Fractal Entanglement Between Observer and Observed

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ABSTRACT

This article explores paradoxical dynamics embedded in the fabric of existence. The logic of Spencer-Brown, as extended by Francisco Varela, is placed within the historical context of cybernetics. Varela's concept of reentry provides a bridge to fractal geometry through recursive iteration on the complex number plane. Fractals are dynamic process-structures that negotiate spatial and temporal interfaces between various forces and dimensions of existence. This article argues that fractal reentry dynamics provide contradictory foundations by which different levels of nature, including mind and matter, both separate and connect. Finally, natural fractals reveal a new level of reflexivity in science, by which the observer is paradoxically embodied within the observed.

KEYWORDS

Fractal Geometry, Imaginary Numbers, Jung, Paradox, Recursive Dynamics, Reentry, Reflexivity, Second-Order Cybernetics, Spencer-Brown, Varela

INTRODUCTION

Do what you will, this life's a fiction/And is made up of contradiction. -William Blake

We easily take for granted the ability to distinguish between ourselves as observers and what we observe in the world. Outwardly our skin seems visible proof of a clear boundary that encases and protects our organs. Inwardly our sense of self, when intact, also feels like a relatively clear boundary, at times even to the point of isolation from others. Yet whether we consider our bodies or minds, the subjective experience of closed boundaries rests precisely on the opposite state of affairs – wide-open portals that continually allow transaction between inside and outside, body and world, self and not-self.

Open portals are evident in our "posthuman" existence (see Hayles, 1999), where the interface between human being and machine presents boundaries which have grown ever more complex over time, with each technological advance. We plug our consciousness into virtual realities, as we augment, even invade our bodies with the presence of machines. This intense exchange between flesh and mechanism demands nothing short of a redefinition of human subjectivity.

Mystical poets, like William Blake in the above epigraph, allude to life as fiction inherently made up of contradiction. Hinduism offers the concept of *Maya* to describe the false perceptual veil by which we shield ourselves from an ultimately mysterious reality. At higher levels of cognitive organization,

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psychologists study related phenomena. For instance, Shelly Taylor (1989) identifies self-deception in the form of "positive illusions," those overly optimistic attitudes and expectations towards the future that may be entirely unrealistic, but nevertheless which can help us to beat the medical odds.

Despite the complexities of our alleged posthuman existence, most of us live as if consistency, certainty, predictability and clear boundaries, especially between truth and falsity, reside at the base of things, from the workings of our bodies and minds to the workings of the universe at large. Boundaries are everywhere, yet most are permeable. By focusing on this highly contradictory state of affairs that extends invisibly under the surface, I follow Blake's lead to explore the paradoxical dynamics embedded in the very fabric of existence.

This paper traces a line of semiotics and logic, begun by George Spencer-Brown and continued by Francisco Varela, which puts paradox at the heart and seam of things. I place Varela's ideas about reentry within the context of a branch of contemporary mathematics called fractal geometry. I argue that a deep understanding of fractals helps to illuminate the profound yet invisible paradoxes that permeate ordinary life.

To set the stage historically, I begin by briefly describing the cybernetics revolution and how reflexivity first entered social sciences. The primitive logic of George Spencer-Brown, plus extensions added by Francisco Varela, are fitted into this historical context. Varela's dynamics of reentry articulate paradoxical foundations not only for logic and but also for the creation of all structure. Next, I connect these logical assertions with mathematics of the complex plane, where imaginary numbers are used to model extra or hidden dimensionality. Imaginary numbers provide the bridge to fractal geometry, whose mathematics involves recursive iteration of simple formulas on the complex plane.

Fractals are dynamic process-structures that etch time into space. They are boundary keepers that negotiate spatial and temporal interfaces between different forces and dimensions of being. My thesis is that fractals provide the paradoxical foundation by which different levels of nature both connect and separate. Every boundary becomes a door, every border a portal. Because the same dynamics hold inside as well as outside the psyche, fractal geometry provides a bridge and language for linking inside and outside worlds. Whether they occur in nature, our bodies or minds, fractal separatrices or boundaries reveal infinite, hidden frontiers in the space between ordinary, Euclidean dimensions.

I conclude this paper by examining the mechanics of fractal production to reveal a new twist in the reflexive march of science. In a world filled with fractals, not only is the observer detectable in the observed, but the observer is also embodied there, in a primordial, concrete way. Natural fractals, like shorelines, reveal how the embodiment of the observer in the observed paradoxically precedes the presence of conscious observers.

THE CYBERNETIC REVOLUTION

The period following World War II was a time of tremendous intellectual growth in America. Emerging from technology developed during the war, several trends converged to legitimate the scientific merit of psychology, including the birth of cybernetics, the science of information. This new field, spearheaded by the mathematician Norbert Wiener, mushroomed out of the interdisciplinary Macy Conferences held yearly between 1946 and 1953 (See Heims, 1991). Cybernetics brought a new variant of the metaphor of the mind as mechanism. Roots of this idea extend at least as far back as Renaissance times, when the natural sciences, one by one, split off from philosophy. As more empirical studies began, the heart resembled a pump, the body a machine, and the whole universe ran like clockwork.

Mechanistic metaphors are evident within the psychoanalytic theories of Freud, where, for example, the primitive instincts of drive theory resemble hydraulics of the steam engine (see Draaisma, 1995/2000). The cybernetic association between mind and machine made in the mid-20th century proved a boost to the neurosciences, when neural loops in the brain were modeled as logical chains. Mechanistic metaphors also ushered in the cognitivist revolution, as activity in the psyche was likened to information processing in computers.

As humanistic thinkers raged against the 'cold', mechanical, and at times reductionist views being espoused, within the Macy Conferences protests of a different kind began to surface. Lawrence Kubie, a psychoanalyst and recent retread from the "harder" field of neuroscience, stimulated heated discussion among his colleagues by pointing to the problem of reflexivity (See Heims, 1991). Reflexivity, by which an assertion points self-referentially to itself, e.g., "What I say now is false," involves a confluence or melding between observer and observer. Reflexivity is inherent in the very subject matter of psychology. It occurs, for example, whenever researchers use consciousness to understand the nature of consciousness, narratives to study the narratives of others, or behavioral repertoires to examine behavioral responses in others. Research in psychology is like the mythical Uroborus, a snake eating its own tale/tail. Despite every attempt to remain objective by sidestepping subjectivity, even behaviorists can find little relief from the Uroboric beast of reflexivity.

During the Macy conferences, Kubie objected to the early cybernetic agenda of separating information fully from its material, embodied sources. The psychoanalyst protested that within any theory, even inside the "hardest" of sciences, reflexivity lurks, and the observer lies hidden within the observed. Kubie claimed that all theories about the outside world say as much about the unconscious of the subject who espouses them as they do about the outside universe as consciously perceived. When it comes to theory and meaning making, no matter what is observed, the observer winds up implicated in the observed. Although Kubie's protests were dismissed by most of his fellow scientists, his ideas about reflexivity later became ingrained within the history of psychoanalysis. Robert Stolorow and his colleagues (Atwood & Stolorow, 1979/1993), cofounders of intersubjectivity theory, argue that every theory of personality is self-reflexive in that it universalizes the therapist's personal solution to the crises of his or her own life history.

During the early years of the Macy conferences, the notion of science still rested upon the hitherto bedrock foundation of objectivity. By requiring a clear separation of subjects from objects, objectivity was a position that ran contrary to reflexivity. Because early members of the Macy conferences were interested in maintaining science as an explicitly objective enterprise, they chose to ignore Kubie rather than to revise their own ideas. Instead of including reflexivity within the rubric of science, they dismissed psychoanalysis as science.

Generally, during this first wave of cybernetics theory, the problem of reflexivity was successfully avoided by isolating pattern as a separate realm from which all others emanate. When the pattern of information reigns supreme, its material substrate can be first ignored and then eliminated from consideration altogether. According to this view, even without matter the pattern still matters. By removing information entirely from its material sources, the need for observers was also eliminated. We are left with pattern as a virtual reality with neither observed nor observer.

This strategy worked temporarily, but only until the whole enterprise of science began taking a reflexive dive. At the cosmic level of grand-scale events, Einstein's earlier discoveries in physics destroyed the previously immutable framework of space and time. The notion of objective observation stretched and deformed, as relativity theory and the subjective stance of observers took center stage. Meanwhile, at the subatomic level of tiny, quantum events, another field spawned by Einstein's work, consciousness began pushing its way self-reflexively into the middle. The still controversial Copenhagen interpretation asserted that at the quantum level, the very act of observation is necessary to materialize that which is observed.

Even mathematics was not immune from a reflexive fall. In the 1930s, an Austrian mathematician named Kurt Gödel used recursive methods in order to code numbers and then talk about them reflexively at a higher, meta-level of abstraction. In the process, Gödel proved that no single theory could ever provide a simultaneously consistent and complete foundation to logic. Gödel's assertions annihilated any residual hopes for perfect objectivity within the mathematical underpinnings of science.

As reflexivity was seeping into the physical and mathematical sciences, a second wave of cybernetics arose between 1960 and 1985. Spearheaded by Francisco Varela, among others, information scientists became better prepared to embrace reflexivity (see Hayles, 1999). In fact, the very name of this new trend, "second-order cybernetics," amounted to the recursive study of observers studying the higher order processes of observation: the observers observed themselves observing themselves.

POSTMODERNISM

Second-order cybernetics arose within a broad, societal sea change known as postmodernism. Over the years the use of this term has been stretched so far as to encompass practically everything, while being deconstructed so thoroughly as to mean almost nothing. For this reason, I beg to dismiss its broader definition in order to focus upon a single facet, its inherent reflexivity. To symbolize the postmodern imagination, Richard Kearney (1988) offers the recursive symbol of two mirrors reflecting one another. He contrasts this with the premodern imagination, symbolized by a single mirror in which human creativity reflects God's creation, as well as with the modern imagination, symbolized by a lamp in which human creativity is illuminated from within.

Because of its reflexivity, the posthuman imagination becomes lost inside an infinite regress of imitations, copies and simulacra. With origins deconstructed into dust, the postmodern being is often portrayed as rootless, wandering inside a mechanical, artificial desert of re-production. Within this bleak frontier, on the one hand, the demise of human creativity and originality is decried. On the other hand, there looms the cybernetic threat of machines usurping the very autonomy, indeed existence, of their humanist creators.

In *How We Became Posthuman*, English professor Katherine Hayles (1999) details the threatened destruction of embodied existence. She analyzes cyberpunk novels with heroes that evaporate into virtual reality as their consciousness becomes thoroughly enmeshed and encapsulated within machines. The flip side of this futuristic nightmare portrays machines sophisticated enough to take over the evolution of life itself. As artificial intelligence becomes increasingly equipped with emotion, creativity, the capacity to learn, self-repair and self-generate, this sci-fi genre depicts humanoid machines that threaten to extinguish carbon-based evolution as we know it, replacing it with the far-superior, silicon-based life forms.

As posthuman boundaries have become more blurred and human beings self-reflexively entangled with facets of their own technological production, lines between observers and observed continue to grow more complex. As reflexivity is integrated more and more consciously into cybernetics, one positive outcome is that the door is thrown open for the scientific study of subjectivity. Since subjects can now study their own subjectivity, consciousness itself has recently regained status as a legitimate and serious object of scientific study. Ever sophisticated capacity for functional brain scans now blends first and third person perspectives (Northoff & Heinzel, 2006), while the new field of hyperscanning (e.g., Babiloni & Astolfi, 2014; Dumas et al., 2011) allows simultaneous brain measurement of two subjectivities in interaction with one another.

In the postmodern view, reflexivity is often viewed as a by-product of modern technology constructed in the context of particular social and economic trends. Contemporary methods such as neural feedback even allow us to become active observers of our own brain processes. Inarguably, computer-driven, cybernetic extensions of our perceptual and conceptual apparatuses do help us to detect, direct and even create reflexivity with greater ease. Yet I believe that the roots of reflexivity are much deeper and more organic than social and historical trends suggested by postmodernism. I maintain that the discipline of fractal geometry provides evidence that reflexivity is intrinsic not only to human-made productions, but also to nature at large.

Fractals help us to advance beyond the cybernetic metaphor of psyche as mechanism to the more organic one of nature, including human nature, as fractal. Here mechanistic means of computer simulation reflexively guide us beyond mechanism, as we circle back to a different kind of origins, for both human and machine, in fractal bases of nature. Before turning to fractal geometry itself, the section to come presents Spencer-Brown and Varela's logical underpinnings for reentry dynamics as they are embedded in the very fabric of creation.

CONTRADICTION BUILT INTO THE FABRIC

A great truth is a truth whose opposite is also a great truth. -Neils Bohr

When developing his "Laws of Form," mathematician and logician George Spencer-Brown (1969; 1979) tried to specify how we create "some-thing from no-thing" in consciousness (See Robertson, 1999). Spencer-Brown used a 2-valued system that consisted only of "marked" and "unmarked" states plus two axioms. From these simple bases, he derived a calculus of first distinctions. Although it is commonly believed that George Boole (1958) developed the most basic form of logic, Spencer-Brown disagreed, claiming his own calculus is so primordial as to provide a cradle not only for logic itself, but also for the basic structure of any universe.

Within Spencer-Brown's system, one distinguishes marked from unmarked states by attributing value to one state over the other. This act of marking or making a distinction requires an observer. We can readily understand this requirement for logic: to make a mark, apply a set of axioms, or distinguish truth from falsity, a conscious observer must be present. But how does this process of valuation apply to more primitive levels of a system that supposedly precede logic and even people? Is an observer implicated along with the observed there too? I will return to this issue in my subsequent discussion of fractal geometry.

As Spencer-Brown progressed with his work, he used basic axioms to derive higher degree equations. But then something strange began to happen: anomalies appeared; reentry of equations back into themselves sometimes resulted in paradox. This occurred when marked states became equated with unmarked ones. Spencer-Brown offered an interesting interpretation. Rather than to view this as the simultaneous presence of contradictory states, he suggested an alternative. Maybe the system was oscillating between opposite states in time. If so, then self-reflexive acts of reentry, or self-indication, would add the dimension of time to that of space already implied by first distinctions. Given enough time, both marked and unmarked can exist in the same space.

Neuroscientist and researcher Francisco Varela was intrigued by Spencer-Brown's ideas, especially by his explanation for the dynamics of reentry. Varela (1975; 1979) developed "A Calculus of Self-Reference" to extend Spencer-Brown's work. In so doing, he took a bold, if not radical leap. Rather than to conceptualize reentry as characterizing higher degree equations only, Varela proposed that reentry be added at the ground floor, as its own term, along with the other two marked and unmarked states.

This simple difference made all the difference, as Gregory Bateson might have said. It signaled Varela's departure from Aristotelian logic, which had held an iron grip around philosophers and logicians for millennia. Varela abandoned Aristotle's dichotomous system, where all propositions are either only true or false; its law of identity, where *A* can never equal *not-A*; as well as its law of the excluded middle, where the space between truth and falsity is pristinely empty.

By adding reentry as a third term, Varela opened up an infinitely deep, Pandora's box of middle ground filled with fuzzy grays, lost identity, and unfathomable complexity. Here not only can something be true and false simultaneously, but even more, Varela actually believed that the existence of autonomy in nature depends upon this contradictory state of affairs. Varela and his mentor, Humberto Maturana, coined the term "autopoeisis" to explain how biological systems self-organize (Varela, Maturana and Utribe, 1974). With reentry dynamics at the core, autopoeitic systems embody paradox at their boundaries, expressing their autonomous functioning through remaining functionally closed, yet structurally open.

By asserting reentry as a third value in its own right, Varela agreed with Spencer-Brown that self-referential dynamics establish the presence of time. But he went even further, to assert that paradox becomes embodied at the most basic level, *in the very form itself.* Whether in organic or inorganic forms, autonomous systems appear supported by inherently contradictory underpinnings.

IMAGINARY NUMBERS AND HIDDEN DIMENSIONS

The shortest path between two truths in the real domain passes through the complex domain. -Jacques Hadamard

To visualize how paradox becomes embodied into form, it helps to understand imaginary numbers. When Spencer-Brown interpreted contradiction as oscillation, he likened his 'discovery' of time to that of the complex number plane:

When Spencer-Brown introduces reentry and arrives at an expression equivalent to its content, f = f⃧, what we call a self-cross, he notes its disconnection with his arithmetic and thus chooses to interpret it as an imaginary state in the form seen in time as an alteration of the two states of the form. This interpretation is, in my opinion, one of his most outstanding contributions. He succeeds in linking time and description in a most natural fashion. (Varela,1975, p. 20)

This linkage may be even deeper than mere analogy. Imaginary numbers, discovered in the 17th century, by the Italian mathematician Jerome Cardan, involve two orthogonal axes, one real and one imaginary, and the seemingly impossible square root of –1. As their name suggests, these numbers originally were considered entirely fanciful. Although they kept cropping up in equations of the form, $X^2 = -1$, they were originally believed to have no practical applications.

Yet as often occurs with even the most far-out seeming mathematical abstractions, unexpected practical uses are eventually found, sometimes in the strangest places. For example, non-Euclidean geometry was originally thought impractical because it seems to contradict everyday perception. Yet its rather strange geometry perfectly models the curved space-time of Einstein's equations.

Such has been the case for imaginary numbers as well. Generally, within mathematical equations, the square root of -1 represents invisible, extra or hidden dimensionality. For example, in electrical engineering it models reversed polarities of alternating currents. In Einstein's famous equation, $E = mc^2$, the square root of -1 represents the 4th dimension – time – added to the three customary dimensions of space – length, width, depth. Imaginary numbers also crop up in quantum mechanics, where they capture (or fail to do so) immeasurable, nonlocal aspects of electron behavior known as "wave functions." Generally, it appears that those artificially constructed "fictions" called imaginary numbers keep emerging in the very same, reflexive places where the observer is increasingly detectable within the observed.

When Einstein revolutionized physics with his work on relativity in the early 20th century, most lay people felt his theories to be beyond their comprehension. Yet Einstein's ideas did find a way to filter down to a segment of the population. Rather than to interpret the 4th dimension narrowly as time, it became fashionable to view this extra dimension more broadly, as the interior space-time of imagination or even consciousness itself.

As mentioned, at about the same point in history, consciousness began occupying center stage in quantum mechanics, where what was found at the microscopic level seemed to depend entirely on methods of observation. The Copenhagen interpretation asserts that in order to collapse the quantum waveform from a state of infinite potentiality, where anything is possible, to that of material reality, where only one possibility is actualized, an observer is required.

Here we have observers postulating the necessity of their own observations to bring into existence the phenomena under observation. Quantum mechanics was closing a loop on itself, by self-referentially implicating consciousness into the phenomenon under study. While an objectivist's nightmare, the zeitgeist seems to have arrived for the recursive inclusion of the observer within the observed.

Inside the realm of psychology, a neophyte field devoted entirely to the reflexive enterprise of consciousness circling back around to examine itself, imaginary numbers also were coming into play. Carl Jung considered the concept of number highly significant to the psyche (see Robertson, 2000). In fact, the Swiss psychiatrist came to view number as the most basic archetype of all. Although unable to unfold many details, Jung conceived of number as providing the basis for a unified stratum, which he termed a *psychoid* level, where inner and outer, mind and matter meet as one.

Mistakenly, Jung called imaginary numbers transcendent ones and named a corresponding psychological function – the transcendent function – after them. Jung interpreted real and imaginary aspects of the complex plane in terms of the union of conscious and unconscious contents of the psyche. This union, for Jung, constitutes the essence of individuation, the process by which we each come most fully into ourselves. During individuation, the "little self" of the conscious ego aligns and balances with the "big Self" of the unconscious whole: the known coincides with the unknown.

Through lenses of Varela's recursive dynamics, the individuation process itself can be seen self-reflexively as a lifelong cycle of reentry. I and my colleagues (Marks-Tarlow, Robertson & Combs, 2002) have described the evolution of consciousness in terms of such cycles. Psychological birth is preceded by the paradoxical union of opposites within the unconscious, as we begin our mental life with good/bad, you/me, inside/outside melded together. In order to make distinctions, nascent consciousness must separate each pole from its opposite. This includes conscious from unconscious elements. And yet, complete psychological evolution requires that we bring together or balance all opposites, including conscious and unconscious realms into a *coincidentia oppositorium, a coincidence of opposites*.

I (Marks-Tarlow, 2008, 2010) suggest that all psychological development possesses paradoxical underpinnings. For example, spiritual advancement can be characterized as the use of self-reflection to achieve increasing objectivity. Yet to follow a path towards "objectivity," is to attempt to step outside ourselves and undertake an endeavor in which, by definition, we can't succeed. For we can never step fully outside ourselves. What is more, most spiritual paths aimed towards objectivity involve paradoxically moving in the exact opposite direction, e.g., using methods of meditation, to delve yet further inside our own subjectivity.

In terms of mathematical modeling, followers of Jung and Einstein played with the idea that imaginary numbers can serve to unify inner and outer worlds. Physicist, psychologist Arnold Mindell (2000) makes a similar assertion, believing all mathematics to be a code for linking observers with the observed. Metaphorically Mindell believes imaginary numbers represent qualitative, subjective aspects of experience, or what he calls "nonconsensual reality." His thinking is influenced by Wolfgang Pauli, a physicist whose dreams inspired Jung to write some of his most important work. Perhaps Pauli's most famous dream involves an inner music teacher who conceptualizes imaginary numbers as the key to unifying physics and psychology (See Wolf, 1994).

I also speculate within the arena of imaginary numbers as a method for invisibly unifying previously separated levels (Marks-Tarlow, 2004, 2012, in press). Fractals are cycles of reentry recursively iterated on the complex number plane. They describe qualitative rather than quantitative aspects of nature, such as the ruggedness of a coastline or the jaggedness of a mountain chain. Since imaginary numbers model hidden dimensionality, in the case of fractals, this consists of infinite expanses lurking in the spaces between ordinary, Euclidean dimensions.

Fractals appear to connect as well as separate inner and outer levels in at least two ways. One is by offering a lexicon of complexity, which applies equally as well to nature around us as it does to human nature inside us. The ability of fractals to describe and unify inner and outer worlds helps to flesh out Gregory Bateson's largely unformulated intuition (1979) concerning 'a necessary unity' of mind and nature. Secondly, fractal separatrices comprise complex boundary zones between various realms of existence, spanning levels from the "lowest" material to the "highest" spiritual realms.

FRACTAL GEOMETRY

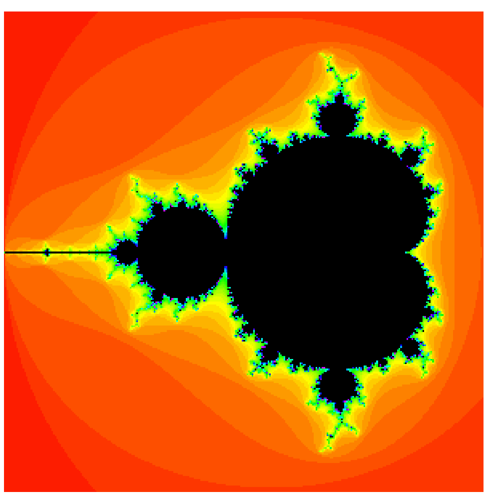
Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line. -Benoit Mandelbrot

Computer-generated fractals provide the most successful tool ever found for simulating nature. To create a mathematical fractal, a very simple formula, such as the original one discovered by the French engineer Benoit Mandelbrot (1977), $z \rightarrow x^2 + c$, is iterated recursively for every point of the complex plane. This means that the same formula is plugged in over and over, with the end products fed back in as new starting points. In theory, this continues indefinitely. In practice, it continues until either the equation settles down to a stable outcome or an arbitrary point is reached indicating a clear direction (see Figure 1).

When observing a fractal image rendered by computer iteration, three distinct zones are apparent. There is the inside of a fractal, which in the case of the Mandelbrot set, is usually indicated by a solid black zone representing stability. Here on the complex plane, the equation converges to order in the form of periodicity, by displaying one or more stable end-points. By contrast the zone outside of the fractal, symbolized by various color gradations, represents the part of the complex plane where the very same equation flies out of control, moving towards infinity at various speeds. The third and most interesting zone consists of the edge between these two. This is the real fractal, which is infinitely deep when the computer is used as a microscope to zoom in at smaller and smaller scales. Here, iteration neither settles down to stability nor flies off to infinity, but instead exhibits unceasing complexity shifting dynamically with the perspective of the observer.

Whether rendered on a computer or found in nature, the hallmark of a fractal is self-similarity. Self-similarity is a newly discovered, self-reflexive symmetry in which part of any natural fractal bears resemblance to the whole thing. Sometimes this resemblance is exact, as in the case of linear fractals, like the Koch snowflake or Cantor dust. Other times, the resemblance is approximate or statistical, as in the case of the Mandelbrot set or other nonlinear fractals. Whereas linear fractals tend to be abstract and idealized mathematical forms, nonlinear tend to be realized in nature. Clouds, mountains, coastlines, and other branching shapes are all part of the natural lexicon of fractals. With fractals, instead of the whole being greater than the sum of its parts, the whole can be detected within the part at multiple scales of observation.

Figure 1. Computer-generated fractals



PARADOXICAL BOUNDARIES

While mountains and rivers appear to be stable "things" to our Western minds, they are instead continually moving processes that evolve dynamically on various time scales. The fiction of stability and "thingness" is reified by the English language, as dominated by nouns acted upon by verbs. The dynamism of fractals in nature seems much more consistent with several American Indian languages, where features such as lightning and coastlines are described as processes using verbs.

As embodied in nature, fractals occupy the complex interface between chaotic forces, such as that between wind, water and heat comprising the weather. However slowly they may move, clouds, riverbeds and mountains are all dynamic processes. They involve recursive cycles of reentry by which time gets etched fractally into self-similar form. Clouds are fractals whose rapid movement provides a minute-to-minute account of wind and weather conditions. Rivers embody minute-to-minute dynamics, but also globally occupy an intermediate time frame of evolution: the present riverbed is but the latest in a series of configurations whose evolution can be traced on the canyon walls. Mountains and hills have the entire history of creeks, rivers, wind and other weather-related forces etched into their rock surfaces over eons.

Fractal dynamics also pervade our bodies (e.g., Iannaccone and Khokha, 1996). Elsewhere (Marks-Tarlow, 2002, 2008) I suggest that fractals comprise zones of communication and transportation between various organs and subsystems of the body, as well as between the body and the outside world. Blood circulates throughout the body in the fractal branching of arteries and veins. The lungs cycle oxygen in and carbon dioxide out through fractal bronchioles. Even the neural pathways in the brain, our main organ for perception and communication, are fractal.

Skin pores, wrinkles and other markings on the "sacks" in which humans and other animals are enclosed are fractally distributed. Self-similar dynamics also pervade psychophysics, by which physical stimuli outside our bodies are transmuted to perception and sensation inside. In human physiology generally, as in nature broadly, fractals serve paradoxical functions as boundary keepers, both to separate and connect various subsystems and levels of being.

Elsewhere (Marks-Tarlow, 1999; 2002, 2008, 2011) I also describe the existence of fractals at a more abstract, symbolic level in the psyche. In the paradoxical space between self and other, fractal dynamics arise in human behavior, as personality traits manifest in self-similar patterns evident at multiple scales of existence. For example, aggressive people may push others aside verbally with overtalk, push ahead of others physically in lines at the bank, while pushing their needs ahead of others' in significant relationships. From micro to macro levels, each instance occurs self-similarly at different scales of social observation. From this brief description of fractals as they occur naturally, it becomes clear that self-similar dynamics span the full range of existence, from the most concrete, material levels to the most highly abstract and psychological ones.

At the abstract level, self-similar dynamics are also evident in the logic of Charles Peirce (e.g., 1998). Within his triadic system and the semiotics based upon it, the *first* is the object; the *second* is the interpretant; and the *third* is the sign. The sign expresses a general or abstract relation between the first and second, and carries the meaning of this relationship. Because each sign can itself be the first for other signs, within *unlimited semiosis*, this system operates as an infinitely recursive network of re-entrant loops, each reflecting back upon the others in self-similar fashion.

Søren Brier (2010) described an ontological framework of cybersemiotics in order to understand the emergence of form, life, mind and consciousness. Nature is viewed in terms of multilevel, multidimensional hierarchies of inter-related clusters that form a metaheterarchy, or heterogeneous general hierarchy. As new levels emerge via related processes, there is self-similarity across levels by which general, translevel principles can be abstracted and placed into a Peircean perspective. Potentialities (firstness) are causally manifested as constraints and forces (secondness), while meaning is created by integrating manifestation with potentiality into regularities and patterns (thirdness). The process continues recursively, with each new, emergent level serving as potential for the development of the next.

In general, self-similar dynamics appear in the joints, in the space between levels, relations and dimensions. They supply boundaries that are infinitely deep and paradoxical. I propose that fractals comprise Varela's (1979) realm of "autonomous functioning," which operates with borders that are functionally closed while remaining structurally open.

FRACTAL DIMENTIONALITY

The imaginary numbers are a wonderful flight of God's spirit; they are almost an amphibian between being and not being. -Leibniz

As they occur around and inside our bodies, fractals occupy the complicated interface *between* various forces in nature. As they occur in the psyche, fractals arise out of endless feedback loops between self and other in relationships. Our sense of self, once again paradoxical in being both open and closed, arises dynamically in the transitional *space between* people.

It appears that everywhere they arise, fractals occupy the boundary zone between. This can be illuminated with a technical understanding of fractal dimensionality, as mathematically, fractals reside in the infinitely complex space *between ordinary Euclidean dimensions*. Clouds are composed of water vapor, zero dimensional points that occupy three-dimensional space. A coastline is a one-dimensional line that occupies a two-dimensional plane. Mountains are two-dimensional surfaces draping a three-dimensional world. Quaternions are products of the hypercomplex plane consisting of one real and three imaginary axes. Because they are three-dimensional shadows of four-dimensional space, if the fourth dimension really does relate to consciousness, quaternions may provide some clues to the internal landscape of higher dimensional thought.

To calculate fractal or Hausdorf dimension (one of many possible ways to measure fractal dimensionality) a log/log relationship estimates the rate at which more information becomes available to us as we shrink the size of our measuring device. Logarithms involve exponents of the powers to which a base number must be raised to equal a given number. For example, the logarithm of 100 in base 10 is 2. We can get a feel for the nonlinearity of logarithms by considering the Richter scale, a logarithmic scale measuring the power of earthquakes. On any logarithmic scale, the distance from the origin to any mark is proportional to the logarithm of the number attached to that mark. On the Richter scale, an earthquake of magnitude 8.0 is not twice as powerful as one measuring 4.0, which would indicate a linear relationship between marks. Instead, a magnitude of 8.0 is 10 x 10 x 10 x 10 times more powerful than one of 4.0.

The log/log graph used to calculate fractal Hausdorf dimension plots one logarithmic relationship against another – the rate by which more information becomes available as we shrink the size of our measuring device. In the log/log relationships of fractal dimensionality, a kind of magic becomes evident: an unexpected relationship exists between the observer and the observed, i.e., between the measuring device we use and that which we measure. With fractal objects, because this same relationship holds at every scale of measurement, we wind up with self-similar pattern.

With mathematical fractals, the smaller our measuring sticks, the larger the measurement. Because the quantity of measure continually alters relative to the size of the yardstick, we can see that on a deep level, fractal dimension is *not* a measurement of *quantity* as we usually conceive it. Instead, it measures the *quality of relations between observer and observed*. This is what remains constant with fractals as we change scales. This is also why fractal pattern turns out to be scale invariant.

With fractals, sticking to quantitative measurement only leads to paradox, precisely because the smaller our measuring device, the longer the measurement. At the limit of an infinitely small device, we will obtain an infinitely large measurement. This led Mandelbrot's (1977) to his famous conclusion that the length of any stretch of coastline is infinitely long. As often happens in science, paradox is averted through new discovery. In this case, expanding the traditional notion of dimensionality into the fractional embodies paradox as it redefines new relations between observers and the observed.

THE OBSERVER IN THE OBSERVED

In the characterization of organizational closure, nothing prevents the observer himself from being part of the process of specifying the system, not only by describing it, but by being one link in the network of process that defines the system. -Francisco Varela

Whether existing abstractly, in the phase space underneath chaos, in physical or material form or psychologically, fractals implicate the observer in the observed. This is apparent in the notion of fractal separatrices, where inside and outside, self and other, spirit and matter are paradoxically separated through fractal boundaries, yet hopelessly entwined. In the previous section, we also saw how the observer lies hidden in the observed as built right into the very concept of fractal dimensionality. This gives us a clue about reflexivity even at the most primitive levels of macroscopic existence.

On every level, recursive cycles of reentry seem to etch temporal dynamics into spatial form. Varela (1975) suggested that self-reference is "the hinge upon which levels of serial inclusiveness intercross."

It appears as if different, successively larger levels are connected and intercross at the point where the constituents of the new lower level refer to themselves, where antinomic [contradictory] forms appear, and time sets in. We recognize this fact in ordinary speech. When trying to convey a description of a new domain we often construct an apparent antinomy to induce the listener's cognition in a way such as to compel his imagination towards the construction of a larger domain where the apparent opposites can exist in unity. (A moral example: once you lose everything, you have everything; a philosophical one: a being is when it ceases to be) (p. 22).

It is easy to view the universe in terms of successively larger levels of serial inclusiveness. As a crude example, physics is embedded within chemistry, which is embedded within biology, which is embedded within psychology. Grim, Mar and St. Denis (1998) have pioneered the use of fractal geometry to envision formal systems, including the representation of paradox and incompleteness.

I propose fractal dynamics to be one way to conceptualize how Varela's levels of serial inclusiveness connect and intercross. Whether comprising attractors beneath chaotic forces in nature, including human nature, whether existing in physical or symbolic form, fractals negotiate the boundary zone, the place where levels contain the antinomy of opposites both unified and separated. Because fractals span all levels, separating and connecting them at boundary points, these dynamics might help to bridge traditional levels of analysis, from the purely physical level of Prigogine's far-from-equilibrium thermodynamics, through biological levels of reentry in Maturana and Varela's autopoietic systems, to the higher order social and cultural levels implied by Peirce's concept of historical drift and praxis.

The irony is this. While we may use 'unnatural' or mechanical means, such as computers, to discover and illuminate the workings of fractals, what we illuminate extends beyond and beneath the postmodern mirrors that reflect infinite regression in forms of human production and reproduction. By illuminating fractals, we self-reflexively illuminate the observer in the observed in nothing short of nature herself.

This insight dovetails with the frequent religious vision of all of creation as a self-reflexive expression of self into form to know, share and lovingly reunite with Self. It also dovetails with the position of neurological positivism espoused by philosopher and psychologist Larry Vandervert (1990). Vandervert claims that evolution itself proceeds self-reflexively, culminating in the most complex object in the known universe, the human brain. As we use our brains self-reflexively to examine ourselves, our models grow more sophisticated and ever closer to the fractal stuff of which our minds, brains and nature at large is composed.

CONCLUSION

With fractals as a new metaphor of mind, we no longer need to deify or defile mechanism as metaphor. Instead we can use mechanism as a tool. As we continue to use the recursive formulas of chaos, complexity, fractal geometry and cellular automata to simulate the natural world, we see across multiple, nested levels of serial inclusiveness, that self-similar fractal dynamics recur as a meta-pattern. Cycles of reentry continually oscillate between creating and erasing the seam where observer and observed, perceiver and perceived, inner and outer, self and other, intersect and self-cross paradoxically. At this seam, self and world appear mutually co-determining. This is where the act of making a distinction creates the world as we perceive it, and where the world brings distinction to the consciousness of the perceiver.

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