Chaos and Complexity in Individual and Family Systems:

A Literature Review and Case Study

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Table of Contents

Abstract

Chaos and complexity are part of an emerging science of non-linear systems whose insights have important implications for counseling theory. This paper provides a brief introduction to several relevant discoveries and to the philosophical changes they suggest. Included is a review of literature that integrates chaos and complexity with the theory and practice of counseling, with emphasis on psychological change and crisis work. The affinities between complexity theory, humanistic psychology and structural family therapy are explored. A case study illustrates key ideas.

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Considering that a single neuron is a relatively simple switch, how does the presence of 10^{11} neurons linked together result in a human mind, rather than just a big box of switches? The new science of chaos and complexity attempts to answer this and similar questions by studying systems comprised of many discrete entities in interaction with one another. The relationships of ants within an anthill, of capital within an economy, and neurons within a brain all result in wholes greater than the sums of their parts. How these dynamic systems grow and change over time is a central focus of chaos and complexity theory.

Chaos theory was born when scientists began trying to understand the behavior of systems far from equilibrium. The hot and cold winds that swirl across the surface of our planet are one example. The air that makes up these currents is comprised of 21% free oxygen, one of the most reactive elements known to science. Deprived of our sun, the dynamo of heat transfer that drives our atmosphere would slow and stop, the plants would die, and the free oxygen would rapidly rust out. Without this life-giving and dynamic "chaos," we would soon find ourselves uncomfortably close to thermal and chemical equilibrium. Our moon is in such a state. It is a much more predictable world than our own, but it is also quite dead.

The study of complexity examines systems on the edge between order and chaos, where the magic that makes wholes emerge from parts seems to occur. Complex systems can be found in every field. All share certain qualities and characteristics with one another, regardless of the particular entities on which the whole resides. According to the principle of universality, "The underlying properties and behaviors of all complex systems are essentially the same" (Fichter, Baedke, & Frangoes, 2006, p. 101). The patterns of relationships among the ants brings about the intricately organized structures of the anthill, just as the patterns of relationships among neurons result in a living brain. Complexity theory provides a language for understanding and describing these phenomena across disciplines. If we know something about the workings of anthills in that language, then there should be a corresponding pattern within individuals, families, cultures, economies, brains, and so on.

This paper explores a few of the implications of chaos and complexity for the theory and practice of counseling. Since the early 1990s, a diverse group of counseling theorists have been attempting to integrate the insights of this new science with existing theory and clinical experience. Much of the work to date has focused on developing a more comprehensive theory of psychological change. Understanding how change occurs in complex systems like our clients is key to choosing the best intervention. After all, counselors are agents of change; clients come to us because they desire something to be different.

The new science also poses important philosophical questions for our field. What does complexity theory suggest can or will be known about human psychology? What does chaos and complexity theory state that we cannot know about human psychology, behavior, and interactions? The second question is perhaps most vital. Knowing what we cannot know constrains the field of inquiry and focuses our energies towards our desired end: an understanding of the human psyche that is useful in bringing about conditions favorable for healing.

A Brief Introduction to Chaos and Complexity

In the early 1960s, Edward Lorenz, a mathematician and meteorologist, was trying to predict the weather. Towards that end, he developed a set of non-linear equations for modeling atmospheric conditions and secured time on a computer. This new device was capable of making accurate calculations at speeds that were unimaginable prior to its invention. The results of the computations would create a model of the behavior of weather patterns across time. One could enter any initial conditions, such as temperature, barometric pressure, and wind speed, and the computer would then print out the conditions that followed a moment later. These results could be fed back into the same equations to calculate the next moment, and the next. Via this iterative process, Lorenz hoped to predict weather conditions a week, month, or a year later.

This is not an unusual way of thinking about the world, and has some important historical foundations in science. Newton's physics describes the movement of bodies of matter as lawful, deterministic, and reversible. One need only know two things to calculate the entire future or past behavior of a system of matter: the right equations, and the precise position and velocity of all the bodies at any single moment in time. Henri Bergson, a 19th century philosopher and advocate for the Newtonian view, summed up the implications this way:

> The general law then deduces from this "initial state" the series of states the system passes through as time progresses, just as logic deduces a conclusion from basic premises. The remarkable feature is that once the forces are known, any single state is sufficient to define the system completely, not only its future but also its past (in Prigogine & Stengers, 1984, p. 60).

This idea is central to the philosophy of mainstream science and has been so since its birth in Newton's time. It forms the basis for a metaphorical view of the universe as a clockwork, a precision machine with a completely determined future and past (Capra, 1996). In the field of counseling, the Newtonian view asserts that, given a complete view of initial conditions in a single moment in 1746, we could have predicted the increase in eating disorders in the 1990s, and even who would have one and who would not. Clients, after all, are just bodies in motion made of smaller bodies in motion. On a more practical scale, this idea suggests that if we understand enough about our client in our first interview, we can use the correct psychological theory to predict what they will do in the future, what their experience was in the past, and naturally how best to intervene to "cure" them in the present.

Lorenz' experiment in modeling atmospheres therefore had sound footing in the scientific philosophy of his day. Perhaps its only point of disagreement was that it attempted to use non-linear equations as a model for understanding the behavior of the atmosphere. What is the difference between linear and non-linear? A linear relationship is one in which an increase in input results in a corresponding relative increase in output. A simple and concise example is "the more the merrier." As the population increases, so does the corresponding merriment. On a graph this relationship appears as a straight line moving from its origin at zero diagonally upwards towards infinity. Given one of the values, we can easily determine its complement. A population of 3 yields a merriment level of 3. A population of 9,462 yields a merriment level of 9,462.

A non-linear relationship is much more complex. Goerner (1996) gives the example of the headache system, in which "Taking ten aspirin does not decrease a headache ten times as much as taking one aspirin" (p. 5). If we graph the results of such an experiment, we see that one aspirin has a certain level of effect. Taking two aspirin works better, but is not precisely equivalent to the effect of a single aspirin times two. Nineteen aspirin has a level of effect that is much lower than one would imagine from the first two, and 9,462 aspirin kills the patient. The curve we are left with is decidedly non-linear.

Newton's linear equations can be used to calculate the gravitational interaction of any two bodies, but adding a third makes the equations unsolvable. In the early 20th century, the French physicist Henri Poincare attempted to address this problem by factoring in the non-linear feedback caused by the third body. His calculations suggested that in certain orbits, the presence of a third body could cause planets to zig-zag across the heavens in strange ways, and even make dramatic and permanent changes in course. Poincare stated that his results were "so bizarre that I cannot bear to contemplate them" (Briggs, 1992, p. 52), and abandoned his work.

Non-linear calculations are extremely difficult and time consuming, especially when done by hand, and often yield results that seem strange and unpredictable. The conventional solution to this problem was to ignore it. For much of the 19th and 20th centuries, non-linear relationships in nature were "linearized" in order to make science conform to the popular belief in an ordered, clockwork universe (Capra, 1996). In the late 20th century, astronomers found clear evidence for the behavior Poincare described in the erratic tumbling of Saturn's moon Hyperion, and in previously inexplicable gaps in the asteroid belt (Briggs, 1992). A few members of the scientific community began to acknowledge that while linear equations were effective at modeling some systems – the movement of billiard balls on a pool table, for example – many others could not be solved so easily. Guessing how a human test subject would respond to complex stimuli was one such problem. Predicting the movement of air and moisture through our atmosphere was another.

Lorenz's computerized model turned out to be quite popular. Fellow scientists made bets about the weather, and often dropped by to see how the patterns had progressed (Gleick, 1987). Although it was much simpler than a real atmosphere, Lorenz's model displayed many of the same characteristics. Seasons, fronts, and even cyclones would move though the simulated world just as real weather patterns move across ours. While general trends were loosely predictable, it was impossible to tell exactly what would happen next without using the simulation itself to find out.

One day, as often happens just prior to a scientific breakthrough, something broke. Lorenz's simulation was cut short by a computer error. Because his algorithm used an iterative equation, all that was required to continue was to enter in the values from an earlier point before the previous simulation went bad. The computer could then crank out the next moment's conditions, use these to calculate the following moment, on and on ad infinitum. Lorenz happened to notice that the results of the second run followed the results of the good data from the first run for a short time before veering off to dramatically different conclusions. This is not supposed to happen: why should the outcome of two different simulations of the lawful interactions of particles be different?

Lorenz realized that he'd rounded off some of the numbers while entering them in for the second run of calculations. For example, where the computer had been using .306123 in the first run, he'd entered the value as .306 for the second. He had chosen to round the numbers because he assumed that such a small difference in starting conditions wouldn't make a difference in the long run. The results of this and later simulations proved otherwise.

Lorenz discovered that non-linear systems are so sensitive to initial conditions that accurate and precise long-term prediction is impossible. In other words, “Slightly vague knowledge of the past leads to extremely vague knowledge of the future” (Goertzel in Chamberlain, 1998, p. 84). Any variance in the starting data, no matter how minor, will have dramatic effects on the outcomes of the model over time. When Lorenz presented his work at a conference a colleague remarked that the flap of a butterfly's wings in Beijing today could cause a storm in New York next month (Capra, 1996, p. 134), and thus the idea of the butterfly effect was born. It is not that the butterfly single-handedly causes the storm, but that without taking into account the butterfly's wing at time 0, we cannot predict the storm a month later; the system is that sensitive. Ward (2001) put it this way:

> ...any model that attempted to show what could happen would have to take in an impossible amount of detail. It would have to include large movements of air such as the jet stream, the trade winds, the Sirocco and Mistral, as well as the exhalations of everything that breathes, the draughts caused by slamming a door and eddies caused by butterflies flapping their wings (p. 73).

Sensitive dependence on initial conditions can be demonstrated mathematically. X-next is a simple equation originally developed as a simplistic model of population change. X-next = rX(1-X). X is the population, r is the rate of growth, and (1-X) the rate of death. After running the equation once we take the result and feed it back in as the next X value, take that result and use it for the next X value, on and on for the desired number of iterations. The X value after each iteration represents the population at that moment in time.

When we plot the results of the X-next equation on a graph we can see a visual representation of sensitive dependence on initial conditions. The image shown displays two plots superimposed on top of one another, one with the initial r value of 4, and the second with an r value of 4.000001, a difference of 1 billionth. At first the two plots look identical (the lines are traced on top of one another), until they begin to diverge around the 20th iteration of the equation.

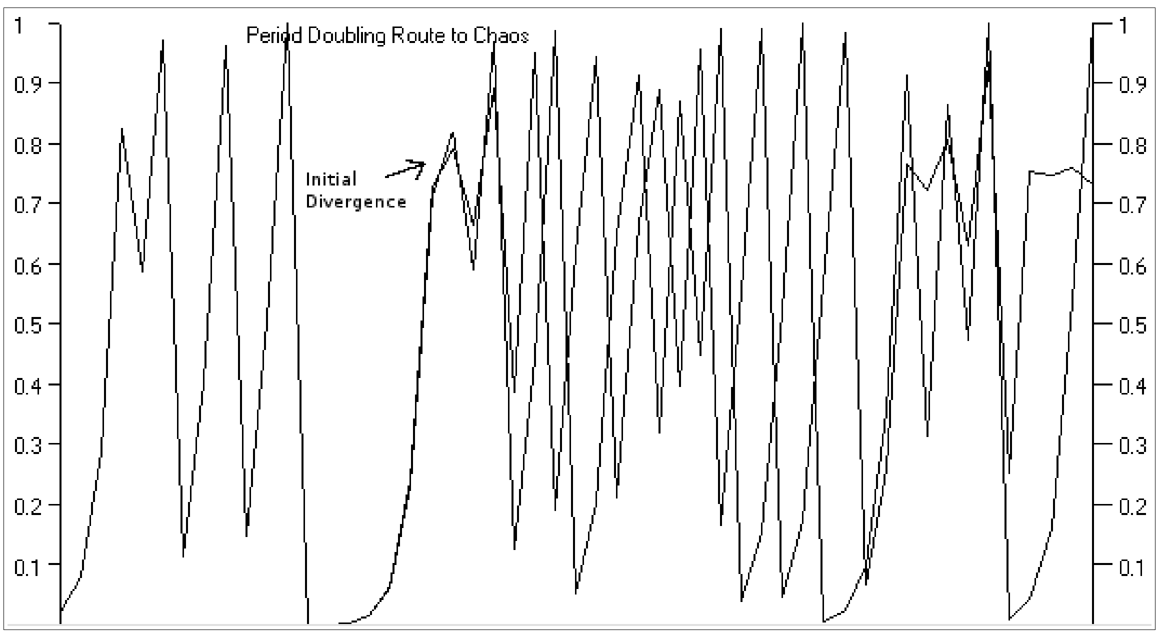

Illustration 1: Sensitive dependence on initial conditions in X-next. Image produced with X-Next software (Baedke & Fichter, 2002)

After the initial divergence, the two plots follow a generally similar pattern for a short while until eventually there is no discernible relationship between the two. It must be emphasized that the difference between the initial conditions of the two models is precisely one billionth, an extremely small quantity. Yet after only 50 iterations (units of time), the results of the two models bear no resemblance to one another.

Sensitive dependence on initial conditions has profound implications for all branches of science, including psychological theory. If a variance of one billionth is enough to dramatically change outcomes over time in even a simple model like X-next, what can we as psychologists hope to be able to precisely predict about non-linear systems like our clients in the real world? Butz et al. (1997) note that sensitive dependence calls into question the predictive capability of psychological research and psychometrics as well.

> ...[W]hen we are dealing with systems that are sensitive to initial conditions (e.g. chaotic), traditional measurement error is devastating in its impact on our ability to predict the future. Keep in mind the butterfly effect, ...where one to three decimals may have influential effects on the direction a system will take. Imagine how much worse off we are when our measurement error may equal 20% of the variance! (p. 226).

Stuart Kauffman (1995), a pioneer in the field of chaos theory as applied to biological systems, cites another reason why prediction breaks down in the face of real world, non-linear conditions. The theory of computation is a branch of computer science that looks at what problems can and cannot be solved using computers, even hypothetical computers that are so powerful they can only be imagined. It concerns the use of algorithms, which are a series of programmatic steps a computer uses to solve a problem. It would be wonderful if we could create an algorithm – in this case one based on the laws of nature – that we could then use to calculate what will occur in the future. Such an algorithm would give us a short cut to knowledge of an outcome in the same way Newton's laws of motion work with artillery. Knowing only the speed and direction of the shell, resistance of the air, and gravity, we can efficiently calculate where the shell will strike. There is no need to run the thousands of calculations necessary to determine every point the shell travels through after it is fired and before it hits the target. This type of algorithm is compressible because it can be used to calculate an outcome at a later time without requiring us to calculate each of the steps in between. Kauffman (1995) points out that compressible algorithms are in the minority.

> The theory of computation is replete with deep theorems. Among the most beautiful are those showing that, in most cases by far, there exists no shorter means of predicting what an algorithm will do than to simply execute it, observing the succession of actions and states as they unfold. The algorithm itself is its own shortest description. It is, in the jargon of the field, incompressible (p.22).

Kauffman suggests that non-equilibrium complex systems, like our clients and our world, may also be "incompressible." The implications are that if one were to design a computer program to determine the future of our world, that program would have to be no less complex and detailed than our world itself. Every complex system on our planet is sensitive dependent on all the others. The butterfly's wing changes the weather, the weather changes the client, the client changes the family, the family changes the society, society changes the economy, etc. We find ourselves in a world so interdependent, non-linear, and sensitively dependent on initial conditions that the only way to know what will happen in the future is to wait and see.

These conclusions complicate the work of any discipline that attempts to deal with non-linear or complex systems. Science is supposed to predict the natural world, thereby giving us control over it. At the very core of empiricism and the scientific method is the necessity of testing a theory for its accuracy by comparing its predictions against experimental observation. This is why physics is often described as a “hard” science, while psychology and the social sciences are considered “soft” and suffer from “physics envy.”

Behaviorism was an attempt to make psychology a “hard” science by utilizing only empirical data to make verifiable predictions about human behavior. The difficulty in doing so successfully lies in quantifying the human mind and experience in such a way as to make precise prediction possible. Behaviorism's answer to this was to deny the existence of complex confounding variables that defy empirical measurement, such as “mind” or “culture.” Strictly empirical models of psychology have never been able to predict complex human behaviors, and are often criticized as overly reductionistic. “Essentially, empiricism's dilemma for psychology is that it provides an extraordinarily effective way of understanding the world by pretending that we do not exist” (Butz et al., 1997, p. 36).

If chaos and complexity prove that prediction in non-linear dynamic systems is impossible, where does that leave us as counselors? One could easily imagine from the ideas put forth so far that the study of chaos and complexity tells us only what cannot be known. This is one of the major criticisms of this new branch of science, one that it is still in the process of being answered by its adherents. As Ward (2002), a dynamical cognitive scientist at M.I.T. put it, “That the brain is a non-linear dynamical system seems beyond dispute. The question is whether saying so enhances our understanding” (p. 237).

Applications of Chaos and Complexity Theory to Counseling

Although sensitive dependence on initial conditions states that precise prediction is impossible, this does not rule out the possibility of recognizing patterns and having some confidence about their general drift. No scientist can state with certainty what the temperature will be in Central Virginia on a given day next July, but we all know with some confidence that it will likely be warmer than it was the previous January. Chaos and complexity theory suggests that what can be known about a client by a clinician is very similar: We cannot know precisely what the client will do at any given moment, but we can have a general idea of his patterns and tendencies and their boundaries. We can know with confidence that our clients cannot fly, walk through walls, or live without oxygen or food. But within these human constraints exist more possibilities than we can possibly imagine. "There are boundaries to the behavior, but within those boundaries exist infinite variations... Chaos is a science of pattern, not predictability" (Butz et al., 1997, p. 70).

For example, we can know that 'music' will always consist of audible frequencies between 20hz and 20khz played across a span of time. But within those constraints there exist an infinite number of permutations. Most can be loosely but reliably classified into general categories like jazz, classical, and rock and roll. While there is no formulaic test for proving definitively that a piece of music is jazz, most people know it when they hear it. And even within the subcategory of music called jazz there are effectively infinite possibilities.

Similarly, clinicians have learned to agree on and classify general patterns of pathology in the minds of human beings, even though no perfect criteria exist to prove a client has a particular mental disorder. A novice therapist may not immediately recognize a client as "borderline," but experienced counselors will "know it when they see it." These patterns grant clinicians a degree of general predictability about the clients and families they work with. A Schizoid patient is unlikely to host a Tupperware party. He is "more likely to choose solitary activities" (American Psychiatric Association. Diagnostic and statistical manual of mental disorders (IV-TR), 2000, p. 697). While we cannot know precisely what those activities will be, we can know the general drift of the pattern. In the language of non-linear dynamics, such a system is said to be following a "strange attractor."

The idea of attractors came about when scientists developed visual representations of the mathematical outcomes of non-linear equations, called "phase portraits." The output of chaotic functions seemed unpredictable when viewed as a list of numbers on a page. But when scientists plotted the results graphically in phase space – "a space in which the axes are the variables that describe the system's states" (Ward, 2002, p. 208) – distinct patterns began to emerge. The results moved around their region of phase space like iron filings subject to the forces of magnets, and thus the idea of an "attractor" was born.

There are three general categories of attractors that systems fit into. The first is called a point attractor. Imagine a penny spiraling down a large funnel and you have a picture of a system moving towards a fixed point. Once the penny reaches the bottom of the funnel, and thus reaches equilibrium with gravity, the system stops changing. The penny's path towards its conclusion at the bottom of the funnel describes the movement of a system with a point attractor. A limit cycle or periodic attractor is more like a pendulum placed in a vacuum. In the phase portrait the results oscillate back and forth between definitive values, and the system repeats itself ad infinitum. At a certain scale of measurement the tides, phases of the moon, and orbits of the planets can all be described as following periodic attractors.

The third type is called a strange attractor. A strange attractor causes the plot to move around a region of phase space without ever exactly repeating itself while still following a recognizable pattern (Ward, 2002). The equation Lorenz used to model the atmosphere is a popular example. The numeric output of the equation that creates this attractor is chaotic and unpredictable, yet one can clearly see that it makes a distinct pattern when portrayed in phase space. A fountain or waterfall is another example of a strange attractor. At each moment in time the shape of the water is unique, yet a distinct pattern that persists across time is recognizable in the turbulence. “No man ever steps in the same river twice, for it's not the same river and he's not the same man” (Heraclitus, n.d.).

Illustration 2: Lorenz Attractor. Image by Daniel Schwen, Georg-August-Universität Göttingen

Fichter et al. (2006) note that as dynamic systems change over time, they can transition back and forth through the various attractor states depending on the amount of energy flowing through the system. A system can begin subject to a point attractor, change into a periodic attractor, transition into a strange attractor and then back again. The behavior is very similar to the way water changes states based on temperature. Such changes occur not only within these esoteric mathematical equations, but in "real life" dynamic complex systems as well.

Imagine water in a stream flowing past a stone on a day in which it is beginning to rain (Presbury, Echterling, & McKee, 2008). When the water is moving slowly, it slips past without much resistance. The energy is flowing smoothly downstream, and the system can be described as being subject to a point attractor. As the flow of the stream increases due to the rainfall, small whirlpools form around the rock. These vortices maintain their shape with the exception of mild oscillations, and the system can now be described as being in a periodic attractor. As the flow of water continues to increase, the whirlpools grow in size until suddenly the water begins breaking around the rock. This chaotic turbulence follows a strange attractor.

Briggs and Peat (in Presbury et al., 2008) were early Chaoticians who began to use the behavior of such systems as metaphors for the human experience. They proposed that we imagine the stream moving smoothly around the stone as a metaphor for optimum mental health. As the energy in the system increases, it forms small whirlpools around the rocks. This can be thought of as "going around in circles," an apt metaphor for the experience of one who is perseverating on a mental problem. As the energy increases still further, turbulence forms and the system reaches a crisis point in which the individual can see no order or sense in his experience. Such a system could be described as "chaotic" (in the conventional sense of the term), or in the case of human beings, extremely anxious or disorganized, a crisis. It is in just such a state of anxiety that many clients seek counseling.

A transition between two attractor states, called a bifurcation, occurs suddenly when the system reaches a critical point. Water freezing as the temperature drops below 32 degrees Fahrenheit, the formation of convection currents in heated liquids, and a horse shifting from a canter to a gallop are all examples of bifurcations. Each dramatic shift is a result of gradual changes in the energy level of the system in question. This paradigm of change differs greatly from the clockworks metaphor of classical, Newtonian thinking. Instead of happening slowly and consistently, change is shown to be non-linear and rapid in complex systems. Even though the increase in energy flow through the system may be smooth and consistent, the system's response is not.

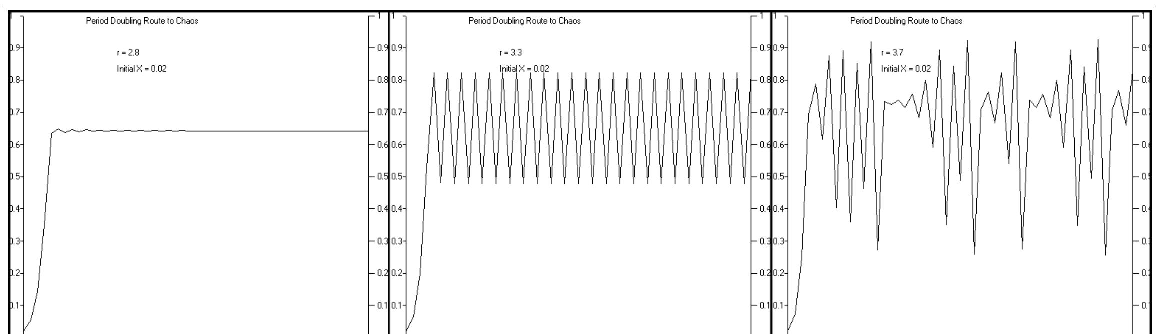

Illustration 3: Point, periodic, and strange attractors from the X-next equation. Image produced with X-Next software (Baedke & Fichter, 2002)

The results of the X-next equation mentioned earlier demonstrate this process of change. The r value represents the level of energy in the system and determines which attractor state the results fall into (Fichter et al. 2006). Values of r between 1 and 3 generate results that fluctuate for a while and then attenuate to a single steady value, following a point attractor. The example shown above uses the value 2.8, but 2.9 or 2.7 look very similar, with only a slight difference in the final value of X. As r is increased past 3, the system suddenly bifurcates into a periodic attractor, where the results continually bounce between two fixed values. The example above uses an r value of 3.3, but 3.2 and 3.4 look about the same, the difference being in the height of the peaks and depths of the valleys. Increasing r past 3.57 causes the system to bifurcate again into a strange attractor, resulting in chaotic fluctuations of the sort that demonstrate sensitive dependence on initial conditions. Results using an r value of 3.7 are given as an example in the illustration above. 3.71 creates a completely different pattern with very little in common with 3.7, as does 3.69.

The "bifurcation" diagram below is another way of visually describing how the system changes as its energy level, represented by the r value, increases. Each point describes a final population outcome of X at the corresponding value of r. The single line portion at the left describes a point attractor. That line splits into two and then four as the system begins to follow a periodic attractor. The dark shading represents the area wherein the system begins to behave chaotically, following a strange attractor. In that area the final value of X is unpredictable, and varies dramatically based on infinitesimal variations in initial conditions.

Fichter et al. (2006) suggest that the behavior of X-next may model how change occurs in all complex systems. Within the realm of point and periodic attractors, systems behave with linear predictability. Our solar system is at such an energy level (with the exception of Hyperion and other highly charged oddities), and thus Newton's laws can be used to effectively predict the movements of the planets and most of their satellites. But living systems exist on the edge of chaos, within the shaded area of the X-next bifurcation diagram. Simple models of cause and effect break down when the energy level within a

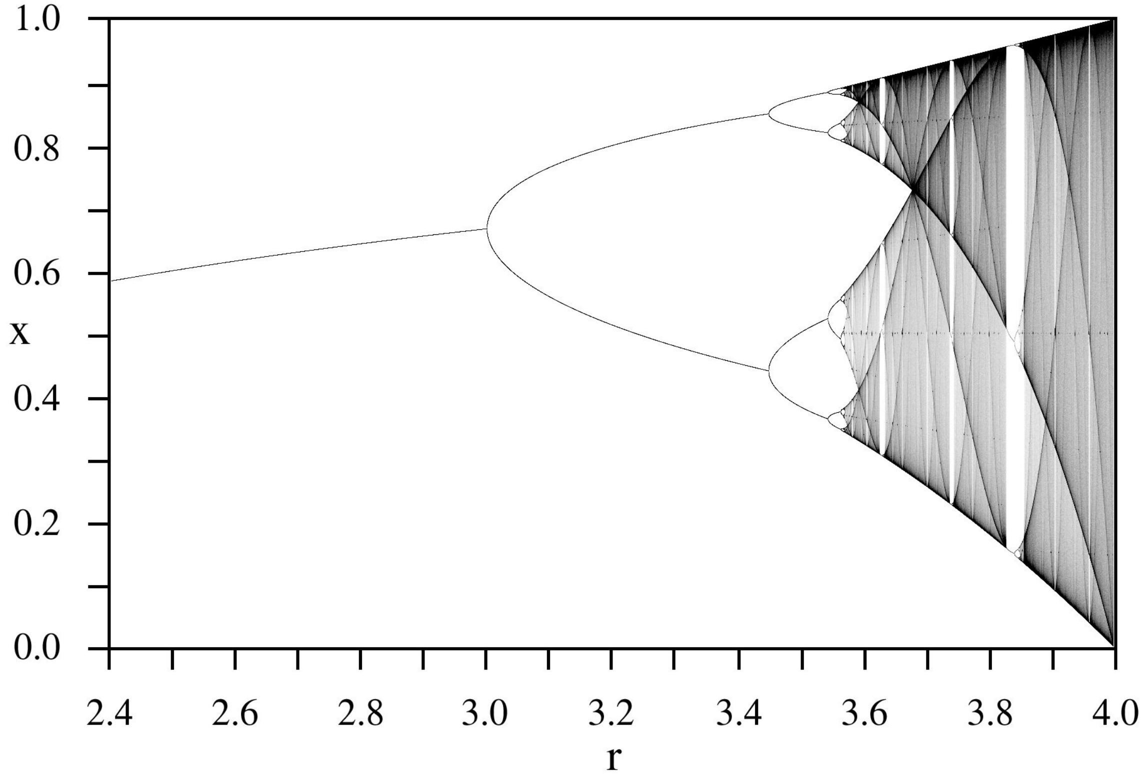

Illustration 4: X-next bifurcation diagram. Public domain image courtesy of WikiCommons.

system causes it to bifurcate into a strange attractor and the resulting behavior becomes non-linear. Fluid dynamics is a fairly simple science when the energy level is low, but as soon as turbulence begins the job becomes vastly more complex.

The principle of universality suggests that if change occurs as bifurcations between these three attractor states in X-next, flowing streams, and other non-linear dynamic systems, then it is worth looking for a similar manifestation of change in the counseling room. Counselors can benefit from a deeper understanding of this process. Towards that end chaos and complexity theorists in the field of psychology have been applying this paradigm of change to the practice of family and individual counseling.

Chaos in Family Conflict Regulation

Proskauer & Butz (1996) use the behavior of the X-next equation as a model for the role of feedback in family conflict regulation. Using the X value as the level of overt conflict and r as the propagation rate of conflict, they relate the behavior of X-next at different r values to common patterns observed by family therapists. In this metaphorical view, the movements of the plotted results represent feedback, both positive and negative, on the level of conflict in the family.

The idea of feedback originated in the theory of cybernetics, and was used to describe and model how a system regulates itself. Positive and negative, when used to describe feedback, have nothing to do with the connotations they have in the common usage. Negative feedback refers to a communication that limits or restricts change, thereby maintaining the system at a steady state. Positive feedback promotes change or transformation. Both can be bad or good depending on the context and what is called for in a given situation.

Becvar and Becvar (2006) use the workings of a thermostat to describe feedback. When the temperature falls below a certain range, the thermostat activates the furnace. The transmission of the information that the house is colder than the lower limit and the furnaces activation combined is an example of positive feedback. When the temperature reaches the desired level, the thermostat gives negative feedback that stops the process of heating, thereby maintaining the desired temperature.

While all living families are technically far from equilibrium and therefore exist biologically in the realm of strange attractors, their subsystems may follow any type of attractor. Proskauer and Butz's (1996) paper focuses on the subsystem of family conflict regulation and the feedback processes that occur within it. They attempt to relate these patterns to the different attractor states of X-next and to the process of change and growth in family therapy.

Proskauer and Butz (1996) describe states corresponding to a point attractor as 'stabilizing.' Feedback within the family is primarily negative and tends to bring the level of conflict down to an acceptable level. Being in such an attractor state confers a level of steadiness and security that is beneficial. However, too rigid adherence to this point attractor puts the family at risk for boredom or excessive conventionality.

When the family's conflict regulation subsystem is following a periodic attractor they experience repeating patterns of stimulation and tension release, and are operating with a mixture of positive and negative feedback. A healthy family experiences this as periodic fighting that allows for the creation of minor drama and release of tension. When taken to a dysfunctional extreme it results in repeating quarrels or violence followed by periods of calm, continuing on and on and without resolution. Pathological families stuck in a periodic attractor suffer from high rates of delinquency and addiction (Proskauer & Butz, 1996).

Families whose conflict regulation patterns are following a strange or chaotic attractor are in crisis. In such a condition there is very little predictability and security, and the family is extremely sensitive to perturbations from within and without. They have the possibility for transformation and creativity, but risk disorientation and despair. This is the state in which a breakthrough or second order change is most likely to occur, and it is therefore necessary for all healthy families to experience it at least some of the time. But families that persist in a state of chaos are extremely disorganized and suffer from unpredictable outbursts of conflict or violence (Proskauer & Butz, 1996).

Because it is a dynamic non-linear system, the family is never static, and neither are its individual members or its surround. In order to survive, the family system must be able to cope with changes and maintain adequate stability while simultaneously allowing for the possibility of transformation. “Even the stabilizing pattern, seemingly the most adaptive, can lead to shallow conventionality and poor tolerance for novelty if it is fixed and unvarying, admitting of no adjustment nor potential for transformation” (Proskauer & Butz, 1996, p. 199). According to this model of conflict regulation, a healthy family regulates conflict by changing attractor states as needed and maintaining an adaptive and dynamic balance. As Abraham, Abraham, and Shaw point out, “Because biopsychological systems bifurcate, it is likely that all types of organization, typified by point, periodic, and chaotic attractors, will represent both desirable and undesirable and both normal and abnormal conditions” (in Krippner, 1994, p. 55). A healthy family responds appropriately to growth, change and death of individual members, as well as to crisis or disasters in the surround.

Proskauer and Butz (1996) give the example of a family system in which one or more of the children are coming of age. The adolescent child acts out, exerting destabilizing positive feedback on the family system in order to secure his or her independence. Parents then try to dampen these oscillations with negative feedback, often by limiting the adolescent's activities, in an attempt to bring the system back to the old dynamic stability. The combination of the two conflicting feedback processes puts the system into a periodic attractor.

Dysfunction occurs if the family system is unable to tolerate the transformation of its relationship to the adolescent child and opts instead to cling to an outdated point attractor. Instead of renegotiating its boundaries, the family devotes more and more energy in the form of negative feedback to an attempt to return to the old stability, "the way things used to be," before the child reached adolescence. The child, of course, responds in kind. The appropriate counseling intervention destabilizes, or allows the system to destabilize itself, and then encourages appropriate renegotiation of the child's independence.

In order to maintain the dynamic stability we call "health," a family must allow itself to move from a point attractor, through a periodic attractor, and into the realm of chaos where transformation can occur. Only after this transformation can the family enjoy the stability of a new and more adaptive point attractor. Security can only be won through the family's willingness to sacrifice it.

Clinical Change as Understood in the Context of Clients as Non-Linear Systems

The study of chaos and complexity cuts across all disciplines because of the principle of universality: all complex systems share similar characteristics and patterns of behavior (Ward, 2001). It is therefore useful to "mine" observations about change from other fields for use in our own. There is a strong debate in paleontology as to whether the evolution of earth's species occurs gradually over time or during brief periods of rapid change. Until recently, the prevailing belief was that speciation occurred in a linear fashion, and that the longer two populations were separated the more their genetic codes diverged. Often associated with this view was the idea that species were evolving towards a more and more perfect ideal, humanity being at the current apex of that progression.

Eldredge and Gould (1972) called into question this belief in gradualism based on evidence in the fossil record that indicated change was more often explosive, sometimes described as “adaptive radiation.” Species would appear and persist with relatively little change for long periods of time, and then suddenly die out. New species would arrive and establish themselves very quickly. Intermediate forms between new species and their presumed ancestors were extremely difficult to find in the fossil record.

This observation formed the basis for Eldredge and Gould's (1972) theory of “punctuated equilibria,” which states that evolution occurs in rapid shifts followed by long periods of stability during which little change occurs. This model accounts for the puzzling lack of transitional species, or “missing links,” in the fossil record by positing that changes occur on a timescale that is extremely brief relative to geologic time. If a new species takes only a thousand years to diverge from its parent species, then that period of transition is unlikely to get much representation in the fossil record. Although the debate continues among biologists, this non-linear view of progress seems to do a better job of explaining our observations about change in evolution.

Chaos and complexity theory suggests that change in individuals or families occurs in a similar fashion: periods of stability followed by relatively rapid changes in organization – a bifurcation. In relationships these events are often described as turning points. Examples of turning points experienced by couples include marriage, birth of a child, saying “I love you,” and becoming sexually intimate. Yerby, Buerkel-Rothfuss and Bochner put it this way: “Turning points are experienced either as breakthroughs, after which the relationship soars to higher levels of commitment, or as breakdowns, after which the relationship falls apart” (in Weigel & Murray, 2000, p. 433).

In chaos theory, rapid shifts like these are often described as catastrophes or avalanches, the result of self-organized criticality. While the terms 'chaos,' 'catastrophe,' 'avalanche,' and 'criticality' all possess negative connotations in the common usage, the phenomena they describe in the context of complexity theory can be positive. Self-organized criticality refers to the tendency of complex systems to move towards greater instability, a process that results in growth. Per Bak (1996) developed the metaphor of a sand pile on which grains of sand are dropped one at a time from a single location above, forming a cone-shaped hill of sand. As the pile grows steeper it organizes itself towards greater criticality, until finally the angle of repose is exceeded and the pile collapses in an avalanche. This results in a wider base on which to build higher peaks that in turn eventually collapse and continue the process. It is impossible to predict which particle of sand will set off the avalanche and thus when it will occur, but it is possible to predict the general trend.

Each avalanche forms a punctuated moment of change in what can be seen on a broader time scale as a gradual process of growth (Fichter et al. 2006). This model is very similar to the concept of punctuated equilibria, and may shed some light on how change can seem gradual when viewed on a scale of eons and dramatic when viewed on a scale of hundreds of years. Such a model of change can be useful in expanding existing theories of learning and human development. For example, if we were to plot the maturation of a human being on a graph with one point per year for 20 years, the curve will represent a more or less gradual process with perhaps a hump around adolescence. But when we increase the resolution to one point per month, we can begin to see the dynamic process of learning occurring as many tiny breakthroughs and breakdowns following periods of relative stability. While the overall trend is positive, it consists of many jagged peaks and valleys. Such a view of human development as punctuated equilibria may have some compatibility with Erikson's (1997) model of psychosocial development and similarly non-linear stage-based models of growth.

While we cannot predict precisely when a change or avalanche will occur, we can have a general idea of the system's current potential for change. Koopmans (1998), using ideas developed by Prigogene and Stengers, described it this way:

> In near equilibrium conditions, structural changes are less likely to take place than in far from equilibrium conditions. In near equilibrium conditions, systems are typically unresponsive to fluctuations of an incidental nature, whereas in far from equilibrium conditions, high levels of fluctuation may be accompanied by a diversification of attractors (i.e., bifurcation) (p. 141).

The steeper the pile of sand, the more likely it is to experience a dramatic reorganization event in response to an outside perturbation. If the angle of the sand pile is shallow it is less likely to respond to interventions from the surround.

Complexity theory suggests that individual clients and families follow the same model of change as species, sand piles, and other complex phenomena. The farther the system is from equilibrium, the more likely it is to reorganize itself in response to outside interventions. In the strictest sense, all clients are far from equilibrium by virtue of the fact that they are alive. But that living range can be described as a continuum between relatively close and relatively far, making a useful metric for understanding a client's potential for change. We can loosely equate the variable “distance from equilibrium” to level of family or individual crisis. A system in crisis is relatively far from equilibrium, and more likely to respond to the therapist's interventions. A system that is not in crisis is less receptive to the possibility of reorganization, and is therefore less likely to respond to information coming from outside.

Understanding the level of crisis in the system is vital to crafting appropriate interventions. For example, an extremely rigid father figure who refuses to acknowledge problems within the family will be highly resistant and difficult to change. Similarly, a client classified as "pre-contemplative" in the stages of change model of addiction (Prochaska, Norcross, & DiClemente, 1994) is unlikely to respond to a therapist's exhortations to quit using drugs. Before change can occur in clients that are close to equilibrium, the therapist must first work to provoke some sort of crisis or dissatisfaction with the status quo. Only then is the client far enough from the previous stability and comfort for significant change to occur.

Implications for Counseling Families in Crisis

Butz et al. (1997) point out that the proper handling of family systems that are far from equilibrium depends on the therapist's ability to recognize the root causes of the crisis. In the case of natural disaster or other external interruption of the family's stability, soothing interventions designed to return the system to the previous adaptive stability are in order. In such situations, the family has been brought to a crisis point by outside forces, and not by its own internal processes. While significant and positive reorganization can still occur, it is not appropriate to try to maintain the crisis in an attempt to promote dramatic systemic change. The therapist has no indication that the old stability was dysfunctional, so the system more or less "returning to normal" is not likely to result in a negative outcome. Interventions designed to restore the family to the previous, functional level of adaptive stability, with an eye out to encouraging incidental breakthroughs, are therefore in order.

In situations wherein the family's own internal processes bring the system to a crisis point, it is important not to use too many soothing or stabilizing interventions. Attempts to calm a family in such a crisis amount to encouraging a return to the old dysfunctional attractor, and are therefore counterproductive. Such action drives the system from chaos, where reorganization and reinvention are possible, back into cyclic patterns of conflict and dysfunction, a periodic attractor. Instead, the therapist should attempt to maintain the family's level of arousal in order to keep them near the edge of chaos, but not too far past it. Significant insight and reorganization is most likely to occur in this realm, improving the possibility that the family will arrive at a more adaptive and healthy dynamic stability.

For example, a family in crisis because of external circumstances – i.e. the destruction of their home in a flood – calls for interventions designed to soothe and return the system to a relatively stable state. A family that is manifesting a self-organized crisis might present as “fed up” with one member's behavior, or describe an interaction leading up to the crisis as “the straw that broke the camel's back.” In such cases the family has itself manifested the crisis in a conscious or unconscious attempt to reorganize. The goal of therapy must be to help this family “through” the crisis to a new stability, not “back” to the way things were prior to the breakdown.

Echterling, Presbury, & McKee (2005) cite the Yerkes-Dodson Law as a metric for managing levels of arousal in clients or family systems. The Yerkes-Dodson Law states that efficiency of performance on any task, physical or mental, is related to the subject's level of emotional arousal. For example, a test taker in a state of extreme apathy will perform poorly, as will a test taker experiencing extreme anxiety. The ideal subject experiences enough anxiety to do her best, but not so much that it distracts from the task at hand. Echterling et al. (2005) recommend keeping clients in just such a zone of emotional arousal in order to maximize the effectiveness and efficiency of the therapeutic process.

Relationship to Existing Theory

The field of counseling has developed a variety of theoretical models to describe the nature of mental pathology and how best to treat it. Chaos and complexity theory calls into question certain founding assumptions of some of these models. For others it provides a context we can use to relate our observations about the human mind to non-linear phenomena across disciplines.

As discussed earlier, behaviorism was an attempt to apply linear models of cause and effect toward understanding human interactions with their world. Its foundations lie in the notions typified by Bergson's statement about the nature of the universe. Seen in its philosophical and historical context, behaviorism was a predictable adaptation of a paradigm that was effective in the realm of classical physics for use in the realm of psychology. Like classical physicists, behaviorists tended to ignore evidence of living systems behaving chaotically, dismissing factors like “mind” and “personality” as so much experimental noise.

Humanistic Psychology

Chamberlain (1998) notes that humanistic psychology developed out of a reaction to behaviorism, and asserted at least some of the conclusions now suggested by chaos and complexity theory:

> It is not surprising that a philosophy of human behavior which developed largely in reaction to the limitations of empirical models would propose that people are too complex to be adequately understood through classic forms of experimentation. ...from the framework of humanism, it is degrading and dehumanizing to equate people with machines or other non-dynamic entities (p. 80).

In a sense, chaos and complexity theory has a relationship to humanistic psychology that is similar to the relationship between behaviorism and the Newtonian model. Humanism was based on a set of assertions about the unique and unpredictable nature of life, but it lacked a rigorous foundation in the natural sciences. Chaos and complexity theory is a late arriving theoretical foundation for those assertions. It provides evidence for a shift in emphasis that Rogers and other founders of humanistic psychology took on faith. “While mainstream psychologists spoke of their goal as the understanding, prediction, and control of behavior, humanistic psychologists emphasized understanding, description, and enhancement” (Krippner, 1994, p. 52).

Further similarities between humanism and complexity theory can be found in theories of self-actualization. Speaking about the client's self motivated movement towards personal growth, Rogers (1961) stated:

> It shows itself in the tendency to reorganize his personality and his relationship to his life in ways which are regarded as more mature. Whether one calls it a growth tendency, a drive towards self-actualization, or a forward-moving directional tendency, it is the mainspring of life, and is, in the last analysis, the tendency upon which all psychotherapy depends. It is the urge which is evident in all organic and human life – the tendency to express and activate all the capacities of the organism... (p. 35).

Chamberlain (1998) noted that “These transitions to a 'self actualized state' often occur as 'leaps,' rather than a gradual accumulation of small changes” (p. 81). In other words, self-actualization occurs through a process of “punctuated equilibria.”

The tendency towards personal growth that Carl Rogers depended on in his theory and practice bears a strong resemblance to the phenomenon of self-organization in complex systems. "Self organization is the spontaneous emergence of new structures and new forms of behavior in open systems far from equilibrium, characterized by internal feedback loops and described mathematically by non-linear equations" (Capra, 1996, p. 85). "Without help from an outside agent, complex systems absorb and store energy up to a critical state where avalanches of chain reaction events spontaneously occur" (Fichter et al. 2006, p. 123). Self-organization has been demonstrated in contexts as diverse as anthills and computer programs. Kauffman's (1995) work on autocatalytic sets shows how, given the right conditions and materials, simple chemical compounds form bounded, self-maintaining structures. This tendency of compounds to self-organize is one of the competing explanations for the origin of life on earth.

Self-organization stands in violation of the second law of thermodynamics, which states that disorder increases over time as energy dissipates. The energy in a cup of hot tea will flow outward into the room until eventually it and the room are the same temperature. Our sun is emitting vast quantities of energy and will (after several bifurcations) eventually reach thermal equilibrium with the surrounding space. This process of order (the organization of the energy within the hot tea and the hot sun) decreasing over time is called entropy. Prigogine notes that classical thermodynamics "is essentially a theory of destruction of structure ... But in some way such a theory has to be completed by a theory of creation of structure" (in Minuchin & Fishman, 1981, p. 21).

We, as living things, tend to increase in order and complexity over time. A child, initially unable to speak or even care for itself, grows up to master a million subtleties of language, social interaction and knowledge. She participates as a member in a family that is evolving, that is a member of a culture that is itself evolving towards greater and greater complexity. In the end, we all die and the law of entropy is preserved. But during our brief time on the planet, we contribute to an order, a self-sustaining pattern of organization, that persists beyond a single lifetime.

Structural Family Therapy

Structural family therapy arose at the same time that key ideas in complexity theory were under development, and had access to bits and pieces of the new science as a theoretical foundation. Minuchin and Fishman (1981), describing Ilya Prigogine's work on systems far from equilibrium in *Family therapy techniques*, noted that:

> In a living system, fluctuations, occurring either internally or externally, take the system to a new structure.... When the fluctuation amplifies, the family may enter a crisis in which transformation results in a different level of functioning that makes coping possible (pp. 21-22).

This bears a strong resemblance to Per Bak's model of self-organized criticality, described earlier.

The process of promoting change in family systems depends on an ability to create intensity, to drive the system from an unhealthy equilibrium into a state where structural change is possible. Minuchin and Fishman devote a chapter of *Family Therapy Techniques* (1981) to methods for increasing intensity, noting that "...[A] therapist's intensity of message will need to vary according to what is being challenged. Sometimes simple communications are intense enough, whereas other situations require high-intensity crisis" (p. 117). In the language of chaos and complexity theory, the goal is to increase the energy flow in the system in order to promote the possibility of a bifurcation to a new attractor. The level of intensity called for depends on the family's relative distance from equilibrium.

For example, Minuchin and Fishman (1981) describe a family in which the identified patient Pauline has been prevented from properly individuating by her family's overly enmeshed boundaries. Minuchin begins by addressing the girl and ignoring her mother's attempts to answer his questions for her.

> Pauline says that she does not shake hands. The consultant [Minuchin] introduces himself to the mother, who shakes hands. Then Pauline says that she can shake hands with him also, which they do.
>
> Mother: I don't usually shake hands, and I think she took after me.
>
> Minuchin (to Pauline): How old are you?
>
> Pauline: Eleven.
>
> Minuchin: And you talk?
>
> Pauline: Yes.
>
> Minuchin: But your mommy talks for you sometimes?
>
> Pauline: Sometimes.
>
> Minuchin: Like just now?
>
> Pauline: Yes. (p. 124)

Minuchin continues to emphasize the family's tendency to answer for the daughter in the transactions that occur throughout the session. This technique for building intensity is called "repetition of isomorphic transactions." The goal is to highlight a particular dysfunctional attractor state as it is enacted in the consultation room, thereby increasing the flow of energy through that subsystem. This increased intensity is intended to bring about a bifurcation into the realm of chaos where reorganization can occur, and then on to a new and healthier point attractor.

In order to raise the energy to a level where a bifurcation can occur, the therapist must avoid the family's negative feedback processes that are designed to reduce intensity, avoid conflict, and maintain the dysfunctional status quo. He must resist “induction by other 'juicy themes' that the mother dangles in front of him” (p. 131), and ignore attempts to triangulate other family members into the conflict. Once the system is driven far from equilibrium and into realm of chaos the therapist can try to nudge it in a healthy direction. If successful, this particular type of pathological relational transaction will bifurcate to a more functional and healthy attractor.

Attractors, self-organized criticality, and change in family systems have thus far been described as if a family could be represented as following a single attractor. But the group of relationships that are collectively called a 'family' are as diverse as any ecosystem. It may be more useful to think of a family system as a dynamic topology of attractors, each with differing distances from equilibrium, and each one affecting other nearby attractors.

Seeing the family system in this light has important implications for family counselors. “When there are several attractors in the phase space, which one determines the ultimate behavior of the system depends on where the system starts, or on outside inputs to the system that might perturb it out of one attractor and into another” (Ward 2002, p. 208). According to this model, we therapists are the outside inputs that families hire to perturb them into healthier attractor states.

Case Study

The case study has been omitted from this abridged version. For the full version, contact the author at lightnin@bokonen.net.

Conclusion

As it stands today, the Newtonian model of the universe as clockwork is the dominant ideology with which we are all trained to understand our world. We think of doctors healing the sick and injured by repairing the patient's body in much the same way as a mechanic fixes a car. Psychologists and counselors diagnose and treat mental “dis-orders,” the implication being that we are experts in clock repair, trained to set right the various springs and balance wheels of the client's mind. Is it any wonder that so many families seeking therapy for the first time do so with the goal of getting the identified patient “fixed?”

The science of chaos and complexity shows us that such a model is insufficient to the task of explaining complex, non-linear phenomena, of which the human mind is but one example. With even the tiniest bit of scrutiny, the idea of the ordered, reversible, and clockwork universe breaks down. A doctor doesn't fix a patient's broken arm anymore than we “cure” a client of neurotic attachment. No one has the power to knit each cell and sinew together, or bathe the bones in the correct balance of nutrients to encourage a new bond. No physician can externally maintain more than a few of the millions of homeostatic rhythms that keep the patient alive. What *is* possible is to set bones and bind wounds in such a way that the body's own processes are given room to do the work of healing. The drive to grow and self organize is innate to all living systems, and not the product of an external force.

We as counselors also set bones and bind wounds. Although the process is very subtle, we can take no more responsibility for its success than can a doctor. We create relationships with our clients through which we try to address obstacles to their innate tendency towards growth and self-organization. If healing occurs, it is always beyond our ability to engineer it, and comes from the clients themselves.

Carl Rogers (1961) realized this a long time ago.

> ...in my early professional years I was asking the question, How can I treat, or cure, or change this person? Now I would phrase the question in this way: How can I provide a relationship which this person may use for his own personal growth? (p.32)

The second law of thermodynamics says that things fall apart; entropy is universal. We, like all living things, stand temporarily in defiance of that law. Given room and the necessary nutrients of mind and body, we fall together, for a little while.

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