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The Self as a Dynamical System

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Sciences of chaos and complexity theory reveal new universalities in nature applicable to psychology. This article proposes that the psychic structure long known as the "self" is best conceptualized as an open, complex, dynamical system. With chaos at the core of development, healthy selves self-organize and evolve to the edge of chaos, where they are capable of flexible reorganization in response to unpredictable social and environmental contingencies. The boundaries of the self are dynamically fluid and ever changing, mediated by complex, recursive, feedback loops existing simultaneously at physical, social, cultural, and historical levels. Because of multiplicity and multistability, wherein multiple descriptions and states are simultaneously possible, it is suggested that the self be considered dynamically as a process-structure that is fractally organized.

KEY WORDS: self; dynamical system; process-structure; self-organization; edge of chaos

THE SELF AS A DYNAMICAL SYSTEM

"Who am I?" At some point, this question entices and perhaps haunts each person. It is a simple query with an endless answer. In the psychoanalytic literature, there have been a multiplicity of approaches to theories of self. They highlight various aspects of the self, including its structure, function and representation. A brief synopsis of major theoretical developments follows, in order to provide a context for the introduction of dynamical systems theory.

In Freud's tripartate model of psyche (1923/1955), the self was conceptualized as a container of unconscious forces objectively discernable by others. This was a structural model by which the three components of

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the psyche, ego, id, and superego, were set during early development. A reductionistic enterprise, psychoanalysis correlated the drive content of psychological and behavioral symptoms with specific phases of psychosexual development. Patients were analyzed in a vacuum, as if functioning wholly independent of immediate factors, situations and relationships, including the therapist-patient dyad.

Several problems existed with this perspective. There was no general theory of character or healthy functioning. The model could not account for aspects of symptoms not traceable to specific drive conflicts, such as the intense attention and capability for hard work of the obsessive-compulsive. Additionally, theory confounded current patient function and attitudes with developmental origins, a shortcoming originally identified by Rieff (1959).

Early ego psychologists, such as Hartmann (1958), suggested sources of psychological structures independent from instinctual drives and drive conflicts. These theorists attended not only to the issue of what motivates patients, but also to how motives operate. The importance of constitutionally given mental faculties, such as memory and perceptual apparatuses, was recognized. These biological roots of psychological structure were believed to influence both adaptive and defensive functioning of the self.

Following World War II, experimentation on the influence of motive on perception (e.g., Klein, 1954) opened the door for individual differences in cognitive style and functioning of the self. Building on the diverse work of others before him, Shapiro (1965) introduced the notion of neurotic styles. He argued that only in the context of the subjective world and ways of functioning can the individual significance of any given mental construct be understood.

Although Shapiro attempted to separate observations of function from speculations about origins, he retained classic psychoanalytic assumptions of drive discharge. However, these have been rejected by other psychoanalytic thinkers. Sullivan (1953), belonging to the cultural school, invoked the role of direct personal experience and interpersonal interaction within a societal and cultural context for shaping the "self-system." Object relations theorists, such as Klein (1948; 1957) or Mahler (1968; Mahler, Pine, & Bergman, 1975) examined how the extended system of personal relationships influence personality development throughout life, becoming internalized as representations of self and others.

Other neo-analytic trends were self-psychology (e.g., Kohut, 1971; 1977; 1984) and intersubjectivity theory (e.g., Stolorow & Atwood, 1992; Stolorow, Brandchaft, & Atwood, 1987; Stolorow, Atwood, & Brandchaft, 1994); these have also turned away from traditional drive theory. Kohut came to believe that his patients needed something from him, rather than seeking to discharge unconscious sexual fantasies or aggressive aims onto

him. He examined how the presence or absence of empathic attunement continually affects the stability, cohesion, and organization of the self, as it functions subjectively in a matrix of current relationships. Intersubjectivity theory examines the interplay between differently organized subjective worlds of the patient and analyst, together forming an indissoluble psychological system or field within which psychological development and pathogenesis of the self takes place.

PLACING THE SELF INTO CONTEXT

In the brief summary of psychoanalytic literature above, descriptions of the self have grown increasingly contextualized, characterized by more and more attention to how the self operates in its current context, supported and maintained by a nexus of ongoing relationships. There has been a shift away from structural, experience-far models of universal stages of development to models that emphasize empirical, experience-near observation of function within unique individual contexts.

Cross-cultural research in developmental psychology displays a similar trend, with descriptions of the self also becoming increasingly contextualized. The self has been portrayed as enculturated (Markus & Kitayama, 1991; Sampson, 1988; 1989), politicized and historicized (Cushman, 1990), embodied and dialogical (Hermans, Kempen & van Loon, 1992). A recent summary article (Cross & Madson, 1997) argues that the concept of independent versus interdependent self-construals unifies diverse research literature regarding gender and cultural differences in the shape and organization of emotion, motivation, preferences, and behavior.

This paper attempts the next step in this theoretical progression towards increased contextualization. The concept of the self as a dynamical system parsimoniously unifies not only clinical and psychoanalytic theory, but cross-cultural and gender findings as well. A dynamical systems perspective is ideal for addressing individual differences in how the self functions, without need to speculate about origins or to confound function with origins.

A dynamical systems perspective contributes to conceptualizations of the self by being entirely process oriented and content free. This helps to establish the self in its broadest context, as an open system interacting at various levels with a body, family, social group, culture, and historical era. Because of its nonreductionistic, nonlinear framework, this perspective easily integrates "bottom-up" factors, like physiological underpinnings, with "top-down" ones, such as theories of cultural or political "driving" forces, permitting bi-directional directions of influence. One can attend to how the body is enculturated as easily as to how historical eras are affected

by changing family relationships. To take this approach necessarily involves crossing disciplinary boundaries.

Dynamical Systems Theory in Historical Context

Insights gleaned from new sciences of dynamical systems theory, chaos and complexity theory, nonequilibrium thermodynamics, and fractal geometry have been quite useful in understanding external complexity (e.g., Briggs & Peat, 1989; Cohen & Stewart, 1994; Coveney & Highfield, 1995; Gleick, 1987; Kauffman, 1995; Lewin, 1992; Prigogine & Stengers, 1984; Waldrop, 1992; West & Deering, 1995). They have been hallmarked for application to clinical, social, and other areas of psychology (e.g., Abraham, Abraham & Shaw, 1990; Abraham & Gilgen, 1995; Barton, 1994; Kelso, 1995; Marks-Tarlow, 1993; 1995; Masterpasqua & Perna, 1997; Robertson & Combs, 1995; Rossi, 1996; Smith & Thelen, 1993; Sulis & Combs, 1996; Thelen & Smith, 1994; Vallacher & Nowak, 1994).

Empirical operationalization and testing of nonlinear, dynamical concepts are in beginning phases as applied to psychology in general, but at ground zero with respect to the self in particular. New methodologies carry the potential to quantify complex, irregular, and discontinuous phenomena so characteristic of the psyche. Techniques use raw data to build models, rather than to prove or disprove hypotheses based on pre-existing models, a practice which often leads to linear and reductionistic biases in scientific research (West & Deering, 1995). However, caution must be exercised, as difficulties exist both in adapting techniques among different fields and in confusion over how to test models (see Barton, 1994).

Current Goals

Recently, Goldstein (1997) discussed the self-organizing psyche as it embraces the random. Stolorow (1997) suggested that dynamic systems theory is a source of powerful new metaphors for psychoanalysis. In this paper, I propose a dynamical systems model to illuminate the interrelationship between structure and function of the self. Through reconceptualizing the self as a dynamical process-structure, I hope to show how the functioning of self can lead to emergent stability and structure, thus eliminating the need for an extra layer of theory. I also suggest that recursive folding of the self back upon itself may account for increased internal complexity necessary for self awareness. Finally, I propose that the fractal geometry

of self explains multiple levels of psychological description, as well as certain paradoxes associated with the self, and clinical phenomenology.

Properties of dynamical systems will be described as they apply to the self. Main concepts of chaos, self-organization, edge of chaos, co-evolution and fractal dynamics, plus supporting concepts of emergence, autogenesis, multiplicity, iteration, recursion, scale invariance, and self-similarity are extended to intrapsychic realms in order to shed light on the development of internal complexity. Drawing upon empirical research, this paper suggests a new theoretical paradigm for conceptualizing the self that can provide a heuristic for future research.

First, chaotic roots of development will be explored generally. Next, a developmental model will be presented in which the self emerges from chaotic roots through processes of self-organization, during multiple iterations of brain processes, perceptual and social experience. The development of internal complexity will be related to the evolution of the self to the edge of chaos. Next, I suggest the self be reconceptualized as a process-structure, characterized by multistability and multiplicity, co-evolving with every facet of its context, from microscopic levels of biophysiology and biochemistry, through increasingly macroscopic and global levels of psychological, social, cultural, and historical organization. Finally, fractal dynamics of the self will be explored, including properties of self-similarity and scale invariance, as well as paradox and recursion.

Before embarking upon this enterprise, a word of caution must be injected about applying empirical and scientific findings metaphorically or transforming findings from one scientific context to another. The theory presented in this paper is entirely speculative, although grounded in empirical research wherever possible. At such initial stages of conceptualization, I ask the reader's permission to present a broad spectrum of new ideas. Ultimately, many may be discredited or disproved, but will at least have served the purpose of springboard for further dialog, empirical translation, verification, or refutation.

CHAOTIC ROOTS OF DEVELOPMENT

A key facet of the new sciences of chaos and complexity theory is the centrality of nonlinear processes, which in the extreme signal "chaos," a technical term coined by Yorke and Li, (1975). Whereas everyday associations to this term connote utter disorder and mayhem, its technical use implies just the opposite, the existence of order underlying systems whose surface behavior appears random (Cohen & Stewart, 1994; Coveney & Highfield, 1995; Gleick, 1987). Chaos is apparent in phenomena as diverse

as turbulence in water or air, the movement of forest fires, or erratic trends in the stock market.

An aspect of nonlinearity, abrupt phase transitions, also abounds in nature, ranging from simple systems such as water, which shifts from solid to liquid to gas at critical temperature points, to highly complex systems, such as the mental states of people, which also shift abruptly between states, e.g., from calm to frenzied to ecstatic. The existence of fundamentally different classes of outcomes, known as multistability, expands the behavioral repertoire of dynamical systems.

Nonlinear dynamics have been used to model discontinuous phase transitions in mental states (Putnam, 1988, 1989; Wolff, 1987). Wolff (1987) examined the parameters connected with dynamic stability and instability of behavioral states in infants. Putnam (1988; 1989) examined state transitions in adults with multiple personality disorder (MPD). He proposed that various mental states in children are imbued with a different sense of self, which due to severe and repeated trauma, never become consolidated in the MPD adult. This leads to instability and abrupt switches between different identities, with attendant sets of memories and affect states. Putnam proposes that chaotic processes are central to psychopathology of the self evident in MPD adults. I propose that chaotic processes are also central to normal development, including the development of the self.

Healthy Chaos

That chaos could be an aspect of healthy development may seem far-fetched, especially to clinical psychologists busy fighting chaos, here meant colloquially, in their patients' lives. Yet, in our bodies, the existence of chaos and related irregularities is often a sign of health (Freeman, 1991; Garfinkel, Spano, Ditto, & Weiss, 1992; Glass & Mackey, 1988; Goldberger, Rigney, & West, 1990; Skarda & Freeman, 1987; West & Deering, 1995). For example, small, chaotic fluctuations in heart beat are normal, often resulting from internal rather than external factors. Certain kinds of heart attack are actually preceded by a kind of pathological periodicity. There is even suggestion (Lipsitz & Goldberger, 1992) that aging is characterized by loss of plasticity and variability afforded by chaos in basic physiological systems.

Like our bodies, our brains need irregularity for proper functioning. Here, chaos may serve as nature's randomizer, mixing up brain wave frequencies where too much regularity or coherence could be damaging. Chaos is evident in normal EEG readings, where irregularity in the brain manifests in electrical waves of slightly and unpredictably varying amplitudes. Epi-

lepsy is one pathological condition where regularity and entrainment can become highly dangerous.

The brain also uses aperiodic, self-organized, low-dimensional chaos in the background of some sensory activities (Freeman, 1991). Studying olfaction in a rabbit, Freeman compared EEG spatio-temporal patterns obtained during certain smells with those obtained between smells, finding that the former were characterized by greater regularity than the latter. Freeman postulated that the presence of low-dimensional chaos, that is, chaos driven by a few important variables, enables sensory systems to exist in a critical state of readiness. In this state, nerve assemblies are maximally sensitive to input, highly responsive to trial and error, and capable of dramatic response to weak stimuli.

Another phenomenon, called stochastic resonance (Bezrukov & Vodyanoy, 1995; Douglass, Wilkens, Pantazelou, & Moss, 1993; Moss, 1994), occurs when information flow in a multistate system, such as the auditory, is enhanced through the presence of optimized, random noise. Douglass and his colleagues studied the timing of action potentials in single mechanoreceptor cells of the crayfish in response to both noise and a coherent signal. They found that detection of a weak stimulus was enhanced by a background of optimal noise intensity. Unlike Freeman's study, the source of the noise was exogenous rather than endogenous.

Rossi (1996) uses stochastic resonance to model the patient's amplification of information out of "noise," in the form of ambiguity, confusion, not-knowing, shocks, and surprises, injected by the therapist during Eriksonian-style hypnotherapy. Neuroscientist Harth (1993) believes chaos may play a similar role to stochastic resonance in the neural dynamics of higher order thinking. Weak sensory and memory traces may constitute a noisy background for strong associations that guide the direction of thought. This proposal is supported anecdotally by reports (e.g., Koestler, 1964) that breakthrough creative thinking is more likely to occur if the mind is nonfocused and between directed activities. When the mind is free to wander randomly, presumably a noisier, more chaotic background is provided than during more directed mental focus. Goldstein (1997) has speculated on the importance of randomness in the dreaming process, as well as during free association.

Motor Development

Nonlinear dynamical systems theory has been applied fruitfully to motor development by developmental psychology researchers (Metzger, 1997; Smith & Thelen, 1993; Thelen & Smith, 1994). There is increasing

empirical evidence that chaos is an intrinsic part of early motor development (Clark, Truly, & Phillips, 1993; Robertson, Cohen, & Mayer-Kress, 1993). The infant begins life spontaneously emitting chaotic, disorganized movements. The many separate muscles of the motor system are not yet coordinated with one another or with sensory data. Irregularity in the infant's action helps avoid locking into repetitive patterns of interaction with the environment. Irregularity may also facilitate exploration, while maximizing information extracted from the environment.

Over time, with increased sensory-motor experience and further development, the infant's muscles become organized into "coordinative structures" (Clark et al., 1993; Goldfield, 1993; Roberton, 1993). These are globally coordinated subsystems hypothesized to collapse the degrees of freedom of an otherwise high dimensional system, characterized by many interacting parts. The dimensionality of a system determines its freedom of movement, with higher dimensionality corresponding to greater freedom of movement in many possible directions. When a system is composed of many interacting parts, a collapse in degrees of freedom is essential for the emergence of regularity and coordinated activity. Thus, over time, with repeated practice, chaos collapses into order. However, chaos at the core of motor behavior enables children and adults to retain the capacity to deviate from regularity and capitalize on inherent variability to perform coordinated, task-specific activities, adapting to the infinite number of real-life conditions under which any motor skill is performed (Goldfield, 1993).

Few empirical studies of language exist yet from a dynamical systems perspective (e.g., Tucker & Hirsh-Pasek, 1993). Nevertheless, it is likely that a similar sequence occurs in children's language development. There is ample literature (e.g., Locke, 1994) that during initial phases, infants' babbling touches upon many sounds, perhaps even all sounds from all languages, only to be canalized and constrained over time into more regular, predictable patterns. To establish the initial, technical presence of chaos, time series data of various stages of infant phoneme production could be analyzed and compared, using methodology that allows a degree of quantification hitherto impossible. If the babbling of infants is another facet of the universal language of chaos, then as language development proceeds, one would expect increasing predictability over time, both in which sounds are produced and the timing of when they are produced.

The Chaos of Emotions

Chaos appears ubiquitous, not only in early motor behaviors, but also in patterns of emotional expression. Wolff (1987) pioneered the application

of concepts derived from nonlinear dynamics to developing mental states in infants. He explored the stability of behaviors such as waking, sleeping, crying, and smiling over time, in some instances finding initial instability that gradually stabilized into greater regularity with the passage of time. In the premature infant, Wolff observed a whole array of spontaneous smiles and facial grimaces, initially occurring unpredictably and at random, only later connected meaningfully with specific organismic or environmental conditions. For adults, there is preliminary evidence (Hannah, 1990) that normal mood variation is chaotic in nature, exhibiting some degree of unpredictability.

In a way, our emotions are an extension of sensory apparati, which crudely speaking, help us discriminate between aspects of the world towards which we gravitate and those from which we are repelled. Whereas primitive instincts derived from the brain stem, such as the fight or flight response, canalize response options to a single output, the evolutionarily higher-order limbic system, seat of emotional expression in mammals, does quite the opposite. It lends plasticity, opening up a myriad of behavioral options in response to subtle emotional nuance. Whereas a frog is reputed to have three alternatives upon encountering foreign, moving objects—to eat those smaller than itself, flee from those larger than itself, and mate with those the same size—a human enjoys a wider range of options for action upon encountering foreign, moving objects, presumably mediated by broader emotional and motivational underpinnings. Perhaps the limbic system functions like a nonlinear modulator upon the static regularity of instinct.

Because so many features of the world are nonlinear, chaotic, and fundamentally unpredictable (Briggs & Peat, 1989; Cohen & Stewart, 1994; Coveney & Highfield, 1995; Gleick, 1987), it makes sense that our capacity to register these elements in mood would follow suit. Chaos in our emotional make-up appears to arise as an evolutionary adaptation to fundamental nonlinearity, evident at every level of existence. As with stochastic resonance in sensory systems, low-dimensional chaos in emotion may facilitate processing of "noisy" environments, where stimuli are ambiguous, yet quick action is required. Like self-organized chaos in the background of perception, low-dimensional mood chaos may leave us perpetually in a state of readiness, where we are maximally sensitive to unpredictable input and capable of rapid response mobilization.

Chaotic Roots of the Self

Impulsivity evident in the infant, in terms of early erratic motor, vocal, and emotional expression which is cognitively unmediated, may represent

the presence of initial chaos in psychological organization generally (Marks-Tarlow, 1993). Because major life conditions and events, from the vicissitudes of weather to the occurrence of sickness or tragedy, follow an unpredictable, nonlinear course, these impulsive roots of psychological organization are adaptive. As with perceptual and motor processes more narrowly, they appear to confer maximal plasticity for exploring the environment and responding to its variability.

The presence of initial chaos in psychological organization generally may represent the precursor from which a more organized, articulated and conscious sense of self emerges later in healthy development. The development of self from early chaotic emotions and impulsive roots could serve as a kind of "neutral" starting point for later socialization and environmental entrainment. Early impulsivity supplies necessary chaotic roots from which later psychological organization can emerge.

If so, rather than signaling the presence of pathology per se, disorders of impulse control, such as substance abuse, gambling, or intermittent explosive disorder, may represent an immature condition of initial chaos never properly constrained through later socialization and development. Perhaps this helps explain why impulsive behaviors are so apt to reappear under stress, when one is likely to regress to earlier coping styles.

SELF-ORGANIZATION AND THE EMERGENCE OF SELF

An important application of chaos to psychological systems is through the broader concept of self-organization (Barton, 1994; Cohen & Stewart, 1994; Kauffman, 1995; Lewin, 1992; Prigogine & Stengers, 1984; Waldrop, 1992). Self-organization describes processes by which order and pattern emerge within an open system, often from chaotic bases, without direction or control from the outside environment. Open dynamical systems require a constant exchange of matter, energy, and information across permeable boundaries.

At the chemical level, self-organization is illustrated by the Beluzhov-Zhabotinsky (BZ) reaction (Prigogine & Stengers, 1984), a chemical mixture wherein if poured and unstirred, reactants spontaneously form spiral and circular waves that propagate through diffusion into complex patterns. At the biological level, self-organization is demonstrated by ordered development from a fertilized egg, organized around branching pathways of cell differentiation in the absence of step-by-step instructions (Kauffman, 1995). At the neurological level, self-organization is demonstrated by the pattern of stable, spatio-temporal patterns found across neurons in olfactory EEG's in response to particular odors (Freeman, 1991).

Critical features of self-organization related to the self are illustrated by the relevance of Freeman's work (1991) to neural underpinnings of memory (Barton, 1994). First, during self-organization, pattern emergence occurs at the large-scale or global level as a result of a myriad of small-scale or local interactions among a multiplicity of similar elements, each following the same set of rules for interaction. Freeman found that perceptual memory for a specific odor is not stored in the waveform in any one region of the olfactory lobe. Instead, it resides in the global pattern of the amplitudes of the waveform emerging from the interconnections between neurons comprising the whole lobe.

These findings are relevant to the self in two different ways. First, it has been speculated that all aspects of experience, including consciousness (Freeman, 1990; Harth, 1993; Skarda, 1990), cognition (Thelen & Smith, 1994), and even one's articulated sense of self (Schwalbe, 1991) emerge globally from patterns of local neural interactivity. Second, in so far as one's sense of self exists flexibly and dynamically over time, circumstances and the course of development, the self emerges as a broad, global pattern, transcending minute-to-minute interactions with people, in particular social and environmental contexts.

There is another way in which Freeman's (1991) work illustrates just how how flexible and dynamic emergent patterns are. In the rabbit, after a second odor is learned and the first reintroduced, the resulting olfactory lobe EEG's reveals not the original pattern, but an altogether different one. At the neurological level, this suggests continuous reorganization of the whole in response to subsequent novelty and learning. It also suggests that stability in perceptual memory organization is characterized by flexible, ever-changing neuronal underpinnings.

Memory is not "fixed" somewhere in the brain, but is continually "reconstructed." If this reconstruction process underlies object constancy for concrete, physical stimuli, such as odors, presumably it also underlies more abstract, symbolic levels of memory, perhaps relating to classic psychoanalytic notions of object constancy, including memory for others and self. Because of such highly dynamic features of self-organizing systems, I argue next that the self is best conceptualized as a process-structure.

Self as Process-Structure

In attempting to integrate a dynamical systems perspective with modern psychoanalytic theory, Stolorow (1997) asserts that the boundary between the conscious and unconscious is fluid and ever shifting, self-organized within a dynamic, intersubjective system. Viewed as an emergent,

global property of a dynamically interactive system, the self is ever in flux, with fluid boundaries. The self is a process that is continually reconstructed on the basis of local interactions occurring at multiple levels—between neurons in the brain, between an infant and its mother, between an individual and culture at large, all of which shifts from moment to moment within a particular historical context.

The self is also a structure characterized by multistability, in that it is capable of adopting any number of discrete states from moment to moment, based on a complex interplay between events, their cognitive interpretation, and emotions they engender. Emotions interact with self-concept in fluid fashion. When depressed, one's sense of self is negative and deflated (e.g., Beck, 1979), whereas when happy, one's sense of self is positive and expanded with possibilities.

From a dynamical systems perspective, because the self is an open system, its maintenance requires a continual flux of energy, matter, and information in and out of the system. Thus, even when viewed as a succession of stable states, the self is still characterized by dynamical flux, in the same way that stable memories are characterized by ever-changing neurological underpinnings. I choose the term process-structure to emphasize this dynamical nature of self, its potential for emergent stability, as well as its continual reconstruction in conditions open to the environment.

This terminology carries important implications for schools of theoretical thought which tend to emphasize one or other pole in the process/structure continuum. The dynamical notion of process-structure provides a new dialectic that bridges structuralist, constructivist, and functionalist positions, helping to shed new light on age-old controversy.

Edge of Chaos

In the study of self-organized, biological systems, one rather powerful concept is that complexity emerges at the edge of chaos (Kauffman, 1995; Lewin, 1992; Waldrop, 1992). The edge of chaos is a dynamic, fluid transition zone existing between two extremes: predictable order and unpredictable chaos. Within this transition zone, there is enough stability to maintain structure, encode and transfer information, yet enough chaos to permit flexibility, adaptability, and creativity.

Kauffman's research (1995) involves complex computer simulations of various micro- and macrobiological processes, leading to two important proposals. The first is that along with random mutation and natural selection, self-organization is yet another critical factor in the evolution of species. Self-organization contributes a kind of "order for free," leading to

the spontaneous emergence of increasing order accompanying increasing system complexity. He suggests that life itself is a highly probable event, contrary to prevailing notions of life's remote statistical likelihood. Kauffman's second proposal is that all of life evolves to the edge of chaos, where it remains flexibly poised in a critical state of readiness.

Perhaps psychologically as well, healthy functioning and maximal complexity capitalize on self-organization thriving at the edge of chaos. Away from this edge, either extreme may be pathological (Marks-Tarlow, 1995). Only between extremes, at the edge of chaos, can psychological balance be achieved. At the edge of chaos, we are best equipped psychologically to deal with erratic and unpredictable events in life. Here, we maintain flexibility and openness to unpredictability, novelty and change, while maximizing our capacity for internal complexity.

The association between psychological health and flexibility is consistent with Rogers' (1961) assertion that effective therapy moves clients from fixity to changingness. This perspective is also consistent with Shapiro's (1965) clinical studies of neurotic styles. Shapiro described the "rigidity" of the obsessive-compulsive. Along with stiff body posture, the obsessive-compulsive carries fixed ideas and behavior patterns, rigidly constricted affect, and intense, unflinching focus and attentional processes, which tend to apply to concrete or immediately manifest features of a situation or task. At the other extreme, Shapiro described conditions of too much lability, such as hysterical style. This style is characterized by fleeting perceptions, quick impressions or hunches, poor memory, especially for detail, and rapid fluctuation of attention and emotion. Here, psychological and perceptual processes are too fluid, with change in perception and focus occurring too readily.

According to Shapiro's description, the "normal" person enjoys the benefits of both styles. Impressionistic hunches can be used to quickly assess the global picture, while more focused, sustained deliberation is available for considering details. Attention is neither gripped nor flighty, but can be shifted smoothly and rapidly at will. In short, the normal person displays flexibility to move readily between the two styles according to the exigencies of the situation. This dovetails with Lipsitz and Goldberger's view (1992) that normal development, in contrast to the pathology of aging, is characterized by plasticity and variability afforded by chaos in basic physiological systems.

In order to test whether Shapiro's typology fits an edge of chaos interpretation, an experiment could be designed to compare empirical data for individuals with obsessive-compulsive style, individuals with hysterical style, and normal controls. Physiological indices or video tape and observational judgment could be used to track shifts in attentional processes among

participants in different diagnostic categories. Time series data could be generated and underlying attractors (the region of phase space, the space of all possible behavioral states, in which a dynamical system converges over time) reconstructed and compared for indices of chaos, such as higher dimensionality and positive Lyapunov exponents (a measure of the degree to which adjacent points diverge on an attractor over time).

Predictions would include highest dimensional attractors and most positive Lyapunov exponents among participants with hysterical style, intermediate levels among normal controls, and lowest values among participants with obsessive-compulsive style. Additionally, it might be predicted that spectral analyses of data gathered from normal controls would demonstrate greater power law distribution than among other participants. This follows from Bak's (1996) assertion that the "edge of chaos" is best conceptualized as "self-organized criticality" as measured by power law distributions, whereby minor perturbations lead to avalanches of change of all sizes.

Psychological Boundaries at the Edge of Chaos

The notion of edge of chaos may be useful not just for examining intrapsychic dynamics, but for examining interpersonal dynamics as well. Structural family therapists use the concept of boundaries to delineate subsystems of a family. Minuchin (1974), for example, defines the boundaries of a subsystem as the rules defining who participates and how. He offers a typology of family boundaries ranging from rigid at one extreme, to diffuse on the other, and clear in normal families.

According to Minuchin, family members with rigid boundaries are disengaged. They are isolated from one another, lacking the capacity for interdependence and communication. Families with diffuse boundaries are enmeshed. Members display a heightened sense of belonging that requires overinvolvement and a major yielding of autonomy. By contrast, families with clear boundaries attain the correct degree of permeability – rigid enough to permit autonomy, but diffuse enough to foster interdependency and communication. Clear boundaries are, in short, flexible ones.

Minuchin's interpersonal typology is reminiscent of Shapiro's intrapsychic one, in that pathology is viewed in terms of extremes of rigidity and fluidity, while normalcy is characterized by flexibility. Just as Shapiro's model is consistent with an edge of chaos interpretation, so is Minuchin's.

It would be a challenge to apply methodology from dynamical systems theory to communication patterns among family members characterized by rigid, diffuse, and clear boundaries. Since social networks have been a

topic of study since the early 1950's, perhaps old data could be revisited through new, nonlinear dynamical lenses.

A new research project developed along these lines would necessarily include a scoring protocol for actual conversations. Perhaps time series data could be collected surrounding who talks to whom, length of communications, and length of silences between communications, in families of approximately the same size and ages, who are completing or solving a designated group task. Examples of constructs of interest might be instances of proaction, withdrawal, cooperation, and competition. In attractors reconstructed from time series data, one might expect the least indices of chaos among disengaged families, the most among enmeshed ones, and the greatest complexity, perhaps characterized by more power law spectral distributions, among families with flexible, clear boundaries.

Development of Internal Complexity

Sociologist Schwalbe (1991) offers a dynamical systems description whereby the infant begins life in an "impulse phase," blindly and continuously dissipating energy through random body movements and vocalizations. This forms the "biomaterial" basis for later development of the self, which occurs through processes of autogenesis. Autogenesis is a hallmark of self-organization, whereby products of self-organization facilitate future processes in a self-perpetuating cycle of growth and development.

According to Schwalbe, self-organization of neural networks leads to the selective capture of perceptual and sensori-motor information by the body. The interaction between a body with certain selective capacities and an environment with certain information potentialities leads to self-organized process-structures in the brain, a perspective supported by connectionist models of learning (Carpenter & Grossberg, 1987; Hanson & Olson, 1990).

The next step is self-organization of impulses by imagery, which occurs only after the infant is capable of memory and stable object representation. Once perceived objects are captured in the enduring world of consciousness, energy flows involving imagery occur in the absence of objects themselves. This creates a new kind of feedback channel allowing for the glimmerings of consciousness in the form of awareness of "things going on in the head." This phase probably corresponds to Stage 6 of Piaget's (1945/1951) sensorimotor period of development, where imaginary play emerges and parts of objects can stand for the whole, such as footsteps signaling mother's soothing presence.

The final step in Schwalbe's model of the autogenesis of self involves

the self-organization of imagery by language. Schwalbe cites the work of Vygotsky (1962), who suggests that external speech precedes learning to use speech silently to guide thought. Internalized speech may bring a grammar that disciplines the flow of imagery through consciousness, allowing for language-governed awareness necessary for a fully formed sense of self.

In Schwalbe's model, each level builds from preceding levels, yet forms an emergent property of the whole. Eventually, autogenesis leads from chaotic roots to processes of self-reflection and self-control, and an increasingly ordered, complex, and consciously articulated sense of self.

Although lacking direct empirical evidence, this picture of development is consistent with infant research (Greenspan, 1991; Stern, 1985), which suggests that the newborn's inner world possesses some degree of perceptual organization. Nevertheless, the presence of a reliable, predictable, and stable caretaker is required to help organize disordered impulses and provide the foundation for internalizing stable interactions. Diverse theorists (e.g., Kernberg, 1976; Loevinger, 1976; Mead, 1934; Sullivan, 1953) have described similar, spiraling process of development, whereby biological processes are organized into impulses, internal visual images, then language, and linked by predominant affective dispositions to eventuate in a conscious sense of self.

The Self as a Special Recursive Case of Consciousness

Schwalbe's developmental model (1991) suggests that the self is globally emergent from complex neural underpinnings. Freeman and others (Freeman, 1990; Harth, 1993; Skarda, 1990) speculate that consciousness is also an emergent property of brain. This means that neuronal underpinnings of consciousness are not to be found in any specific location, instead residing in patterns of interconnectivity spread across the whole brain. If true, then consciousness exists as a global property of brain, with no sharply delineated edges. If the self is also globally emergent from neuronal underpinnings, then as with consciousness (Freeman, 1990), it becomes difficult to pinpoint origins of the self, either in terms of a specific brain location, the precise history of an individual, or the emergence of self in evolutionary history.

The notion that mental phenomena emerge from neuronal dynamics has not been proven conclusively, and would be extremely difficult, if not impossible, to do. Philosophically, it presupposes a monistic stance of material realism (see Goswami, 1993), by which mental phenomena are believed inseparable and emergent from material bases. This presumption contrasts, for example, with philosophical positions either of monistic ideal-

ism—that consciousness provides the foundation for material reality—or of dualism—that mental and material phenomena form two completely separate realms of existence.

Regardless of origins, I speculate that the emergence of self awareness is a special case of consciousness, which upon reaching a certain level of complexity, recursively folds back upon itself, psychologically manifesting as consciousness of consciousness. Consciousness may be considered recursive if viewed as a set of internal algorithms that operates continually upon objects and aspects of the external world. Iteration occurs through feedback processes, whereby products of one state of consciousness become the starting point for the next state.

The Baker's transformation (see Schroeder, 1991), which models all kinds of mixing processes, may be considered by analogy. Like the stretching and folding of vanilla into cake batter, this transformation "stretches" a unit square into a rectangle, then recursively "folds" it back again, stacking one half upon the other. The operation continues time and time again. After many iterations, the result is a uniform mixture, a fractal concoction of layer upon layer of embedded, self-similar complexity.

The Baker's transformation resembles the endless iteration of perception-action-reflection feedback loops that characterize the stew of ontological existence, by which people constantly stir in and enfold the ingredients of new experience into ongoing phenomenology. People stretch through action based on current perception, and then fold back upon themselves through processes of proprioception and reflection, in preparation for the next cycle. Rossler (1976), who formulated one of the simplest models of a strange attractor utilizing stretch and fold dynamics, speculated about the utility of such dynamics for modeling human consciousness and experience (see Rossi, 1996).

Piaget (1936/1952) might have argued that actual dynamics involved are ones of accommodation and assimilation. In the case of assimilation, recursive enfolding involves the repetitive application of the same schema to new experiences. In the case of accommodation, internal complexity builds with the emergence of new schemata. Loevinger (1976) might have argued that various models of ego, intellectual and moral development supply the content of an increasingly complex self. However, caution must be exercised in application, as these are purely structural models, based upon presumptions of equilibrium. By contrast, the process-structure model set forth in this paper, as well as nonlinear dynamics generally, presume far-from-equilibrium conditions.

Caution aside, the Baker's transformation analogy is especially compatible with certain social models of the self, where internal complexity builds through what Loevinger (1976) terms "circular reactions." For example,

Cooley (1902/1968) used the term "looking-glass self" to describe "oneself" integrally connected to a correlative sense of "you." I am looking at you looking at me; the eyes of others provide mirrors for the self. In Baldwin's (1897/1902) model, first the infant learns to distinguish persons from other objects. Next, the self is recognized as a person among people, but with special feelings not recognized in others. Finally, the child sees others possessing feelings discerned in the self. Internal complexity builds through continual repetition of a cycle of seeing the self in light of what is observed in others, and inferring in others what is felt within the self.

Similarly, in Mead's (1934) social behaviorism, mind and consciousness are constituted out of social behavior, arising when children learn to represent themselves to themselves, initially through taking the view of particular others, and later of a "generalized other." This resembles Bem's (1972) radical behavioristic self-perception theory, where people are postulated to learn about their inner states from linguistic cues suggested by others under various conditions of observation. Whereas Mead assumes a relatively stable structure of self based upon internalized expectations from a "generalized other," Bem refrains from postulating about stable, internal structure. Instead, his is a process theory, where individuals constantly re-evaluate themselves based on perceived effects of their own behavior. The proposal of self as process-structure offered by this paper helps unify these apparently divergent perspectives.

All of these models, possessing what Loevinger (1976) calls "circular reactions," could be considered examples of recursive processes in dynamical theory language, whereby the output from a previous stage of development becomes the input for the next stage in a circular feedback system. Social behaviors are first conducted on the basis of current perception, then observed, and subsequently "fed-back," or internalized through reflective processes, into a consciously articulated sense of self. Similar thinking also provides the foundation for psychoanalytic models based on object relations theory (e.g., Klein, 1948; 1957; Mahler, 1968; Mahler, Pine, & Bergman, 1975), where one's extended system of interpersonal relations becomes internalized as representations of self.

Mead speculates that consciousness does not precede the social act, but emerges out of it. Language does not represent things already there; rather the act of symbolizing itself constitutes objects. For Mead, the self is one outcome of symbolization, arising just at the point of self-consciousness. This echoes Schwalbe's (1991) suggestion that language is necessary for a fully conscious sense of self. It is possible that as the iterative loop of perception-action-reflection continues and a certain level of complexity of internal experience is reached, eventually consciousness folds back upon itself, resulting in "order for free," or a new emergent level: consciousness

of consciousness. This may be the point at which a consciously articulated self emerges from preconscious and preverbal roots.

These ideas are extremely difficult to test, as self awareness is an elusive, intrapsychic property. Empirically, one might speculate that cultures with a highly distinct, individualistic concept of self may be characterized by greater cognitive and/or semantic complexity and emphasis on reflective processes than cultures without such a concept of self.

CO-EVOLUTION OF SELVES

If the self is truly an open, self-organizing system, then its emergence and development neither occur in an experiential vacuum nor in a social vacuum, as explored in this section. McKenna, Mosko, Dungy, and McAninch (1990) use methodology of nonlinear dynamics to demonstrate how co-sleeping between mothers and babies helps stabilize and "reset" various physiological functions within the infant. Evidence for entrainment, or coupling, at the physiological level appears to hold at the emotional level as well.

Current infant research (Beebe & Lachmann, 1988; Beebe, Jaffe, & Lachmann, 1992) suggests that not only are the mother's or other primary caretaker's emotions and responses critical in shaping the developing baby's sense of self, but the reverse holds as well. There is bi-directionality of influence, sometimes called mutual or co-regulation between infant and caretaker, through which the selves of mother and child are integrally linked. How the child comes to view him- or herself depends critically upon mother's emotional responsiveness; how the mother views herself depends critically on baby's emotional responsiveness.

Coupling of Selves

Reciprocal influence between mother and infant is modeled well by nonlinear dynamical theory (e.g., Schore, 1994; 1997). Nonreductionistic concepts allow for highly complex feedback systems and multilayered, multidirectional conceptualizations of causality. In dynamical systems language, co-regulation occurs between the selves of parent and child because the two open, dynamical systems are "coupled" with one another. This is akin to the eventual lockstep of two relatively same-sized people walking or the synchronous ticking of two cuckoo clocks hung on the same wall. Schore's work on the neurophysiology of development (1994; 1997) illuminates physiological substrates of emotional entrainment between mother and child.

Multiplicity or multilayered coupling occurs when we consider that

the self of the child is coupled not just to specific caretakers, but to the phenomenon of culture at large. Like the individual self, culture also can be considered a dynamical system which is self-organized. It is a kind of "collective self" globally emergent from the myriad of local interactions between individual selves, each with similar internalized set of rules for interaction. As with individual selves, culture cannot be located in any specific place or element comprising it, but is to be found only in the interconnections.

The coupling of individual selves to culture at large is supported by the postmodern rubric of social constructivism, where an increasing body of literature (e.g., Kitayama & Markus, 1994; Markus & Kitayama, 1991; Sampson, 1988, 1989; Shweder & LeVine, 1984) contests the old, universalist assumption (e.g., Ekman, 1984) that emotional expression is everywhere the same, hardwired by biology. Social constructivists maintain a reciprocally interactive relationship between culture and emotion. Emotions are formed through active adaptation to culture, in turn serving to maintain, regulate, and sometimes challenge the cultural environment to which they are tuned.

Along with the cultural regulation of emotion, this view posits the centrality of enculturated emotion to the developing self. For example, in Western cultures, validation of anger functions to uphold individualistic values, whereas in other cultures suppression of anger functions to uphold collectivist ones. This tuning of physiology, emotion, cognition, and motivation to cultural landscapes gives rise to fundamental differences in the very core organization of the self (Greenfield & Cocking, 1994; Markus & Kitayama, 1991; Shweder & LeVine, 1984).

The independent conception of the self pervading much of Western literature arises out of a view of the individual as self-contained and autonomous. This contrasts with the interdependent view held by many Asian, African and Latin American cultures, where the self is seen as inextricably connected with others, encompassed, and organized by social relationships (Cross & Madson, 1997; Greenfield & Cocking, 1994; Markus & Kitayama, 1991; Schwartz & Bilsky, 1990). The relation between individual selves and culture is autogenetic. Simply put, culture enlists the body, emotions, motivations and cognitions of individual selves, which in turn promote the growth of culture.

The Importance of Historicity

Highly nonlinear systems are characterized by sensitive dependence on initial conditions. Sensitive dependence means that a tiny perturbation

or change in initial conditions in the trajectory of a nonlinear system has disproportionaly large consequences for its future trajectory. Because initial conditions can never be specified perfectly, the trajectories of nonlinear systems rapidly become unpredictable. As a consequence, highly nonlinear systems tend to display historicity, demonstrating future behavior that is contingent on minute details of their histories.

In viewing the self as a dynamical system, not just social and cultural factors, but historical ones are equally as important for understanding its open nature and the precise course of its trajectory. This proposal is consistent with the work of Cushman (1990) and others (Baumeister, 1986; Foucault, 1979) who argue that cultural variations in conceptualizations and configurations of self are themselves formed and driven by the economies and politics of their respective eras. In our own culture, Cushman (1990) describes a shift from the Victorian, sexually restricted, deep self of Freud's day, to the empty, fragmented self of the post-World War II period, fueled by an economy of rampant commercialism, easy credit, continual production, and limitless consumption.

Multiple Levels of Description

In clinical and psychoanalytic description, there is little agreement as to how the self should be conceptualized. Subjectivists treat the self exclusively as an interior experience, inaccessible to others. Other analytic writers, such as Freud (1923/1955), include in the purview of self the one who does the experiencing, as abstracted from unconscious dynamics and intrapsychic structures. Social behaviorists, such as Mead (1934), broaden the focus to a socially constructed self, which includes not just personal experience and intrapsychic dynamics, but social interactions. Postmodern, social constructivists, like Kitayama and Markus (1994), define the self as entirely enculturated, including physiological, neurological, cognitive, and psychological underpinnings. Universalists, such as Jung (1953/1976), use the broadest lens of all, including universal, transpersonal and archetypal elements. Here the Self (with a capital "S") becomes the supraordinate, self-regulatory center of a collective unconscious, which provides pan-cultural themes woven into tapestries of local, personal and cultural variation.

Because the self is an open system coupled to other dynamical systems of broadening social scope, there is multiplicity, in the sense of multiple levels of description. Each of these multiple selves corresponds to a different level of description and different theoretical approach to the self taken by Western psychologists and philosophers. Historically, these perspectives have vied for the prize of ultimate truth. However, I propose that each

perspective folds into the next, with each equally as valid and useful. Stolorow (1997) asserts that because of the "continual flow of reciprocal mutual influence," there has been a false dichotomy in psychoanalysis between intrapsychic and interpersonal theorizing. I maintain that the same is true for interpersonal versus other levels of social and cultural theory.

Individual identity is an emergent level that occurs within a person embedded in a system of caretakers. Cultural identity is an emergent level that occurs between persons embedded in a larger social context. Cultural identity is itself multifaceted. Family identity is born out of interaction with one's relatives. Professional identity is born out of interaction with others connected to one's job and training. Community identity is born out of interaction with one's neighbors. National identity is born out of interaction with others inside and across one's country's borders.

Each level of self is formed through interaction and complex feedback loops occurring at various physiological, psychological, and social levels. Each level of self is emergent and embedded in the next, in the same way that Schwalbe describes the neurological, imagistic, and linguistic subsystems of the fully conscious self. Each level appears to contain similar dynamics—interaction across open boundaries, feedback loops that move in both bottom up and top down direction, self-organization, autogenesis, and emergence.

FRACTAL DYNAMICS

The kind of multiplicity described above, in the form of complex, recursively enfolded dynamics, recurring at different scales of observation, suggests a fractal organization of the self. Fractal organization is integrally related to chaotic and complex systems (Bak, 1996; Gleick, 1987; Schroeder, 1991). The hallmark of fractal organization is self-similarity, in which patterns are invariant across changes in size and scale (Gleick, 1987; Mandelbrot, 1977; Schroeder, 1991).

Physical fractals, such as mountains, clouds, or coastlines, display invariance across space. Temporal fractals, such as stock market trends or noise in transmission lines display invariance over time. Schroeder (1991) suggests that self-similarity can arise not only through repetition of algebraic or geometric operations, but through repetition of symbolic operations. This opens the door for extending fractal dynamics into psychological phase space.

Fractal dynamics often characterize both the underlying structure of chaotic attractors, as well as the overt organization of complex systems self-organized to the point of criticality. When evolved to a state of criti-

cality, "nature is perpetually out of balance, but organized in a poised state—the critical state—where anything can happen within well-defined statistical laws" (Bak, 1996, p. xi).

In subsections to follow, fractal dynamics related to the self as process-structure are separated into four main aspects. Internal attractor structure is related to repetitive behavioral patterns in people. The nature of attractor boundaries is identified with logic and other cognitive processes which drive as well as reflect behavioral patterns. Self-similar power laws are implicated in change processes. Finally, the structure of the self and its differentiation from non-self are examined in terms of fractal separatrices, both for pathological as well as normal psychological boundaries.

Clinical Examples of Self-Similarity

The hallmark of fractal organization, self-similarity occurring at various scales of social observation, is clinically observable in trajectories of complex narratives and behavior patterns, both spoken and enacted in the psychologist's office. For example, the self-concept of Mr. P, a highly ambitious male patient, was organized around aggression and competition. Self-similar interactional patterns were evident at multiple scales of observation. At a more molecular level, this man repeatedly interrupted and/or disregarded what others said, including myself. He bragged of road rage, regularly cutting off others in lines and on the freeway. At a more molar level, he was ruthless in his academic position, where he ignored the achievements of students and debased those of co-workers in attempts to aggrandize himself. On many scales of social observation, Mr. P's self concept depended upon pushing aside others in order to be visible and excel in life.

Fractal dynamics manifest themselves in common therapist lore. For example, it is said that the process of a session tends to mirror its content. It is also said that the session as a whole tends to recapitulate the first point of contact that occurs when the patient enters the therapy room. Indeed, fractal patterns extend not only across various levels of social interaction, but also from interpersonal into intrapsychic realms.

This extension of fractal patterns from the interpersonal into the intrapsychic is illustrated by the case of Mr. O, a Chinese-American man with intimacy problems. During individual therapy, this man described intense fear of his wife's emotionality, especially anger. He would reject her invitations to communicate, and continually avoid negotiating psychological boundaries, such as defining what was hurtful to him or who should control particular decisions in the household. Mr. O withdrew emotionally instead.

These same dynamics were enacted not only in the relationship with

his therapist, but also with respect to his intrapsychic world during the therapy process. Mr. O was afraid of his own feelings, which he described metaphorically at times as a "landscape he couldn't navigate," or as an "egg he didn't want to crack." He was especially reluctant to tap into his own anger, for fear it would lead to violence. This was understandable in light of Mr. O's history of physical abuse by his father. Because Mr. O considered his own inner landscape so dangerous, he had trouble accepting my invitations towards self-exploration in therapy. His sessions were filled with silences, and he tended to withdraw emotionally, especially at the beginning of treatment, or after interventions concerning intimacy, which were especially difficult to hear.

Repetitive Behavior and Underlying Attractors

In the cases described above, repeating patterns of behavior are clinically observable, persisting over time, in different contexts and scales of social observation. Since attractors are well-organized behavior patterns extending over time, repetitive behavioral patterns could denote underlying attractors in the cases of Mr. O and Mr. P. The notion of regularity in the form of underlying attractors is consistent with a trait-centered view of personality (e.g., Allport, 1961; Cattell, 1969; Eysenck, 1970). Trait theory proposes that source or primary traits or factors underlie and produce surface traits, or clusters of similar overt behavior in similar situations. In the case of Mr. P, for example, patterns of aggression in various contexts might correspond to Allport's notion of a primary trait or Cattell's notion of a surface trait.

Traditionally, source traits or factors were not believed directly observable, but were postulated as abstract, e.g., "neuropsychic " (Allport, 1961), structures. Such structures were identified statistically, using a variety of psychological measures plus factor analyses to identify linear patterns of co-variance. In nonlinear dynamical theory methodology, as with traditional personality theory, underlying patterns are also not directly observable. They are abstract and identified statistically, in the form of self-similar attractors existing in phase space, rather than in real space-time.

A dynamical system perspective approaches repetitive behavior patterns through the use of time series data and nonlinear methods of attractor reconstruction and dimensional analysis. These methods have the advantage of casting a wider net. They are highly ideographic, able to accommodate greater irregularity, variability, discontinuity, and even unpredictability of behavior. In personality theory, empirical findings of inconsistency from context to context plus difficulties predicting behavior spawned dissatisfac-

tion with global dispositional approaches, and gave rise to the situationalist revolution (e.g., Bandura, 1969, Mischel, 1968). Nonlinear dynamics offers the hitherto unrecognized possibility of underlying, stable pattern accompanying surface level unpredictability. Perhaps the use of chaotic attractors for describing stable pattern underneath unstable behavior can help explain the "consistency paradox" (e.g., Bem & Allen, 1974; Mischel, 1984). The consistency paradox consists in the persistence of traditional trait thinking, in both psychology research as well as in everyday intuition, and the popularity of instruments such as the Meyers-Briggs, despite the overall failure of personality research to capture behavioral stability (e.g., Mischel, 1968).

Dynamics of Change

In the model proposed in this paper, psychological health resides at the edge of chaos. The more stereotyped the behavioral patterns, the more evidence for underlying pathology. If psychopathology represents a loss of complexity, then behavioral regularity should be more apparent, in the form of more point and cycle attractors and lower dimensional attractors, in instances of psychopathology than in instances of normalcy. This empirically testable hypothesis is supported by Mischel's (1984) research showing that children characterized as aggressive or as tending to withdraw showed greater consistency of behavior in stressful situations than than did children characterized by more competency in social functioning.

Presumably, the more healthy the individual, the less stereotyped and predictable the behavioral patterns. This is consistent with the Gestalt therapy perspective, where psychological health is viewed in terms of the relative absence of personality structure. Conceptualized as a complex, adaptive system, a healthy organization of self displays optimal environmental sensitivity and behavioral flexibility. The ability of healthy individuals to adapt to changing situational contexts is consistent with situationalist thinking, such as Mischel (1968; 1984) or Bandura (1969), as well as with social role theory (for a summary, see Biddle & Thomas, 1966). Social role theory exists at the other end of the psychological spectrum from trait theory, postulating that people select different behavior depending upon the requirements of spectific roles. Perhaps a dynamical systems model can help resolve the old dispute between dispositionalists, who focus on internal stability, and situationalists, who focus on cross-situational inconsistency.

Not only do people change behavior depending on social context, but change also occurs intrapsychically as the self evolves. In the case of Mr. O described above, a dramatic turning point came in his intimacy struggles one day during a psychotherapy session. He took the risk of expressing

anger, by telling me how disregarded he felt when I arrived several minutes late for our appointment. Mr. O had an experience of safety and success. He learned that not only can anger be worked out, but under circumstances of openness, nondefensiveness, mutual trust and caring, it can even lead to closeness. The event heralded a new phase self-exploration, of honesty with himself and his wife, whom he began to confront more often.

Clinically, I have noted frequently that significant change during psychotherapy may be initiated by the escalation of a tiny event in the therapy room to other, larger social contexts. As a complex adaptive system, one might speculate that the self evolves to the point of criticality (Bak, 1996) in the context of psychotherapy. Here, the tiniest input has the potential to trigger major avalanches of change. This notion is supported by recent evidence that all therapies, regardless of type, lead to greater self-organization, in the form of increased "Landsberg order" between initial and final sessions, positively associated with other therapy outcome measures (Tschacher, Scheier, & Grawe, 1998).

If self-organization evolves to the point of criticality, fractal dynamics should be evident in self-similar power laws that govern cascades of changes surrounding the self. Once again, self-similarity would be statistical in nature, displaying invariance across time and/or size scales. Empirically, this would mean that small changes would display highly frequency, medium changes intermediate frequency, and major changes relative rarity. In a clinical setting, large cascades of change following a single event, such as displayed by Mr. O, are relatively rare, compared with the more common experience of many changes in small increments, in response to frequent therapist repetition, amidst plenty of relapse.

One advantage to a nonlinear dynamical theory of self could prove to be its power to conceptualize irregularity, unpredictability, and punctuated change as a natural part of development, normal under nonequilibrium conditions (Bütz, Chamberlain, & McCown, 1996; Koopmans, 1998; Rossi, 1996). Perhaps carefully documented clinical observations, involving escalation of self-similar events from small to large-scale levels of social behavior, could contribute to a theory of psychological change, based on newly discovered universalities within the nonlinear dynamics paradigm.

The Concept of Psychological Relativity Expanded

Fractal organization of behavioral attractors brings a new kind of relativity to the self. This relativity extends beyond Sullivan's (1953) concept of participant-observation, borrowed from insights of quantum mechanics and developed by others (e.g., Ehrenberg, 1992; Levenson, 1983). In a

controversial interpretation of quantum dynamics, popular during the time of Sullivan's writings, observers were believed always to influence and change the quantum system under study. Sullivan was among the first to recognize that the therapist can never be the "blank screen" of classical psychoanalytic theory, whereby patients were thought to project unconscious fantasies and aims onto the objective, neutral presence of the analyst. The analyst cannot stand outside the clinical situation and observe it, without constantly affecting and being affected by it. What is seen always depends upon who does the observing. This is the essence of much constructivist and neoanalytic thinking.

Fractal geometry takes relativity one step further. How the self is seen depends not only on who does the looking, but also upon the scale of the measuring stick supplied by different levels of observation. Each description of self remains valid and useful within its level of observation; each is recursively enfolded in the next, more inclusive level. Each is an emergent whole, arising from dynamics at other levels of description, yet indivisible in its global manifestation. This new kind of relativity applies not only to the self interacting with others, but also, as suggested by the clinical case of Mr. O described above, to the self interacting with oneself.

Attractor Boundaries and Chaotic Logic

According to Goertzel's (1994) work regarding chaotic logic, an attractor is formed by a system of logical connections that remain firm. This dynamical systems perspective dovetails with cognitive learning theory, whereby information processing based on computer models (e.g., Posner & Mitchell, 1967), schemata (e.g., Rumelhart, 1978), or other internal mental processes (e.g., Bandura, 1989), is believed to mediate behavioral responses. Goertzel (1994) identifies one type of pathological attractor that contains circular reasoning and other illogical props, to maintain the integrity of a twisted logical basis and keep it from unraveling through interaction with other information sources.

A clinical example of this kind of closed, circular reasoning may be found in Shapiro's (1965) description of paranoid style, as one of constant vigilance. Rather than looking at the environment, which implies a process open to new information, the paranoid is scanning the environment for signs that confirm his or her worst fears. The quip, "Just because I'm paranoid doesn't mean they're not out to get me" captures the prototypical paranoid confusion about whether "evidence" for one's fears sought and inevitably found is discovered from without or created from within.

Another example of chaotic logic may be found in borderline personal-

ity disorder (BPD), a character disorder originally named for borderline psychotic features, but which fundamentally involves the shattered or missing experience of subjectivity (Ogden, 1986). Confusion surrounding one's core sense of self leads to complex intrapsychic dynamics that escape into the world, inevitably ensnaring the therapist.

A BPD patient of mine, Ms. S, harboring central issues of rage and shame, repeatedly expressed confusion between self and other. This confusion involved continual experiences of feeling blamed, which regularly led to the following internal query on my part: "Is she right that I'm to blame for what she feels—that in my subtle choice of words I'm blaming her, standing in denial of my true motivation, and evading responsibility for her hurt feelings? Or am I right that I'm not invested in blame as a concept? But, if I'm right, then she's right, because she's also accusing me of always wanting to be right at her expense."

The BPD potential for endless recursion in interaction is reminiscent of the intrapsychic landscape of psychosis, a psychopathology also involving a shattered sense of self (Ogden, 1986). In psychosis, confusion regarding what is inside and what is outside reaches a crescendo in visual and/or auditory hallucinations, which are externally perceived projections of internal events. Recursive tangles and twisted logic in psychotic patients are beautifully documented in a tiny book called, "Knots," by R. D. Laing (1972).

Recursive tangles such as those characteristic of Ms. S leave the patient and/or therapist grappling with a paradox. This may be an external reverberation of the paradoxical core of BPD psychopathology. The paradoxical core consists of a self actively trying to deny its own existence. For example, "I'm not anyone," or "I don't have a self" were common utterances for Ms. S. Self-denial and self-annihilation in the borderline are the ontological equivalents of the liar's paradox ("This statement is a lie"), which is true only if it is false and false only if it is true, in an endlessly recursive cycle.

A group of philosophers at Stony Brook have taken a geometric approach to semantic complexity (Grim, Mar, Neiger, & St. Denis, 1993; Grim, Mar, & St. Denis, 1998; Mar & Grim, 1991; Stewart, 1993). They use fuzzy, or multivariate, logic to represent various relf-referential paradoxes, which are translated into mathematical equations and iterated by computer. This results in chaotic attractors and fractal escape time diagrams. It would be interesting to extend these techniques to the iteration of self-referential psycho-logic of various diagnostic categories.

Normal Boundaries

The clinical examples above could lead one to conclude that fractal separatrices between self and other, inside and outside, and endless re-

cursion result only from faulty logic or pathological conditions. Yet, in keeping with arguments made previously about the chaotic core of healthy processes, I propose that fractal separatrices characterize not only pathological boundaries, but in fact all psychological boundaries defining the self as process-structure.

Consider the edge of the Mandelbrot set, by analogy, in order to understand how fractal separatrices can model the kind of infinitely complex entanglement found at the edges of the self (Marks-Tarlow, 1995). The Mandelbrot set is the most complex object in mathematics, yet paradoxically it is the iteration of a very simple mapping, $z \rightarrow z^2 + c$, in the complex plane. At one scale of observation, a shape globally characterizes the outside edge of the set; at another, it characterizes a detail squarely inside the set. What is inside and what is outside become endlessly entwined. All attempts to resolve this complexity by attending to finer and finer microscopic detail are doomed to failure, because with the computer as microscope, fractal boundaries are infinitely deep and unresolvable at any scale. In fact, the deeper one looks, the more information is to be found.

A number of developmental theorists, such as Mahler (1968; Mahler et al., 1975), speculate that early psychological development during infancy is characterized by difficulty distinguishing inside from outside, self from other, although the extent to which this holds remains controversial. Confusion between what is inside and what is outside persists through life, albeit at a more abstract level.

Consider the seemingly irresolvable debate that has existed for thousands of years and still rages today between various philosophical positions. At one extreme, monistic idealism argues that external material reality is an illusion and really an aspect of consciousness or internal experience. At the other extreme, material realism argues that conscious experience is the illusion and nothing more than an emergent aspect of external, material reality.

Endless Frontiers of the Self

Fractal separatrices lead to a lifelong task of unresolvable complexity in defining the self, as exemplified by processes of self-exploration. During middle stages of therapy, patients often become afraid of dependency needs, as they catch a glimpse of endless frontiers for self-exploration. Do endless frontiers mean patients must stay in therapy forever? Indeed, as momentum gathers, the more one looks at one's inner patterns, the more there is to see, just like computer-generated fractals. In fact, the clinical use of fractal generation as a metaphor for intrapsychic exploration can help emotionally

to neutralize and destigmatize both the amount of clinical material that emerges and tendencies towards repetition.

When addressing issues related to the self in psychotherapy, the same patterns do tend to reappear, albeit in more sophisticated variation, often with a shortened time frame, higher level defenses, and/or truncated intensity of emotional cycles. In my observation, this holds true no matter how long or successful the treatment. To ultimately come to peace with oneself partly means to accept fundamentally unalterable core patterns of process-structure that constitute the self.

Paradoxes and Self-Reference

In so far as fractal boundaries are tied into paradoxes of self-reference, the latter do not only occur as deviant cases. Paradoxes are inevitable whenever a sufficiently complex system attempts to fully account for itself (Varela, 1975), whether involving language, logic, the psychological case of a borderline, or for that matter, any self looking at itself. Antinomies, or contradictions in propositions that arise from self-reference, reveal the collapsed distinction between the act of expression and the content to which that act addresses itself.

Just as most of us use language and logic without worrying about irreconcilable contradictions, for most of us, the fractal edges to our psychological selves are not bothersome. This is especially true when our sense of self, its stability and cohesion, do not depend upon resolving the complex and paradoxical nature of such boundaries. Part of normal development consists of accepting apparently self-contradictory or ambivalent emotions and impulses, as well as accepting unavoidable ambiguities in one's self and surroundings.

Among the important characteristics of Maslow's (1962) definition for self-actualization include: transcendence of contradictions and polarities; tolerance for ambiguity; openness to development as a changing process; availability of inner life; as well as greater integration and sense of identity. Apparently, to focus inwards and still make peace with polarities, ambivalences and ambiguities facilitates the development of internal complexity as well as an actualized identity.

Normal development appears to involve not so much the absence of unresolvably complex fractal edges, but an ability to understand, accept, and even appreciate them. This stands in contrast to psychopathological conditions, such as paranoid or borderline character disorders, where these ontological inevitabilities are rejected, because one's very sense of psycho-

logical survival or well-being seems to depend upon resolving endlessly convoluted and impossible queries.

If psychological health resides at the edge of chaos, then our infinitely deep fractal edges may be as much a source of renewal, inspiration, and creativity as a source of confusion and pathology. Processes of self-exploration and meditation are potentially endless, recursive endeavors, limited only by the time and energy we wish to invest. Fractal relativity suggests that what we find is linked inextricably to qualities of looking, such as processing time and level of fine-graining. The common character, indeed wonder, of fractal boundaries may be best reflected in the belief, common among transpersonal psychologists, that the true Self contains worlds within worlds that reflect the equally-expansive landscapes of outer worlds.

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