Title: Some-thing from No-thing: G. Spencer-brown’s Laws of Form.

Abstract: G. Spencer-Brown’s *Laws of Form* is summarized and the philosophical implications examined. *Laws of Form* is a mathematical system which deals with the emergence of anything out of the void. It traces how a single distinction in a void leads to the creation of *space*, where space is considered at its most primitive, without dimension. This in turn leads to two seemingly self-evident “laws”. With those laws taken as axioms, first an arithmetic is developed, then an algebra based on the arithmetic. The algebra is formally equivalent to Boolean algebra, though it satisfies all 2-valued systems. By following the implications of the algebra to its logical conclusions, self-reference emerges within the system in the guise of re-entry into the system. Spencer-Brown interprets this re-entry as creating time in much the same way in which distinction created space. Finally the paper considers the question of self-reference as seen in Francisco Varela’s *Principles of Biological Autonomy*, which extended Spencer-Brown’s *Laws of Form* to a 3-valued system.

SOME-THING FROM NO-THING:

G. SPENCER-BROWN'S LAWS OF FORM

> The knowledge of the ancients was perfect. How so? At first, they did not yet know there were things. That is the most perfect knowledge; nothing can be added. Next, they knew that there were things, but they did not yet make distinctions between them. Next they made distinctions, but they did not yet pass judgements on them. But when the judgements were passed, the Whole was destroyed. With the destruction of the Whole, individual bias arose.
>
> \- Chuang Tzu.

Anyone who thinks deeply enough about anything eventually comes to wonder about nothingness, and how something (literally some-thing) ever emerges from nothing (no-thing). A mathematician, G. Spencer-Brown (the G is for George) made a remarkable attempt to deal with this question with the publication of *Laws of Form* in 1969. He showed how the mere act of making a distinction creates space, then developed two "laws" that emerge ineluctably from the creation of space. Further, by following the implications of his system to their logical conclusion Spencer-Brown demonstrated how not only space, but time also emerges out of the undifferentiated world that precedes distinctions. I propose that Spencer-Brown's distinctions create the most elementary forms from which anything arises out of the void, most specifically how consciousness emerges. In this paper I will introduce his ideas in order to explore the archetypal foundations of consciousness. I'll gradually unfold his discoveries by first outlining some of the history of ideas that lie behind them.

George Boole's Laws of Thought

> Pure mathematics was discovered by Boole in a work which he called *The Laws of Thought*.

- Bertrand Russell.

In the 1950's Spencer-Brown left the safe confines of his duties as a mathematician and logician at Cambridge and Oxford to work for an engineering firm that specialized in electronic circuit networks, including those necessary to support the British railways system. Networks are composed of a series of branching possibilities: left or right, this way or that way. At each junction, a choice must be made between several possibilities. From a mathematical perspective, a choice between multiple branches can be reduced to a series of choices between only two possibilities. Thus network design involved virtually identical problems with logic, where one constructs complex combinations of propositions, each of which can be either true or false. Because of this, the firm hoped to find in Spencer-Brown a logician who could help them design better networks. Spencer-Brown in turn tried to apply a branch of mathematics known as Boolean algebra to their problem, initially to little avail, as we will see. Before we present Spencer-Brown's ideas, we need to know a little about the first attempt by mathematics to deal with the problems of opposites in the mind: Boolean Algebra.

By the mid-19th century, mathematics was undergoing a sea-change. Where previously mathematics had been considered the "science of magnitude or number", mathematicians were coming to realize that their true domain was symbol manipulation, regardless of whether those symbols might represent numbers. In 1854, the English educator and mathematician George Boole [1815–1864] produced the first major formal system embodying this new view of mathematics, an astonishing work: *Laws of Thought*. His ambitious purpose was no less than capturing the actual mechanics of the human mind. In Boole's words: "The design of the following treatise is to investigate the fundamental laws of those operations of the mind by which reasoning is performed; to give expression to them in the symbolical language of a

Calculus, and upon this foundation to establish the science of Logic and construct its method" (Boole, 1854/1958, p. 1).

With some degree of hyperbole, philosopher and logician Bertrand Russell once said that "pure mathematics was discovered by Boole in a work which he called *The Laws of Thought*" (Boyer, 1985. p. 634). In contrast, Boole was not only ambitious, but realistic; even in the throes of his creation, he understood that there was more to mathematics than logic, and certainly more to the mind than logic. In a pamphlet Boole's wife wrote about her husband's method, she said that he told her that when he was 17, he had a flash of insight where he realized that we not only acquire knowledge from sensory observation but also from "the unconscious" (Bell, 1965, pp. 446-7). In this discrimination, Boole was amazingly modern. He was intuiting a new approach to explore the fundamental nature of archetypal reality at its most basic level. G. Spencer-Brown was to bring that new approach to fruition.

Algebra vs. Arithmetic

> To find the arithmetic of the algebra of logic, as it is called, is to find the constant of which the algebra is an exposition of the variables—no more, no less. Not just to find the constant, because that would be, in terms of arithmetic of numbers, only to find the number. But to find how they combine, and how they relate—and that is the arithmetic.
>
> - G. Spencer-Brown (1973).

Spencer-Brown quickly discovered that the complexity of real world problems far exceeded those he had studied in an academic setting. He started out using traditional Boolean algebra, but found he needed tools not available in Boolean algebra. In essence he needed an arithmetic, which was a problem as Boolean algebra was commonly considered the only algebra that doesn't have an arithmetic. Now what is the difference between arithmetic and algebra? Put most simply, arithmetic deals with constants (the familiar numbers 1, 2, 3,…for the arithmetic we all grew up learning to use), while algebra deals with variables. Again, if you cast your mind back to the algebra you may have taken in junior high school, high school or college, variables are simply symbols which can stand for unknown constants. That is, an X or a Y or a Z might represent any number at all in an equation.

Boole had formed his logical algebra by close analogy to the normal algebra of numbers, using the normal symbols for addition, subtraction and multiplication, but giving them special meanings for logical relationships. In his “algebra”, the equivalent of numbers were simply the two conditions: “true”and “false”. Just as the solution to an equation in normal algebra is a number, the solution to an equation in Boolean algebra is either “true” or “false”.

Boole’s concept of making his algebra almost exactly parallel to numerical algebra (in the symbolic form that it was normally presented), made it easier for later mathematicians to understand and accept (though, as is unfortunately all too usual, that had to await his death.) But the symbol system most usual for numeric algebra isn’t necessarily the best for logical algebra. In practice, complicated logical statements lead to complicated Boolean equations which are difficult to disentangle in order to determine whether or not they are true. And the absence of an arithmetic underlying the algebra meant that one could never drop down into arithmetic to solve a complex algebraic problem.

Since computers and other networks deal with just such binary situations—yes or no, left or right, up or down—it was natural to look to Boolean algebra for answers for network problems. But because Boolean algebra had developed without an underlying arithmetic, it was exceptionally difficult to find ways to deal with the problems.

Spencer-Brown was forced backwards into developing an arithmetic for Boolean algebra simply to have better tools with which to work. As with so many of the hardest problems encountered in mathematics, what he really needed was an easily manipulable symbol system for formulating problems. Mathematicians had grown so used to Boole's system, which was developed as a variation on the normal algebra of numbers, that it never occurred to them than a more elegant symbolism might be possible. What Spencer-Brown finally developed, after much experimentation over time, is seemingly the most basic symbol system possible, involving only the void and a distinction in the void.

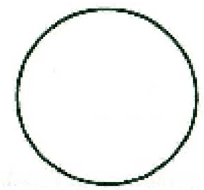
The Emergence of Some-thing from No-thing

> Nothing is the same as fullness. In the endless state fullness is the same as emptiness. The Nothing is both empty and full. One may just as well state some other thing about the Nothing, namely that it is white or that it is black or that is exists or that it exists not. That which is endless and eternal has no qualities, because it has all qualities.
>
> C. G. Jung (1920/1983).

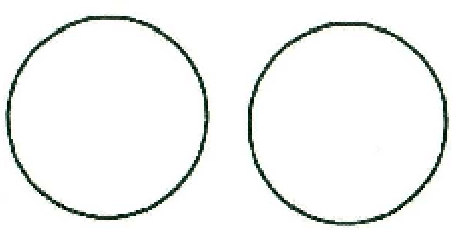
Try to imagine nothingness. Perhaps you envision a great white expanse. But then you have to take away the quality of white. Or perhaps you think of the vacuum of space. But first you have to take away space itself. Whatever the void is, it has no definition, no differentiation, no distinction. When all is the same, when all is one, there is no-thing, nothing. Paradoxically, in Jung's words: "nothing is the same as fullness."

Now make a mark, a distinction, within this void. As soon as that happens, there is a polarity. Where before there was only a void, a no-thing, now there is the distinction (the mark) and that which is not the distinction. Now we can speak of "nothing" as some-thing, since it is defined by being other than the distinction.

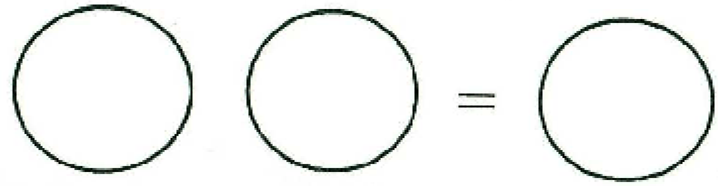
Don't throw up your hands in despair at trying to understand the abstract nature of all this. Let's bring it down to earth with an example. For our void, our nothingness, imagine a flat sheet of paper. Let's imagine that it has no edges, that it keeps extending forever. In mathematics this is called the plane. Of course, this infinitely extended piece of paper isn't really nothing, but it is undifferentiated—every part of it is the same as every other part. So it can at least be a representation of nothing. Now draw a circle in it, as below. You'll have to imagine also that this circle has no thickness at all. It simply separates two different states, which we would normally think of as "inside" and "outside." Following Spencer-Brown's terminology, we'll call this the "first distinction."



Where before there was no-thing, drawing the circle creates two things: an inside and an outside (of course, we could just as readily call the outside the inside and vice versa. The names are arbitrary.) Let that which is enclosed be considered the distinction, the mark, and what is outside "not the mark" (remember, the circle has no thickness whatsoever.) Now, of course, any distinction whatsoever would do. Any difference one could make which would divide a unitary world into two things would be a proper distinction. Freudians like to point to an infant's discovery that the breast is separate from itself as the first distinction that leads to consciousness. For many early cultures, the first mythological distinction was the separation of land and sea, or light from darkness. In Jungian work, one first draws a circle, a mandala *in potentia*, into which one projects emerging distinctions in one's personality and consciousness. But there are infinitely many distinctions possible within the world.

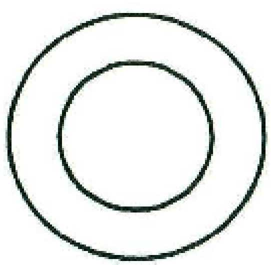


Now let us flesh out this space we have created, discover its laws. Start by drawing a second circle beside the one we've already drawn. Imagine you are blind and wandering around the plane represented above. You bump up against one of the circles and pass inside. After wandering around inside a while, you come up against the edge of the circle again and pass outside. Wandering some more, you encounter the edge of the second circle and again pass inside, then later outside. Is there any

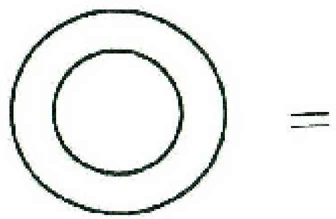


way you could possibly know that there were two circles, not one? How could you know whether you had gone into one of the circles twice or into both circles once? All you could know was that you had encountered what you regarded as an inside and an outside. Hence for all practical purposes, two distinctions (or three, or a million) of the same nature are the same as one. Nothing (remember literally no-thing) has been added. Spencer-Brown calls this the law of condensation; i.e., multiple distinctions of the same sort simply condense into a single distinction.

Are there any other laws we have to find about this strange two-state space? Bear with me, there is only one other situation to consider. Let's go back to our original circle, the "first distinction." Let us draw a second circle, but this time draw it around the first, creating nested circles.



Once more imagine you are blind, wandering around the plane. You encounter the edge of a circle and pass within, thus distinguishing what you consider to be inside and outside. Once inside, you wander some more, then again you encounter the edge of a circle and pass outside. Or did you? Perhaps the edge you encountered was the edge of the inner circle and you passed within it. You are not able to distinguish between the inside of the inner circle and the outside of both circles. (I hate to keep reminding you that our circle has no thickness at all, it merely divides the world into two states.) In such a world, two insides make one outside.



Let's assume that the outer circle stretches farther and farther away from the inner circle until you are no longer aware that it even exists. As far as you are concerned there is only the single circle through which you pass inside or outside. But a godlike observer who could see the whole plane would realize that when you passed inside the inner circle, you were actually reentering the space outside the outer circle. It all depends on how privileged your perspective. Nested distinctions erase distinction. Spencer-Brown refers to this principle as the law of cancellation.

These two laws govern all two-valued worlds. We recognize that the tension between conscious and unconscious is as old as life itself. Even the simplest one-celled creature has to distinguish between food, which it wants to eat, and danger, from which it needs to flee. It is forced to make a Spencer-Brown distinction, to take one or the other of two paths. Life began by first developing the skill to make distinctions, to create boundaries, at the molecular level. Evolution progresses by making ever more complex distinctions until the emergence of consciousness itself. From the extension of Spencer-Brown's perspective that we are presenting here, we could say that consciousness itself is the progressive emergence of a self-reflective, recursive cycle of ever more subtle distinctions. Mathematician Norbert Wiener invented the term "cybernetics" to investigate the self-reflective, informational dynamics of such distinctions. And consciousness emerges ineluctably from the process of making distinctions.

Laws of Form

> Although all forms, and thus all universes, are possible, and any particular form is mutable, it becomes evident that the laws relating such forms are the same in any universe.

- G. Spencer-Brown, 1979, p. xxix).

These two laws are the only ones possible within the space created by a distinction. No matter how many distinctions we choose to make, they simply become combinations of paired or nested distinctions.

These almost transparently obvious laws are all that Spencer-Brown needed to develop first his full arithmetic, then his algebra. In proper mathematical form, they are presented as axioms from which all else will be derived, but there is something unique going on here. In formal mathematical system axioms are not themselves open to examination. Axioms are considered primitive assumptions beyond questions of true or falsity. The remainder of a system is then developed formally from these primitives. In contrast, Spencer-Brown's axioms seem to be indisputable conclusions about the deepest archetypal nature of reality. They formally express the little we can say about something and nothing.

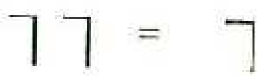
This is one of several reasons why Spencer-Brown's *Laws of Form* has been either reviled or worshiped. Mathematicians are deeply suspicious of any attempt to assert that axioms might actually be assertions about reality, and with good reason. For over two thousand years, the greatest minds believed that Euclid's geometry was not only a logically complete system, but one that could be checked by reference to physical reality itself. Only with the development of non-Euclidian geometries in the nineteenth century did it become apparent that Euclid's axioms might be merely arbitrary assumptions, and that a different set of assumptions could lead to an equally complete and consistent geometry.

Once bitten, twice shy—mathematicians became much more concerned with abstraction and formality. They separated what they knew in their mathematical world from what scientists asserted about the physical world. Mathematics was supposed to be the science which dealt with the formal rules for manipulating meaningless signs. Spencer-Brown's attempt to develop axioms that asserted something important about reality definitely went against the grain of modern mathematics.

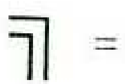
The Dynamics of Spencer-Brown's Archetypal Distinctions

Let's consider the elegant symbol system Spencer-Brown used to express and manipulate distinctions. Instead of our example of a circle in a plane, let a mark symbolized by the top and bottom of a square represent distinction:

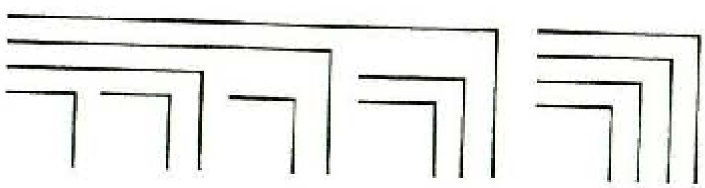
Our two laws then become:



and



Using only those two laws, the most complex combinations of marks can be reduced either to a mark or to no mark. Try yourself to use the two laws to reduce this example to either a mark or to nothing (hint: it should end up as a mark.):



These two laws are the full and complete set of rules for Spencer-Brown's arithmetic. As we have already stressed, it's a very strange arithmetic in which the constants, comparable to 1, 2, 3, . . . in normal arithmetic are simply the mark, and the non-mark.

Though any combination of marks, no matter how complex, can be reduced using this simple arithmetic, Spencer-Brown found it useful to extend the arithmetic to an algebra by allowing variables; i.e., alphabetic characters that stand for combinations of marks. For example, the letters p or q or r might each stand for some complex combination of marks. He then developed theorems involving combinations of marks and variables which would be true no matter what the variable might be. Since his whole point was to develop the arithmetic which underlay Boolean algebra, of course the algebra he developed was equivalent to Boolean algebra. But, as he points out, the great advantage is that since his arithmetic was totally indifferent to what two-valued system it was applied to, the resulting algebra is equally indifferent to its application. It can certainly be interpreted as a Boolean algebra, but it can equally well be interpreted as an algebra of network design, or any other two-valued system, a point which has been either ignored or dismissed by critics.

Self-Reference, Imaginary Numbers, and Time

> Space is what would be if there could be a distinction. Time is what would be if there could be oscillation.
>
> - G. Spencer-Brown (1973).

Spencer-Brown's Laws of Form are an examination of what happens when a distinction is made, when something emerges from the unconscious into consciousness. Hopefully, the first of Spencer-Brown's two rather oracular statements above now makes sense. We have seen how space emerges from the mere fact of making a distinction. Neuro-biologist and cybernetics expert Francisco Varela has called the latter, the creation of time, "in my opinion, one of his most outstanding contributions" (1979, p. 138). Let's see if we can bring equal sense to it.

In solving many of the complex network problems, Spencer-Brown (and his brother, who worked with him) used a further mathematical trick which he avoided mentioning to his superiors, since he couldn't then justify its use. He had been working with his new techniques for over six years and was in the process of writing the book that became *Laws of Form* when it finally hit him that he had made use of the equivalent of imaginary numbers within his system.

Imaginary numbers evolved in mathematics because mathematicians kept running into equations where the only solution involved something seemingly impossible: the square root of -1 (symbolized by sqrt -1.) If you will recall from your school days, squaring a number simply means multiplying it by itself. Taking the square root means the opposite. For example, the square of 5 is 25; inversely the square root of 25 is 5. But we've ignored whether a number is positive or negative. Multiplying a positive number times a positive yields a positive number; but also multiplying a negative number times a negative number also yields a positive number. So the square root of 25 might be either +5 or -5. But what then could the square root of a negative number mean?

This was so puzzling to mathematicians that they simply pretended such a thing could not happen. This wasn't the first time they had done this. Initially negative numbers were viewed with the same uneasiness. The same thing happened with irrational numbers such as the square root of 2 (an irrational number cannot be expressed as the ratio of two integers). Finally, in the 16^{th} century, an Italian mathematician named Cardan had the temerity to use the square root of a negative number as a solution for an equation. He quickly excused himself by saying that, of course, such numbers could only be "imaginary." The name stuck as more and more mathematicians found the technique useful, and the symbol forsqrt -1 became *i* (short for imaginary).

Spencer-Brown had come up with an equivalent situation in solving network problems. Instead of the square root of a negative number, he found equations where a variable was forced to refer to itself, like below:

$$f_2 = \overline{\overline{f_2}\,|}\,| \qquad\qquad f_3 = \overline{f_3}\,|$$

Remember that f has to stand for some combination of marks that ultimately reduces to either a mark or no mark. There is no problem with the first equation, where it works equally well whether we substitute a mark or no mark. But in the second equation, if we assume that f_3 = the mark , then f_3 = no mark. Similarly, if f_3 = no mark , then f_3 = the mark. That is, if the value of the function is a mark, then it's not a mark; if the value is not a mark, then it is a mark. Just as with imaginary numbers, we are dealing with an impossibility, in this case caused by self-reference.

Spencer-Brown simply made use of these impossible numbers in his calculations without understanding what they meant. With the realization that these were equivalent to imaginary numbers, he not only understood what they represented, but had an insight to how imaginary numbers could be interpreted as well: both imaginary numbers and his self-referential functions were "oscillations" in and out of the normal system. Let's pause and make that very clear. In the system created by Spencer-Brown's Laws of Form, there are only two possible solutions to an equation: the mark and no-mark. Yet these self-referential equations have a 3rd solution, one that oscillates in and out of the system: first the solution is the mark, then it's not the mark, and so forth endlessly. Since this solution cannot be found within the space created by the system, it has to be a movement in time.

Just as the space created by Laws of Form has no dimensions, neither does the time created by it. You can't refer to it in seconds or minutes; it is more primitive than that. This concept of dimensionless time as a resolution for problems of self-reference has become a commonplace through the wide use of computers. Computer programmers use the term "iteration" to describe the movement of a program from one state to another. For example, computer programs commonly count the number of times a sub-routine has run by adding an instruction like "n = n + 1", then checking the value of "n" to see if the sub-routine has run enough times. It is understood that the "n" on the left side of the equation is a later stage than the "n" on the right side. Time has entered the picture. But note that this time is dimensionless. We can't say that one "n" is a day or an hour or a minute or a second later than the other "n"; all we know is that one state of "n" is later than the other state. This is analogous to how we created a space without dimension by the simple act of making a distinction.

$$f = \overline{f\;}\rceil$$

Spencer-Brown realized that his simple but puzzling little equation brought time at its simplest manifestation into the timeless world of his Laws of Form. Such equations simply "oscillate" between one value and another, just as imaginary numbers provide the possibility of oscillating between values that lie first on the real number line, than off it, then on it again, and so forth.

Where to Go Next

Paradox, however, lies beyond opinion. Unfortunately, orthodox attempts to establish the orthodoxy of the orthodox result in paradox, and, conversely, the appearance of paradox within the orthodox puts an end to the orthodoxy of the orthodox. In other words, paradox is the apostle of sedition in the kingdom of the orthodox.

Richard Herbert Howe and Heinz von Foerster (1975, pp. 1-3).

The most logical way to advance past Laws of Form is to start where it ends: with self-reference. Spencer-Brown wisely finished his work at the point when self-reference entered the picture, satisfied with the deep insight that self-reference introduces time. He left it for others—non-mathematicians perhaps?—to think about the implications of what happens when his timeless, dimensionless calculus enters the world of space, time, and dimension in which we actually live.

A decade after the original publication of *Laws of Form* in 1969, Francisco Varela's *Principles of Biological Autonomy* (1979) extended Spencer-Brown's work from a 2-value system to a 3-valued one in which self-reference joins the mark and the not-mark as the three primary entities that constitute all reality. Varela was attempting to find the simplest possible way to symbolize a reality which explicitly includes self-reference, since self-reference, in his words "is the nerve of the kind of dynamics we have been considering in living systems and autopoieses." It's important to realize that, while this extension provides a way to extend Spencer-Brown's calculus into biological systems, it in no way resolves the paradoxical issues raised by the fact that a system as simple as that in Laws of Form led inevitably to issues of self-reference that are undefinable within the system. Rather Varela admits self-reference as a distinction as valid as the primary distinction Spencer-Brown made, thus accepting it as part of physical reality without questioning what that means. This is not a failure to understand the issue presented by the appearance of time within Spencer-Brown's calculus, it is instead an explicit creation of a new calculus in which self-reference will be the core.

A deeper understanding of self-reference is necessary to escape from logical conundrums of the sort that appeared when self-reference necessarily began to poke its head into science and mathematics in the late nineteenth and early twentieth centuries. Varela comments that:

> it is, I suspect, only in a nineteenth-century social science that the abstraction of the dialectics of opposites could have been established. This also applies to the observer's properties.…There is mutual reflection between describer and description. But here again we have been used to taking these terms as opposites: observer/observed, subject/object as Hegelian pairs. From my point of view, these poles are not effectively opposed, but moments of a larger unity that sits on a metalevel with respect to both terms. (1979, p. 101).

Hegel's version of the "dialectics of opposites" was organic. First there was a thesis, which necessarily called into existence its antithesis. Out of the interplay between thesis and antithesis over time, ineluctably emerged a new synthesis of both. Then the cycle would repeat with the emergent synthesis as a new thesis, which created a new antithesis, and so on ad infinitum. The essentially nineteenth century slant of the dialectic was the emphasis on the organic evolution over time. After Darwin, time could never again be ignored in considering such issues. But note that effectively for Hegel, thesis and antithesis are related in a self-referential loop, from which eventually a new synthesis emerges. It was simply a little too early in Hegel's time for the mathematics to emerge.

Let me just give one final extended quote from Varela on this issue of self-reference, in this case under the seemingly less fearful physical term of feedback. He comments that:

> When [Norbert] Wiener brought the feedback idea to the foreground, not only did it become immediately recognized as a fundamental concept, but it also raised major philosophical questions as to the validity of the cause-effect doctrine.…the nature of

feedback is that it gives a mechanism, which is independent of particular properties, of components, for constituting a stable unit. And from this mechanism, the appearance of stability gives a rationale to the observed purposive behavior of systems and a possibility of understanding teleology.…Since Wiener, the analysis of various types of systems has borne this same generalization: Whenever a whole is identified, its interactions turn out to be circularly interconnected, and cannot be taken as linear cause-effect relationships if one is not to lose the system's characteristics (1979, pp. 166-167).

There are several important realizations within that statement. "Feedback…gives a mechanism, which is independent of particular properties, of components, for constituting a stable unit." And consider the follow-up statement that "the appearance of stability gives a rationale to the observed purposive behavior of systems *and a possibility of understanding teleology*." In other words, cause-and-effect is perhaps an overly crude description of any reality that involves feedback. Feedback enables systems to preserve a personal integrity over time, despite a widely varying set of outer circumstances. Once that self-referential definition of a system is in place, the system is both necessarily purposeful, and its evolution can be considered from a teleological, as well as a causal viewpoint, *since the definition of identity is more significant than the causal factors within which it functions.*

So we find that whenever we attempt to describe sufficiently complex closed systems, self-reference is necessary in order to explain how those systems remain closed. On the other side of the coin, chaos theory also emerges when sufficiently complex, self-referential open systems are considered. Self-reference is the common denominator that underlies both organic closure and change through the stages of chaos.

Therefore, it's easy to understand why first Spencer-Brown, then Varela, wanted to isolate what distinguished self-reference at its most basic. Though Spencer-Brown was dealing with one of the purest (perhaps the single purest) mathematical systems ever developed, its development led him inevitably to self-reference, and that led him to the question of the relationship between form and time. These issues, introduced by Spencer-Brown, extended by Varela, remain as central and, unfortunately, as ignored or misunderstood as when *Laws of Form* was first published. It is always difficult to interest the orthodoxy in questions that end in paradox.

[In order to advance further in dealing with the self-referential issues presented by *Laws of Form*, we have to turn to the work of mathematician Louis Kauffman, whose collaboration with Varela on "Form Dynamics (Kauffman and Varela, 1980), formed the core of [the discussion of wave forms in] chapter 12 of *Principles of Biological Autonomy*, the chapter in which the mathematics of the 3-valued logic was presented. Kauffman's own work adds significantly to Spencer-Brown's original work as it moves back-and-forth between the place of "linguistic singularity", as he terms the world of Spencer-Brown distinctions (Kauffman, 1998) and the outside world in which such self-referential issues do not collapse into singularities. This work builds on his concept of the "indicative shift" and culminates in his collaboration with James M. Flagg on what Kauffman refers to as the "Flagg Resolution". Kauffman has presented this work to the readers on *Cybernetics and Human Knowing* in his column "Virtual Logic." I hope in the near future to complement this presentation with a paper similar in format to the current paper on *Laws of Form*.]

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