leads unto our true selves is laid clear by the Manifestation of God, through His teachings, and through His Person. But this is where our role comes in: we must make, in the words of Shoghi Effendi, "sustained and intelligent effort" [7] towards this end, and this is done fundamentally through prayer and meditation. From this spiritual storehouse we are able to manifest the attributes of God amongst each other through, in the words of 'Abdu'l-Bahá, "good actions, which are the fruits of faith" [8]. Does it end here? Not quite, because by attaining the highest level of spiritual progress, i.e. the manifestation of Divine virtues through tangible deeds, one's spiritual capacity is increased, and therefore one is able to 'know and to love' God to a greater extent, and this after all is our ultimate purpose in existing. And so it is that we return to the beginning of the spiritual cycle, and indeed the process is infinitely cyclic, with each cycle possessing greater capacity than the previous one.

This is an idealized model, and in practice it is not quite so simple, not quite so straight-cut. If it was, we would all be wonderfully virtuous, and God's Kingdom would well and truly have been established on earth. It is highly likely that the cyclic 'feedback' process described above is in fact inherently nonlinear. While the paths towards spiritual progress may appear clear enough, it is proposed here that they are infinitesimally spaced along a manifold. By this is meant that any spiritual path is, when examined in *minute* detail, constructed from an infinite number of equally likely sub-paths, paths that are fractal in nature, in the sense that they are self-similar. Thus, setting out on one sub-set of one path may lead to an entirely different end than if

[20] This is attested to in the Bahá'í scriptures as well as all others. By Man is meant, in the author's opinion, any creature that possesses the intellectual capacity 'to know and to love' God, be it in this world or any other.

one had set out on even a slightly different sub-set. Again, we see the markings of a type of chaotic dynamics in operation: small differences in initial conditions leading to vastly different outcomes.

Unfortunately no experiment can ever be devised to test this theory. One never has a second chance at life on this planet, so we can never have two 'trials' at life, like we may with spinning tops. But if there is some consolation, it is this: no matter what path one does take, even if in time that path turns out to be a mistake and leads to a fate far removed from what one might have imagined or hoped for, as long as one is not totally reckless in one's undertakings, then one *will still remain* on the stable 'strange attractor'[21] that allows for the total range of possible spiritual experiences. An analogy can be made with the swinging pendulum. Slight disturbances to the pendulum will only temporarily disturb its trajectory, but in time it will again settle down to its regular periodic motion.

There are many examples in all our lives in which we have made a mistake, but which some good nevertheless comes from that mistake, and from which we have taken great strides forward on the path of spiritual progress. This is an example of choosing a sub-set of a particular path that may not have been ideal when viewed with hindsight, but which remarkably still leads us to advance our spiritual condition, and which may ultimately bring us great reward and personal fulfillment. It is an example of how complexity in the spiritual world can be beneficial to us.[22] In fact, one could reasonably argue that it is indispensable for our development as creatures that are fundamentally spiritual in nature. But then, this also depends upon our own intelligence, and our willingness to learn from our mistakes, and this comes down to the importance of volition, again a topic in itself so vast that it requires a series of articles in its own right.

So what have we learned from all this? Perhaps most importantly it should be this: Do not be afraid of the strange and complex universe we live in, and the unpredictable nature of the laws that govern it, laws that describe both the physical and spiritual domains of existence. Remember that these laws are themselves but reflections of God's purpose for Man, reflections of His Will. No matter how unpredictable our future, be assured that despite the small errors that we make from time to time, we will still move along our 'strange attractor', confined to within the limits of God's decree, yet with an infinite degree of latitude to explore the vast richness of spiritual and material existence. The only thing to be truly cautious about is that these small errors in judgment remain small. For if the errors get larger and larger we run the risk of creating for ourselves an *unstable attractor*, and then we *have* entered the

[21] Strange attractor is parenthesised here because one must be cautious in extrapolating spiritual reality into physical or mathematical terms. One uses 'strange attractor' here as a metaphor for a spiritual reality that is analogous to the strange attractors measurable in the physical world.

[22] It is also an example of how marvellously merciful God is to Man!

9th circle of Dante's hellish Inferno, from which there is little chance of escape.

The title of this article has the word "benevolence" in it. Where is benevolence to be found in chaos? It is in this: a linear, simpler world is in fact the cruelest and most awful of all places to live in. It would be testimony to an uncaring God Who does not wish to have creatures to know or love Him; a sole, alone God Who wants to love none other than Himself and has time or interest for nothing else. Recall that linear laws of Nature preclude not only life, but the very formation of the universe itself! The universe exists, life exists, *we exist*, our purpose in life in knowing and attaining the presence of God, is only possible *because* of the benevolence of our highly nonlinear world, and the chaos and uncertainty that is part-and-parcel of it. And this benevolence is itself a mere reflection of the benevolence of God in the hearts and minds of Man.

Finally, a closing remark about He Who brought all this about in the first place. If God has so willed that our universe and our eternal lives be bound within an infinitely unknowable reality, a reality that is at its core nonlinear, complex and chaotic, then what does that say about God Himself? Is not His universe but a reflection of His Purpose? Is God, therefore, *nonlinear*? Is He – far from being simple in Essence – in fact quite the opposite: complex beyond all imagination? Is He chaotic?

Fortunately, such questions are ridiculous. The reason that they are ridiculous is encapsulated by an unambiguous statement by Bahá'u'lláh, in which He says clearly that God is "exalted beyond every human attribute, such as corporeal existence, ascent or descent, egress and regress" and that "He is, and hath ever been, veiled in the ancient eternity of His Essence, and will remain in His Reality everlastingly hidden from the sight of men [9]." By this is implied that the universe, and all within it, is contained by God, but that God can never be contained by it. So it is that the universe and Man in his totality are indeed nonlinear. This is how God designed His Creation. So be it. Bahá'u'lláh also says "…the utmost limit to which they who lift their hearts to Thee can rise is the confession of their powerlessness to enter the realms of Thy holy and transcendent unity, and that the highest station which they who aspire to know Thee can reach is the acknowledgment of their impotence to attain the retreats of Thy sublime knowledge…[10]" God is, for want of a suitable superlative, *supra-linear*, and there is no definition in any language in any world for what this really means. The Essence of God, no, actually the essence of *anything*, is where our knowledge strictly ceases.

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