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The Theory of Chaos
Scientific Openness and Religious Commitment

- Kuruvilla Pandikattu[1]

Abstract: *Although from the dawn of creation chaos has been dumped in the limbo of the undesirables, recent developments in science, assisted by the versatility and unprecedented computing power of the computer technology, have brought to light many of its positive and creative aspects. This paper discusses how this important turnaround came about, what the different elements of contemporary chaos theory are, and how it can help us to get a better understanding of our universe. In particular it highlights the contributions of Henry Poincaré, Daniel Stein, Ilya Progogine, etc. The social and religious implications of chaos theory are also discussed.*

Key Words: *Chaos, The Butterfly Effect, Strange Attractors, Fractals, Non-linear Systems*

"Yea verily, I say unto you A man must have chaos yet within him to birth a dancing star."[2]

"To this day God is the name by which I designate all things which cross my wilful path violently and recklessly, all things which upset my subjective views, plans and intentions and change the course of life for better or worse."[3]

Order and disorder! Cosmos and chaos! Design and confusion! Humans have often wondered at these polarities. Are they opposed to each other? The emerging mathematical theory of chaos has something profoundly new to offer with regard to the relationship between these polarities. The insights from chaos theory are capable of altering our vision of the world, humans and God. This mathematical theory challenges our conceptual and philosophical framework, just like the earlier scientific theories of quantum mechanics and relativity.

In this paper I want to outline briefly this mathematical theory, draw the main features of it and trace its importance for the real world. This section will be descriptive. Then I outline some of the significant implications of this theory at the religious or philosophical level. This article, therefore, has the modest aim of acquainting the readers with the general features of the theory of chaos[4] in order to relate these insights to the religious values and visions. It is hoped that in this process science and religion can encounter and enrich each other leading to greater openness and commitment.

Emergence of Chaos

The dictionary definition of chaos is turmoil and undesired randomness. But scientifically chaos is a situation that is extremely sensitive to initial conditions. Chaos also refers to the question of whether or not it is possible to make good long-term predictions about how a system will act. A chaotic system can actually develop in a way that appears very smooth and ordered and will end up totally unpredictable.

The word "chaos" can be traced in Hesiod's *Theogeny* (700 B.C.E.): "At the beginning there was chaos, nothing but void, formless matter, infinite space."[5] The Bible speaks of creation from chaos. Later Milton in *Paradise Lost* affirms: "In the beginning, how the heav'ns and earth rose out of chaos."[6] Both Shakespeare (*Othello*) and Henry Miller (*Black Spring*) refer to chaos. In these cases one inferred that chaos was an undesirable, disordered quality. Historically our vernacular incorporated this idea of disorder into chaos; dictionaries defined chaos as turmoil, turbulence, primordial abyss, and biblical references to *Tohu* and *Bohu* had the same referential character of undesired randomness. Scientifically, chaos definitely implies the existence of the undesirable randomness, but the self-organization at the edge of chaos denotes an order that emerges from chaos. The American essayist and historian

Henry Adams (1858-1918) expressed the scientific meaning of "chaos" succinctly: "Chaos often breeds life, when order breeds habit."[7]

Tien Yien Li and James Yorke[8] coined the word "chaos" in 1975 to refer to the mathematical problem that described a phenomenon with sensitive dependence on initial conditions. Robert May, a mathematician-biologist, used the word and the theory from Li and Yorke's paper, thus making the term famous.[9]

Ilya Prigogine, the 1977 Nobel Prize winner in chemistry, pioneered the work in entropy of open systems. This was the inflow and outflow of matter, energy, or information between the system and its environment. Prigogine used dissipative systems to show that more complex structures can evolve from simpler ones, or order coming out of chaos.

Daniel Stein[10] compares chaos/complexity to a "theological concept," because lots of people talked about it but no one knew what it really was.[11] Several descriptions of chaos theory like synthesis, cross-discipline, edge of chaos, dynamical, cellular automata, or neural networks, all carry with them the concept of complex systems. The implications of chaos are profound, for who could know the absolute conditions of any system for a complete prediction to be made of the behavior of that system.

Historical Evolution of the Theory

For thousands of years humans have noted that small causes could have large effects and that it was hard to predict anything for certain. What had caused a stir among scientists was that in some systems small changes of initial conditions could lead to predictions totally different and so useless. At the end of the 19th century, the French mathematician Jacques Hadamard proved a theorem on the sensitive dependence on initial conditions of the frictionless motion of a point on a surface or the flow on a surface of negative curvature. All this was about billiard balls and why you could not predict what three of them would do when they careened off each other on the table. Another French physicist Pierre Duhem understood the significance of Hadamard's theorem. He published a paper in 1906 that made it quite plain that prediction was "forever unusable" because of the necessarily present uncertain initial conditions in Hadamard's theorem. These papers went unnoticed or rather unnoted by the man who was recognized as the Father of chaos theory, Henri Poincaré (1854-1912).

In 1908 he published *Science et methode,*[12] that contained one sentence concerning the idea of chance being the determining factor in dynamic systems because of some factor in the beginning that we didn't know about. All these men and their ideas went unnoticed because quantum mechanics had disrupted the whole world of ideas of physics, because there were no mathematical tools to measure their ideas and because there were no computers to simulate what these theorems proved.[13]

In 1846 the planet Neptune was discovered, causing quite a bit of triumphant celebration in the classical Newtonian mechanical world. This had been predicted from the observation of small deviations in the orbit of Uranus. Something unexpected happened in 1889 when King Oscar II of Norway offered a prize for the solution to the problem of whether the solar system was stable. Henri Poincaré submitted his solution and won the prize, but a colleague happened to discover an error in the calculations. Poincaré was given six months to rectify the matter in order to keep his prize. In consternation Poincaré showed that no solution was ever possible.[14] He had found results that upset the accepted view of a purely deterministic universe that had reigned since Sir Isaac Newton outlined linear mathematics. In his 1890 paper, he showed that Newton's laws did not provide a solution to the "three-body problem." In other words, we cannot have exact predictions taking into account the movement of the earth, the moon and the sun at the same time. He had found that small differences in the initial conditions in any one of them produced very great ones in the final phenomena, defying prediction. Poincaré's discoveries were dismissed in favour of Newton's linear model. The three-body problem had to be interpreted with a two-body system of mathematics. In short, he was trying to discover order in a system where none could be discerned.

Poincaré's negative answer caused positive consequences towards the formulation of chaos theory. About eighty years later, as early as 1963, Edward N. Lorenz,[15] using Poincaré's mathematics, described a simple mathematical model of a weather system that was made up of three linked nonlinear differential equations that showed rates of change in temperature and wind speed. Some surprising results showed complex behaviour from supposedly simple equations; also the behaviour of the system of equations was *sensitively dependent on the initial conditions* of the mathematical model. He spelled out the implications of his discovery, implying that if there were any errors in observing the initial state of the system (which is inevitable in any real system), prediction as to a future state of the system was impossible. Lorenz labeled these systems that exhibited sensitive dependence on initial conditions as having the "butterfly effect":[16] this unique name came from the proposition that a butterfly flapping its wings in Hong Kong can affect the course of a tornado in Texas. This has become the emblem of chaos theory, following James Gleik.

During 1970-71, interest in turbulence,[17] strange attractors and sensitive dependence on initial conditions arose in the world of physics. E. N. Lorenz published a paper, "Deterministic Nonperiodic Flow," in 1963 that proved that meteorologists could never predict the weather with full accuracy. A chaotic system is sensitive to initial conditions and causes the system to become unstable. A. B. Cambel identifies chaos as inherent in both the complexity in nature and the complexity in knowledge.[18] The nature side of chaos entails all the physical sciences. The knowledge side of chaos deals with the human sciences. Chaos may manifest itself in either form or function or in both. Chaos studies the interdependence of things in a far-from-equilibrium state. Every open nonlinear dissipative system has some relationship to another open system and their operations will intersect, overlap and converge. If the systems are sensitive to the initial conditions, in other words, you don't know exactly in detail every little piece of information, and then you have a potentially chaotic system. Not all systems will be chaotic. Those systems which are sensitive to initial conditions have an indeterminate quality about them. Therefore, they are unpredictable.

If these systems are perturbed either internally or externally, they will display chaotic behavior and this behavior will be amplified microscopically and macroscopically. Further research in non-linear dynamical systems[19] that displayed a *sensitive dependence on initial* *conditions* came from Ilya Prigogine who first began work with far-from-equilibrium systems in thermodynamics research. Prigogine's research in non-linear dissipative structures led to the concept of equilibrium and far-from-equilibrium to categorize the *state* of a system. In the physical studies of thermodynamics, Prigogine's research revealed far-from-equilibrium conditions that led to systemic behaviour different from what was expected by the customary interpretation of the Second Law of Thermodynamics. The phenomena of bifurcation and self-organization emerged from systems in equilibrium if there was disruption or interference. This disruption or interference became the next step in chaos theory; it became chaos/complexity theory. Prigogine talked about his theory authoritatively that a far-from-equilibrium system could go 'from being to becoming.'[20] These 'becoming' phenomena showed order coming out of chaos in heat systems, chemical systems, and living systems.

From Lorenz simulation, René Thom, a mathematician, proposed the 'catastrophe theory,' or a mathematical description of how a chaos system bifurcates or branches. Out of these bifurcations came pattern, coherence, stable dynamic structures, networks, coupling, synchronization and synergy. From the study of complex adaptive systems used by Poincaré, Lorenz and Prigogine, Norman Packard and Chris Langton developed theories about the 'edge of chaos' in their research with cellular automata.[21] The energy flowing through the system and the fluctuations cause endless change which may either dampen or amplify the effects. In a phase transition of chaotic flux, (when a system changes from one state to another), it may completely reorganize the whole system in an unpredictable manner.[22]

Two scientists, physicist Mitchell Feigenbaum and computer scientist Oscar Lanford, came up with a picture of chaos in hydrodynamics using Renormalization ideas. They were studying non-linear systems and their transformations. Since then chaos theory or nonlinear science has taken the scientific world by a storm, with papers coming in from all fields of science and the humanities. *Strange attractors* were showing up in biology, statistics, psychology and economics and in every field of endeavour.[23]

The Beginnings of Chaos Theory

Ilya Prigogine showed that complex structures could come from simpler ones. This is like order coming from chaos. Henri Poincaré was really the "Father of Chaos [Theory]," however. It was Edward Lorenz, a meteorologist at MIT working on a project to simulate weather patterns on a computer, who popularized this theory. Lorenz's initial brush with chaos is described best by James Gleik in his *Chaos:*[24]

> One day in the winter of 1961, wanting to examine one sequence at greater length, Lorenz took a shortcut. Instead of starting the whole run over, he started midway through. To give the machine its initial conditions, he typed the numbers straight from the earlier printout. Then he walked down the hall to get away from the noise and drink a cup of coffee. When he returned an hour later, he saw something unexpected, something that planted a seed for a new science.

This new run should have exactly duplicated the old. Lorenz had copied the numbers into the machine himself. The program had not changed. Yet as he stared at the new printout, Lorenz saw his weather diverging so rapidly from the pattern of the last run that, within just a few months, all resemblance had disappeared. He looked at one set of numbers, then back at the other. He might as well have chosen two random weathers out of a hat. His first thought was that another vacuum tube had gone bad.

Suddenly he realized the truth. There had been no malfunction. The problem lay in the numbers he had typed. In the computer's memory, six decimal places were stored: .506127. On the printout to save space, just three appeared: .506. Lorenz had entered the shorter, rounded-off numbers, assuming that the difference - one part in a thousand - was inconsequential.

It was a reasonable assumption. If a weather satellite can read ocean-surface temperature to within one part in a thousand, its operators consider themselves lucky. Lorenz's Royal McBee was implementing the classical program. It used a purely deterministic system of equations. Given a particular starting point, the weather would unfold exactly the same way each time. Given a slightly different starting point, the weather should unfold in a slightly different way. A small numerical error was like a small puff of wind - surely the small puffs faded or canceled each other out before they could change important, large-scale features of the weather. Yet in Lorenz's particular system of equations small errors proved catastrophic.

And there is the show-stopper: *small errors prove catastrophic.* Lorenz entitled a 1979 paper, "Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?" and the title struck. Today sensitive dependence on initial conditions is referred to as "The Butterfly Effect."

Chaos theory is a further development of the dynamical systems theory which focuses on highly complex motions called chaotic motions.[25] These were discovered originally by Poincare around 1890 in his unsuccessful efforts to prove the stability of the solar system.

Some Features of Chaos Theory

Chaos theory describes complex motions and the dynamics of sensitive systems. Chaotic systems are mathematically deterministic but nearly impossible to predict. Chaos is more evident in long-term systems than in short-term ones. Behavior in chaotic systems is aperiodic, meaning that no variable describing the state of the system undergoes a regular repetition of values. A chaotic system can actually evolve in a way that appears to be smooth and ordered, however. Chaos refers to the issue of whether or not it is possible to make accurate long-term predictions of any system if the initial conditions are known to an accurate degree. A general idea of the theory of chaos can be had by studying three of its key principles: the butterfly effect, strange attractors and ubiquitous fractals.

The Butterfly Effect

As discussed already, during the 1960's E. Lorenz accidentally stumbled upon the butterfly effect after deviations in calculations went off by thousandths causing drastic changes in the simulations. The Butterfly Effect, as we have seen, reflects how changes on the small scale affect things on the large scale. It is the classic example of chaos, as small changes lead to large changes.

The sensitive dependence on initial conditions asserts that if you run the system through, recording precisely how it travels, then rerun the system with the initial points even slightly different, they will eventually diverge (go different paths) to the point that it is not obvious that they were ever so close. In fact, they will eventually be arbitrarily far apart (as long as it is within our legal range for the system). In such systems, accurate long term predictions are impossible from a practical point of view.

The main feature of self-generated complexity is the presence of an iterative mechanism which transforms the information contained in the initial conditions in a deterministic way. In this sense, it is possible to view complexity as elaborated simplicity. Sensitive dependence on initial conditions means similar causes do not produce similar effects.

A variation so small and almost insignificant in the beginning can create vast differences as the system evolves, making it impossible to track or predict. In the Consciousness Restructuring Process of natural healing, just as one traumatic incident may pattern a lifelong disorder, one healing therapeutic event may completely and permanently restructure the whole system from the most fundamental level. After a bifurcation there can be no return to the old situation.

Such a dependence or the popularly called "Butterfly Effect" was vaguely understood centuries ago and is still satisfactorily portrayed in folklore:

"For want of a nail, the shoe was lost;
For want of a shoe, the horse was lost;
For want of a horse, the rider was lost;
For want of a rider, a message was lost;
For want of a message, the battle was lost;
For want of a battle, the kingdom was lost!"

Small variations in initial conditions result in huge, dynamic transformations in concluding events. That is to say that there was no nail, and, therefore, the kingdom was lost. The graphs of what seem to be identical, dynamic systems appear to diverge as time goes on until all resemblance disappears. This is because it is usually impossible to be sure that measurements of the state of a system at a given time are exactly right. In some cases, our measurements are necessarily coarse. If such a system also has sensitive dependence, any long term predictions we make will be rather questionable.

This is probably why weather forecasts are so unreliable, even a few days in advance. Our capacity to measure the global state of the weather is limited, and weather systems almost certainly exhibit sensitive dependence most of the time.

Strange Attractors

Attractors are a property of complex systems, which tends to settle down. A set of attractors is a restricted set of unusual events. A strange attractor is the property of some systems to be non-periodic (irregular) and periodic (regular) at the same time. When such systems settle down, though we do not know the exact point, we do know its final range exactly.

Investigation of the mechanism of turbulence led to the invention of strange attractor, a term coined by David Reulle. The turbulence that is described by strange attractors is "turbulence in time" – deterministic chaos, or temporal chaos. Graphic depictions of attractors allow us to map a dynamical system's behaviour in discrete-time or phase-space. Roughly speaking, an attractor is what the behaviour of a system settles down to, or is attracted to. A system may have several attractors. Strange attractors are the core of unpredictable variation with limits. For humans this means any perturbation from conception onward can be a determining factor in structure and personality. Personality traits can be construed as strange attractors of behaviour. The feature of a strange attractor is that though they are of finite dimension in space they can represent infinite dimensions. Natural chaos allows adaptation and self-organization for evolutionary change.[26]

Ubiquitous Fractals

Our world does not consist of pure lines, ideal circles or perfect squares, but approximations of these which are called fractals. Fractals are a way of measuring qualities that otherwise have no clear definition: the degree of roughness or brokenness or irregularity of an object. A fractal is an object that reveals more and more details as it is increasingly magnified, like seeing the universe in a grain of sand. Self-similarity repeats its conformations from the most fundamental to the most complex level. In fractals the image appears in a myriad of self-similar forms revealed through the levels of the consciousness journey. One traumatic event can shape a life; one intense therapeutic event can reshape it.[27]

Fractals are geometric shapes that are very complex and infinitely detailed. You can zoom in on a section and it will have just as much detail as the whole fractal. They are recursively defined, and small sections of them are similar to large ones.[28]

Benoit Mandelbrot was a Poland-born French mathematician who greatly advanced fractals. When he was young, his father showed him the Julia set of fractals. He was not greatly interested in fractals at the time, but in the 1970's he became interested again and he greatly improved upon them, laying out the foundation for fractal geometry. He also advanced fractals by showing that fractals cannot be treated as whole-number dimensions; they must instead have fractional dimensions. Benoit Mandelbrot believed that fractals were found nearly everywhere in nature, at places such as coastlines, mountains, clouds, aggregates, and galaxy clusters.[29] To cite him: "I coined fractal from the Latin adjective fractus. The corresponding Latin verb frangere means 'to break': to create irregular fragments. It is therefore sensible – and how appropriate for our needs! – that, in addition to 'fragmented,' fractus should also mean 'irregular,' both meanings being preserved in fragment."[30]

Sierpinski's Triangle is a great example of a fractal, and one of the simplest ones. It is recursively defined and thus has infinite details. It starts as a triangle and every new iteration of it creates a triangle with the midpoints of the other triangles. Sierpinski's Triangle has an infinite number of triangles in it. The Koch Snowflake is another good example of a fractal. It starts as a triangle and adds on triangles to its trisection points that point outward for all infinity. This causes it to look like a snowflake after a few iterations. Fractals provide us with an immediate link with nature. Trees and mountains are examples of fractals.

Importance of Chaos Theory

Here are a few of the statements that Cambel makes about the importance of chaos:

1. Complexity can occur in natural and human-made systems, as well as in social structures and human beings.
2. Complex dynamical systems may be very large or very small. Indeed, in some complex systems, large and small components live cooperatively.
3. The system is neither completely deterministic nor completely random, and exhibits both characteristics.
4. The causes and effects of the events that the system experiences are not proportional.
5. The different parts of complex systems are linked and affect one another in a synergistic manner.
6. There is positive and negative feedback. The level of complexity depends on the character of the system, its environment, and the nature of the interactions between them.[31]

Every branch of pure mathematics has applications, usually to science or technology, which are important to society. In the case of the dynamical systems theory, extensive and ongoing applications to all of the physical, biological, and social sciences have been fundamental to our evolving culture. The most frequent kind of application is to the technology of modelling complex natural systems. The importance of chaos theory has been in the context of this modelling aspect of applied dynamics. Because of the new wisdom of chaotic motions, many more complex systems now have useful models: the biosphere, the global economy, the human immune system, and so on. Different models for subsystems, created by scientists of disjoint specialities, may now be combined into a single complex supermodel, thanks to chaos theory. It provides a new technique for the unification of the sciences.

Chaos in the Real World

The question may be raised: is the chaos of chaos theory the same as the chaos in everyday life? Off hand, it is not obvious that the chaotic motions of chaos have any direct bearing on the chaotic experiences of everyday life. However, as the applications of chaos theory to the social sciences evolve, more and more everyday chaos is brought into the embrace of chaos theory.

In the real world, there are three very good examples of instability: disease, political unrest, and family and community dysfunction. Disease is unstable because at any moment there could be an outbreak of some deadly disease for which there is no cure. This would cause terror and chaos. Political unrest is very unstable because people can revolt, throw out the government and create a terrible war. A war is another type of a chaotic system. Family and community dysfunction is also unstable because whether you have a very tiny problem with a few people or a huge problem with many people, the outcome can be huge with many people involved and many people's lives in ruin. Chaos is also found in systems as complex as electric circuits, lasers, clashing gears, heart rhythms, measles outbreaks, electrical brain activity, circadian rhythms, fluids, animal populations, and chemical reactions, and in systems as simple as the pendulum. It also has been thought possibly to occur in the stock market.[32]

One of the most interesting issues in the study of chaotic systems is whether or not the presence of chaos may actually produce ordered structures and patterns on a larger scale. It has been found that the presence of chaos may actually be necessary for larger scale physical patterns, such as mountains and galaxies, to arise. The presence of chaos in physics is what gives the universe its "arrow of time," the irreversible flow from the past to the future. For centuries mathematicians and physicists have overlooked dynamical systems as being random and unpredictable. The only systems that could be understood in the past were those that were believed to be linear, but in actuality, we do not live in a linear world at all. In this world linearity is incredibly scarce. The reason physicists didn't know about and study chaos earlier is because the computer is our "telescope" when studying chaos, and they didn't have computers or anything that could carry out extremely complex calculations in minimal time. Now, thanks to computers, we understand chaos a little bit more each and every day.

The first consumer product to exploit chaos theory was produced in 1993 by Goldstar Company in the form of a revolutionary washing machine. A chaotic washing machine? The washing machine is based on the principle that there are identifiable and predictable movements in nonlinear systems. The new washing machine was designed to produce cleaner and less tangled clothes. The key to the chaotic cleaning process can be found in a small pulsator that rises and falls randomly as the main pulsator rotates. The new machine was surprisingly successful. However, Daewoo, a competitor of Goldstar, claims that they first started commercializing chaos theory in their "bubble machine" which was released in 1990. The "bubble machine" was the first to use the revolutionary "fuzzy logic circuits." These circuits are capable of making choices between zero and one, and between true and false. Hence, the "fuzzy logic circuits" are responsible for controlling the amount of bubbles, the turbulence of the machine, and even the wobble of the machine. Indeed, chaos theory is very much a factor in today's consumer world market.

The stock markets are said to be nonlinear, dynamic systems. Chaos theory is the mathematics for studying such nonlinear, dynamic systems. Does this mean that chaoticians can predict when stocks will rise and fall? Not quite; however, chaoticians have determined that the market prices are highly random, but with a trend. The stock market is accepted as a self-similar system in the sense that the individual parts are related to the whole. Another self-similar system in the area of mathematics is fractals. Could the stock market be associated with a fractal? Why not? In the market price action, if one looks at the market monthly, weekly, daily, and intra day bar charts, the structure has a similar appearance. However, just like a fractal, the stock market has sensitive dependence on initial conditions. This factor is what makes dynamic market systems so difficult to predict. Because we cannot accurately describe the current situation with the detail necessary, we cannot accurately predict the state of the system at a future time. Stock market success can be predicted by chaoticians. Short-term investing, such as intra day exchanges are a waste of time. Short-term traders will fail over time due to nothing more than the cost of trading. However, over time, long-term price action is not random. Traders can succeed trading from daily or weekly charts if they follow the trends. A system can be random in the short-term and deterministic in the long term.

Pictorial Representation

Dynamical systems, of which chaos is a special case, are systems that are in constant flux. Other examples include the ecosystems, the weather and the human body. The list is endless. Traditional mathematics based on Newtonian principles has only been able to understand and model these systems by taking them apart and looking at the individual pieces. We can use linear equations to model the pieces. However, this gives us an incomplete picture of the behaviour of these systems. Eventually, we run up against the need to model these systems using non-linear equations, most of which are unsolvable. But many of the pioneers in chaos discovered that graphing these equations using feedback loops and computers allowed them to look at pictures of these systems, and we are beginning to understand much more about them using these graphs.

Religious Significance

We need to rethink our vision of the world, God and humans in the lights of the insights drawn from chaos theory. Actually the radical challenges posed by quantum mechanics in physics and postmodernism in philosophy are reinforced by the theory of chaos in mathematics, the most noble and secure of the disciplines. The theory of chaos urges to have new categories of words while speaking of the ultimate notions and to expand our horizon of thinking about the Divine and to usher in new interpretations of reality. It challenges us to own values which embrace the whole and opens us to the new without disowning the concrete, limited realities. The theory of chaos enables us to formulate a more refined and nuanced understanding of the world, God and the self, which vibrates better with modern philosophical and theological concerns like process philosophy, liberation theology, feminist and ecological issues.

Neither Deterministic Nor Chaotic

Chaos theory does not imply, as the name suggests, that everything is chaotic. Still it is vehemently opposed to a deterministic viewpoint both metaphysically and religiously. Chaos asserts that there can emerge order from chaos and vice-versa. So when we deal with the ultimate questions (religion) and ultimate reality (metaphysics) we need to take seriously the insight of chaos theory that reality is neither purely deterministic nor purely random. There is an interplay between them which has created the beautiful life we know of, the reality that we can perceive. Can we not understand better the mental and biological structures in terms of the interplay of chaos and order? Can we not trace such qualities in the divine too?

Beyond Certainty or Relativity

In the same vein chaos theory does not do away with all certainties. The epistemological certitude has to take the uncertainty principle seriously. Added to that is the claim of chaos theory that certitude (and predictability) are impossible at least in some domains. At the same time we need to keep in mind that chaos theory does not absolutize relativity. It does not assert that the whole reality is random and the result of chance happenings. So the theory of chaos forces us to go beyond the two opposites of certainty and relativity, predictability and randomness, consistence and chance.

Neither Mechanical Nor Purely Spiritual

Chaos theory clearly goes beyond the mechanical cause-effect principle of reality. It makes the linear way of interpreting reality redundant, though practical at times. At the same time the other extreme of spiritualising reality is also to be questioned. Just because the mechanical theory of life (and reality) is no longer valid, it does not mean that everything is purely spiritual. The theory of chaos that explains extremely complicated phenomena can base itself on simple equations or initial conditions. Therefore, if chaos theory demolishes the myth of world as a mere machine, it does not promote the myth of reality as pure soul.

Transcending Dualities and Non-dualities

Ours is a world conveniently fashioned on the principle of duality: you and me, this world and the next world, body and soul, material and spiritual. Determinism and randomness is another of the dualities that we are used to. Chaos theory indicates that methodologically such an "either or" logic is not valid for the whole of reality. The "fuzzy logic" with more than two truth-values has become inevitable. So we are forced to go beyond the dualities of order-disorder, evil-good, light-darkness and even death and eternal life. When we are urged to go beyond the dualities, we are not required to deny the distinction between them. The challenge facing us is to view reality neither in pure dualistic nor in pure non-dualistic (mental or metaphysical) categories, but to be open to go beyond.

Open to the More and Rooted to the Particular

This urges us to be open to the mysterious while remaining rooted to our concrete world. The concrete world has many dimensions which are explained by linear functions, through the category of good and bad, right and wrong. It has also other dimensions which urges us to transcend these distinctions without denying them. We are therefore confronted with a puzzling enigma. What is reality? Can we at all make sense of it? On the one hand, there is need to be rooted to the concrete life. On the other hand, there is an open horizon which draws us to a more "mysterious" dimension of reality. Chaos theory challenges us to move beyond our dualistic, mechanical and deterministic way of thinking and living. It points to a life and reality that is open-ended with an ever-widening horizon which is simultaneously rooted in our concrete existence.

Conclusion: A New Mode of Being

The challenge before us is to evolve a more significant understanding of the world, God and humans that goes beyond the purely mechanical interpretation of classical physics and spiritual interpretation of Platonism. The theory of chaos makes it abundantly clear that the reality around us (including ourselves, the subjects of experience, and God, the Ultimate Experience) is far more profound than we have ever thought. It cannot be bound by the dualistic categories of "This or That" good or bad, order or disorder. We need to evolve a deeper dimension of consciousness (and existence) which does not absolutize reality. "The real importance of chaos is its capacity as a new tool for solving problems and a new way of thinking about nature, the physical world and ourselves."[33]

On the one hand there is scope for commitment, concern, love and care for concrete things of our life. The ordinary experiences, rough edges, daily weather, personal moods are to be taken seriously. For the initial conditions, however tiny they may be, can cause a hurricane! On the other hand, we are open to the infinite, taking us beyond every limit. Life is the prime example of chaos. There is order emerging from disorder. There is disorder that can give rise to order. The theory of chaos is closely related to life and to the whole of reality. The theory of chaos makes room for surprise even in the scientific field. It lets us be open to the unexpected, including the divine, the source of all novelties. It breathes some fresh air to the rustic soul (spirit) of the academicians (mathematicians) and theologians. It is a welcome change! That is a new creation with freshness and vigour.

Within the background of chaos we can sing with renewed meaning and desire the creation song from the Vedas:

> There was neither existence nor non-existence then,
> Neither the world nor the sky that lies beyond it;
> What lay enveloped? And where? And who gave it protection?
> Was water there, deep and unfathomable?
>
> There was no death then, nor immortality,
> Nor of night or day was there any sign.
> The ONE breathed airless by self-impulse;
> Other than THAT was nothing whatsoever.

Darkness was concealed in darkness there,
And all this was indiscriminate chaos;
That ONE which had been covered by void
Through the might of *Tapas* was manifested.

In the beginning there was desire,
Which was the primal germ of the mind;
The sages searching in their hearts with wisdom
Found in non-existence the kin of existence.[34]

Notes

1. Dr. Kuruvilla Pandikattu is Reader in systematic philosophy at Jnana Deepa Vidyapeethg, Pune.
2. This is a quote attributed to F. Nietzsche. Cited in Iona Miller and Graywolf Swinney "Chaos Theory & Complex Dynamical Systems: Its Emergence in Human Consciousness and Healing," From the web, February, 2003.
3. Quote from Carl Jung. Cited in "Chaos Theory & Complex Dynamical Systems."
4. Some definitions of chaos: "a kind of order without periodicity," "apparent random recurrent behaviour in a simple deterministic (clockwork-like) system," "the qualitative study of unstable aperiodic behviour in deterministic nonlinear dynamic systems," or more mathematically, "variable aperiodic system dynamics nonlinear." Sardar and Abrams, *Introducing Chaos* (New York: Totem Books, 1999), p. 9.
5. Quoted in http://www.princeton.edu/~rhwebb/hesiod.html
6. See http://www.literature.org/Works/John-Milton/paradise-lost/
7. See http://www.wfu.edu/~petrejh4/HISTORYchaos.htm#ff1. This may be compared to: "Where is the wisdom we have lost in knowledge? Where is the knowledge we have lost in information?" T.S. Eliot (1963).
8. http://www.wfu.edu/~petrejh4/HISTORYchaos.htm#ff2. See Li, T. Y. and Yorke, J.A. "Period Three Implies Chaos." *American Mathematical Monthly*, 82 (1975),. pp. 995-992. James Yorke, an applied mathematician from the University of Maryland, along with T.Y. Li, was the first to use the name Chaos, but actually it was not even a chaos situation, but the name caught on.
9. Chaos theory came through the backdoor, so to speak, of the researcher's world. It was not a law like in thermodynamics or quantum physics, but it did

enable the researcher to analyze events or areas with many problematic intricacies.

10. Stein wrote in the Preface to the first volume of lectures given at the 1988 Complex Systems Summer School for the Sante Fe Institute in New Mexico.

11. It may be noted that Stein smacks of a positivistic trend towards theology. See http://www.wfu.edu/~petrejh4/HISTORYchaos.htm#ff4. Further, Goethe's statement, "We are all doing it; very few of us understand what we are doing" can point to chaos in human life and theology.

12. Jules Henri Poincare, *Science and Method* (New York: Dover, 1952).

13. For this section I am indebted to http://www.wfu.edu/~petrejh4/HISTORYchaos.htm. It may be noted that the arrival of computers (with its ability to visualise phases and points) has enormously helped the growth of chaos theory.

14. I. Peterson, *Newton's Clock: Chaos in the Solar System* (New York: MacMillan, 1993).

15. http://www.wfu.edu/~petrejh4/HISTORYchaos.htm#ff8.

16. See http://hyperion.advanced.org/12170/history/lorenz.html

17. Turbulance is the "graveyard of theories," since none of the known laws of physics can predict or explain turbulence. The theory of chaos tries to comprehend turbulence.

18. A. B. Cambel, *Applied Chaos Theory: A Paradigm for Complexity* (San Diego: Academic Press, Inc, 1993).

19. Stephen Kellert, *In the Wake of Chaos: Unpredictable Order in Synamical Systems* (Chicago: The University of Chicago Press, 1993), p. 3.

20. J. Petree, "History of Chaos Theory," http://www.wfu.edu/~petrejh4/HISTORYchaos.htm#ff15

21. http://www.wfu.edu/~petrejh4/HISTORYchaos.htm#ff16

22. For this section, I am indebted to http://www.wfu.edu/~petrejh4/HISTORYchaos.htm#ff20

23. http://www.fractalwisdom.com/FractalWisdom/fourattr.html#strange.

24. James Gleik, Chaos (London, 1988), p. 17.25 By the broadest definition, every motion more complicated than fixed (no motion) or periodic (cyclically repeating) motion is considered chaotic.

26. Lorenz also discovered the Lorenz Attractor, an area that pulls points towards itself. He did so during a 3D weather simulation.

27. While we are ordinarily confronted with objects of 1, 2 or 3 dimensions, fractals indicate dimensions which are fractions. The fractal of dimension 1.263 has more “roughness” and so it corresponds more closely to the real world. We know that in the real world there are no “perfect” squares, triangles or lines!

28. One way to think of fractals for a function f(x) is to consider x, f(x), f(f(x)), f(f(f(x))), f(f(f(f(x)))), etc. Fractals are related to chaos because they are complex systems that have definite properties.

29. Mandelbrot currently works at IBM’s Watson Research Center and is a professor at Yale University. He has been awarded the Barnard Medal for Meritorious Service to Science, the Franklin Medal, the Alexander von Humboldt Prize, the Nevada Medal, and the Steinmetz Medal for his works. It may be noted the one of the starting points of chaos theory is finding the exact distance between two points along a coastline. If we take into account all the contours, the exact distance works out to be infinity! A ridiculous idea!

30. Sardar and Abrams, *Introducing Chaos*, p. 32.

31. See Judy Petree, “History of Chaos Theory” in internet “Chaos Theory History.htm.” See also A. B. Cambel, *Applied Chaos Theory: A Paradigm for Complexity*, pp. 3-4.

32. Chaos is ubiquitous in nature, hidden in the most ordered and solid-seeming places.

33. So says Ian Stewart one of the leading theoreticians of chaos. See *Introducing Chaos*, p. 171.

34. Abinash Chandra Bose, “ The Hymn of Creation,” *Hymns from the Vedas: Original Text and English Translation with Introduction and Notes* (Bombay: Asia Publishing House, 1966), pp. 303-305.