Are There Universal Principles Governing Architecture in the Mechanical, Biological and Social Realms? The Evidence So Far.

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Here I examine a set of principles that appear to operate across the natural world. They are called the genotypical design principles and they were originally discovered in the process of making and studying organizational change (Emery F, 1967). Before we examine the evidence for the operation of these genotypical principles across both biological and social forms, it is worth asking whether such a search for basic laws or principles of operation through diverse realms of life is even feasible. Well, yes. Perhaps one of the best known examples of such ubiquity is the Fibernachy number series found to be operating through many areas of life. Another more recent, and still controversial with far reaching consequences for human endeavour if confirmed, is the log-periodic oscillations preceding the catastrophic rupture of materials, everything from concrete to tectonic plates to uterine muscles to stock markets. While such phenomena as earth quakes and landslides have been determined to be too unpredictable to utter warnings, it would appear as if once again, science may have been looking at the phenotypes rather than searching for the underlying genotypes.

Didier Sornette has found evidence of "a subtle underlying signal, common to many catastrophes, that can sound the alarm before its too late" (Ravilious, 2001, p31). Sornette originally listened to the sounds made by the materials as they developed microcracks that grew, eventually resulting in rupture. Regardless of the nature of the material studies, a pattern appeared over time, allowing him to accurately predict the time of rupture. Testing his laboratory findings on real life events such as seismic data for landslides and earthquakes, and the electrical signals sent by uterine contractions for birth, he has thrown a spanner into the orthodoxy that "there's no fundamental difference behind different sized cracks. Most researchers follow the model that crack networks in any brittle material…are 'scale invariant'" (Ravilious, 2001, p33). Sornette has shown that there is a discrete scale invariance for systems under stress, with variations for each different material but also with a discernible pattern of log-periodic signals which herald collapse. For financial data to also show the same patterning for what is in effect a humanly constructed system, the stock market, has worried other researchers of critical systems. As Ravilious (p34) points out, it seems "just too good to be plausible, let alone true - although so far no one has come out and told him flat that he's wrong". Yet we must ask why it is too good to be true, when in other fields it has been long established that there do appear to be invariant laws operating across different sphere of life.

Dedication to the narrow reductionist approach to science and its experimentation and the assumptions commonly held within it today appears to continuously get in the way of making sense of our world. The assumptions in particular appear to be a major obstacle. In another groundbreaking, but chance, piece of work, it has been discovered that assumptions of linearity do not hold when substances are dissolved in water and then further diluted. The *New Scientist* in something of a departure from its normally aware stance stated "*common sense* says it shouldn't work" (emphasis added) and the author adds "it defies belief" (Coghlan, 2001, p5).

It defies belief and is common sense only if you follow the linear logic that says that the more you dilute a substance, the more space there is between the molecules of the substance. Take away that assumption and there is no reason why you shouldn't believe that diluting a substance could improve its potency. In fact there are many reasons why you should believe it, not the least of which is continued observation over long periods of time by many people in many fields. The reason their observations were ridiculed was that they violated a mechanistic assumption. Now repeated tests have shown that as a solution is sequentially diluted, the molecules do not spread apart, they clump together, providing evidence for homeopathic claims that potency increases with further dilutions. The growth of the clumps was not linear and it depended on the concentration of the original solution. Also, it only worked in polar solvents like water, in which one end of the molecule has a pronounced positive charge while the other end is negative. One researcher was quoted as saying "Its surprising and worrying" (Coghlan, 2001, p5).

So if we:

- put away our equating of common sense with linear logic,
- substitute systems thinking for reductionism and,
- keep an open mind on whether Mother Nature employed a basic set of design principles and formula for her inventions, merely exploiting variations on a theme for the myriad of phenotypical differences we see around us,

we may have a better chance of speeding up our understanding of our world. In other words, let us look behind the phenotypical diversity for the genotypical laws and principles that govern the operations of the apparently diverse phenomena.

Noting a Coincidence

In the January edition of *Scientific American* 1998, Ingber published an article on ‘tensegrity’, the architecture of life. While reading this article I recognized a set of social and biological parallels which I was prompted to explore in greater depth. Writing them down could partly test whether they stood up to more rigorous analysis, and they appeared to. The other part of the prompt came from Don deGuerre who then read the note, told me to elaborate it and pointed me to Volk’s 1995 book on *Metapatterns*. Volk too had noticed ubiquitous parallels in biological and social organization. While Volk explored the patterns in both biology and society, Ingber explored the fundamental principles underlying these patterns. It is these fundamental or genotypical principles which suggested the parallels I noted, specifically, with the two organizational design principles (Emery F, 1967; Emery & Emery, 1974).

Ingber rejects the biological quest which copycats the reductionist physical quest, for discovering and cataloguing the smallest most critical particles of matter and life as fundamental to understanding life. “Understanding what the parts of a complex machine are made of...does little to explain how the whole systems works...Identifying and describing the molecular puzzle pieces will do little if we do not understand the rules for their assembly” (Ingber, 1998a, p30). With a lot of observation, clear thinking and some ingenious experiments, he has shown that there is a set of simple rules governing the genotypical structure or architecture of life forms. Towards the end he speculates that this may also govern the structure of the physical universe or cosmology, but he does not touch upon the structure of social forms. If nature is, however, as economical in her genotypes as his work implies, then there is good reason to assume that they also apply to natural stable forms of social arrangement. Nature can be extremely wasteful or so it would appear in cases such as sperm production but in other cases such as basic structures and genes, it would appear that she is very economical (Ananthaswamy, 2003). Fuller (1975, p334) wondered how nature formulated these "lovely geometries" so rapidly. His answer was that she must have some fundamentally *pure and simple* way of developing them. This paper explores the possibility that the pure and simple principles found to operate in the physical and biological realms are exactly the same principles found in the social realm. As we see below, some parallels appear to be there.

Synergetics and Tensegrity

Ingber whose work on cells sparked my interest himself recognized the correspondence between the architecture of cells and the work of Buckminster Fuller on stable structures as he gave the name ‘tensegrity’ to his genotypical concept. Fuller coined the term 'tensegrity' as a contraction of 'tensional integrity'. It describes a common form of architecture governing normal stable self-assembly. "Tensegrity describes a structural-relationship principle in which structural shape is guaranteed by the finitely closed, comprehensively continuous, tensional behaviors of the system and not by the discontinuous and exclusively local compressional member behaviors. Tensegrity provides the ability to yield increasingly without ultimately breaking or coming asunder" (Fuller, 1975, p372). Fuller is known for Bucky Balls and his best known invention is the geodesic dome, a geodesic tensegrity sphere.

Tension and compression are inseparable and coordinate functions of structural systems. At any stage one may be prominent while the other is less prominent (Fuller, 1975, p356). "They are always and only interfunctioning covariables" (p359).

If you tighten one point in a tensegrity system, all the other parts of it tighten evenly. As tensegrity systems are taughtened, they approach but never attain rigidity, being nonredundant structures. Every part is nonredundant. Note again here that Fuller is referring strictly to redundancy of parts as he makes clear in his discussion of redundant parts and systems in aeroplanes, other machines and building codes. Fuller distinguishes 'structural' or physical and 'metaphysical' redundancies, the latter of which appear to correspond to redundancy of functions in human beings. He refers to them as "redundant acts", either "conscious and knowledgeably competent, and subconscious and ignorantly fearful cautionaries" (1975, p397).

"The tensegrity system is synergetic - a behavior of the whole system unpredicted by the behavior of the parts. Old stone-age columns and lintels are energetic and only interact locally with whole buildings. The whole tensegrity-icosahedron system, when loaded oppositely at two diametric points, contracts symmetrically, and because it contracts symmetrically, its parts get symmetrically closer to one another; therefore, gravity increases as of the second power, and the whole system gets uniformly stronger. This is the way atoms behave" (Fuller, 1975, p401). This is opposite to the way in which compression based structures, by acting independently of the whole, weaken the whole when force is applied.

Fuller searched for the highest order generalizations, those that hold without exception (p14). "Pure principles are usable. They are reducible from theory to practice" (p32). And of course, the theory can be derived from practice and observation. While being an abstract theorist, he was also a realist, e.g. "mathematicians feel that they can do anything with their abstraction because they don't relate it to reality. And of course, they *can* really do anything they want with their abstractions, even though, like masturbation, it is irrelevant to the propagation of life" (Fuller, 1975, p32).

Fuller's overall principle is that of '*synergy*' which "means behavior of whole systems unpredicted by the behavior of their parts taken separately" (Fuller, 1975, p3). Synergy and energy are companions but energy studies are more familiar. "Energy relates to differentiating out sub-functions of nature, studying objects isolated out of the whole complex of Universe - for instance, studying soil minerals without consideration of hydraulics or of plant genetics" (Fuller, 1975, p3), i.e. energy in this sense yields a reductionist science. Synergy is an ecological or systemic concept with its associated congruent practices. One can only start from the whole and work back to the behaviour of the parts. "The solving of problems in synergetics starts with the known behavior of the whole system plus the known behavior of some of the system's parts, which makes possible the discovery of other heretofore unknown parts of the system and their respective behaviors" (Fuller, 1975, p29). This is called the *principle of synergetic advantage* where synergetic advantage is only to be gained by macro to micro procedures. Micro to macro procedures are inherently frustrated (p61). Here we see the impossibility of arguing from bits of DNA to human behaviour, the discussion of which deserves a whole article to itself.

Synergetics derives from experientially invoked mathematics and is a triangular and tetrahedral system. At the heart of Fuller's concept of structure is the "discontinuous-compression, continuous-tension system" (Fuller, 1975, p29). Only triangles are structure and lacking triangulation, there is no structural integrity (p44). It uses 60-degree coordination instead of 90-degree coordination (pp22-3). The tetrahedron is the prime structural *system* in nature (p48). Without 4 nodes and 6 sides (i.e. relationships) there is no stable structure. The tetrahedron encloses the least volume with the most surface (p51). By implication, therefore, it provides maximum exposure to the environment. This is vitally important for social structures because those with maximum exposure to their social and physical environments have the opportunity to be more actively adaptive (Emery M, 1999). One of the great advantages of DP2 structures is that change can be initiated by anybody anywhere in the structure as they note important changes in either the external or internal fields.

Within this one system, it is possible to incorporate quantum and vector based geometric mechanics. "It embraces all of the known mathematics" (Fuller, 1975, p23) and rejects all a priori and 'self evident' assumptions. Fuller argues that our more conventional, non-systemic approach, has created the gap between the sciences and the humanities (p24) through the inability of the non-systemic approaches to model their concepts and principles.

Note here that when Fuller uses the word 'closed' he does not mean a 'closed system' in the sense of impermeable boundaries. He makes this perfectly clear in other sections where he refers to geodesic structures being designed to keep out the weather while admitting microwaves and light from the sun (p409). There is always a coexistent insideness-outsideness of systems (p38) and "there is no absolutely enclosed surface, and there is no absolutely enclosed volume. Universe means 'toward one-ness' and implies a minimum of twoness" (Fuller, 1975, p83). In other words, any entity or system has an environment. He says (Fuller, 1975, p98) that "systems are unpredicted by oneness, twoness, or threeness". Only when four entities, relationships or 'events' are considered can we define or predict a system. This gives us the minimum set of L11, L22 and the two 'transport equations' of L21 and L12, the basic lawful parameters of the open system (Emery & Trist, 1965). In fact, Fuller appears to recognize the directive correlation (Sommerhoff, 1969) as the fundamental building block of an open system. In 1962 (p12) when arguing for an education for creativity rather than conformity, he said of the new form he was seeking, "The new form must be spontaneously complimentary to the innate faculties and capabilities of life". In other words, it must establish a new set of directive correlations between human abilities and the realities of the world we know.

This raises another direct correspondence between the physical and the social realms as Fuller clearly realized. The 'insideness-outsideness' or the relation between human abilities and the realities of the world we know is expressed as the relationship between affordances and effectivities, central concepts within open systems theory. Affordances are properties of the environment relative to a system, the acts or behaviours permitted by objects, places and events, ie. the physical and social realities. "It is the affordance that is perceived." (Gibson, 1967; Reed & Jones, 1982; Michaels & Carello, 1981, p42). Affordances are real and persistent properties of the world as we know it. Our abilities or capabilities are expressed as effectivities, the potential, purposive behaviours of a perceiver in the field and again are relative to that field. For perceptions to be valuable they must be manifested in effective and appropriate actions on the environment and of course, for actions to be effective and appropriate, they must be informed and constrained by accurate perceptions.

Tensegrity in Biology

From his mathematical base, Fuller built complex geodesic structures that could take highly concentrated local loads or impacts with minimum effort while swiftly distributing and inhibiting the outward waves of stress from the point of concentrated loading. Built up from the tetrahedron which has the greatest resistance of any structure to externally applied concentrated load, it is the same basic form that viruses use for their protective protein shells (Fuller, 1975, p324). As Glanz wrote "Although geodesic domes may be out of fashion now, their principles could live on in biology" (Glanz, 1997, p679).

A team at Harvard Medical School and Children's Hospital has demonstrated "that mammalian cells are densely 'hardwired' with force-carrying connections that reach all the way from the membrane through the cytoskeleton to the genome" (Glanz, 1998, p678). They have shown that the cell is an integrated entity where all the parts are connected, in other words, a system. They have shown that *chemistry is structure* and the strictly chemical and mechanical cannot be separated. "All living cells continually generate mechanical tension within their contractile cytoskeletal microfilaments and they transmit these forces to all parts of the cell. Thus, this form of signal transmission involves modulation of biochemical events by changing the level of stress[1] in the cell. For this reason, the response of the cell to an external stress may vary depending on cell extension and the initial prestress (internal tension) in the cytoskeleton…much like how the quality of a musical tone varies when one tunes a guitar string" (Ingber, 1998b, p234). They have shown that cells use a tension-based system of architecture, that described above by Fuller as tensegrity. Stresses from local sources promote long range structural rearrangements through the cell and nucleus. "This dependence of the structural stability of individual molecules on internal

[1] It should be noted that the term 'stress' in the tensegrity literature is used in the mechanical or physical sense. It is not used in today's sense of feeling 'stressed'. This concept of ‘stress’ as it is used in common language is not particularly useful. There is a curvilinear relationship between stimulation and what is in the vernacular called ‘stress’. It has long been known in human affairs that one person’s challenge or excitement is another’s anxiety or despair because the range of individual differences in response to pressure is huge. An external stimulus or a 'local force' in the mechanical sense can then have different effects on different people. When people say they feel 'stress', they mean they either feel under pressure to do or not do something or would do it differently, or that they are feeling ‘distressed’. Distress is a basic affect and the affect system is a motivational system in its own right, one of our most powerful subsystems (Tomkins, 1962).

prestress, continuous tension and local compression is characteristic of tensegrity architecture, which also guides the organization of living cells and tissues" (Ingber as above, p235).

At the phenotypical level, certain patterns appear, such as spirals, pentagons etc and these appear in both organic and inorganic building blocks. “The only difference is how the atoms are arranged in three-dimensional space” (Ingber, 1998a, p30). Tensegrity governs all scales of life from carbon atoms to viruses and the many levels of organization of the human body, from molecules which self assemble into cells which self assemble into tissues, which self assemble into organs which self assemble into a body organized hierarchically as tiers of systems within systems. “If we are to understand fully the way living creatures *form and function*, we need to uncover these basic principles that guide biological organization” (emphasis added). Ingber clearly understands the difference between generic and serial genetic concepts (Cassirer, 1923).

Tensegrity refers to a system that stabilizes itself mechanically because of the way in which tensional and compressive forces are distributed and balanced within the structure, ie. stability is given by the balance of tension and compression (Ingber, 1998a, p30 & p38). Biological material is continuously removed and replaced but what we call life appears to be the maintenance of pattern and architecture. Therefore in Ingber’s model, illness would represent a partial breakdown of the maintenance of that pattern and architecture and death is the ultimate breakdown.

Here we see another level of convergence as Ingber has implicitly in his reference to the removal and replacement of biological material, the concept of directive correlation (Sommerhoff, 1969), the core concept of open systems thinking. “Formally, the picture that has emerged is that of a physical system whose parts and part-activities are connected by complex hierarchies of directive correlations which have the necessities of survival and reproduction as ultimate goals at the apex of the hierarchy. The existence of this all-embracing system of directive correlations with its ultimate goal of self-preservation is what makes the organism into a living, biological unit. The irreversible collapse of this system of directive correlations in the breakdown of its *animation*, is *death. Ageing* is the gradual shrinkage of the degrees of these directive correlations that precedes the final collapse (Sommerhoff, 1969, p189). Because it seems difficult in any real sense to decide where learning and becoming more coordinated with the environment ends and ‘ageing’ begins, illness would appear more useful than ageing.

This evidence creates huge problems not only for genetic engineering but also for the deterministic evolutionists. Ingber (1998b) explicitly takes an open systems view. "The same stimulus can produce an entirely different response depending on the cellular context…in other words, the cellular response is dependent on both the chemical and mechanical context in which signal transduction proceeds. Thus, the key question is not which signaling molecule is activated, as currently dominates existing approaches. Rather, it is how all these different signaling pathways are integrated inside the cell" (Ingber, 1998b, p233). The work of this team is based on the behaviour of real life cells in their real life context, not taken out of context as has been the fashion in so much biological science. They prefer to study the structural complexity in which transduction pathways must function in the living cell. As we have seen in so many fields, radically new discoveries result from considering the whole in context, often overturning whole bodies of scientific orthodoxies. When Ingber's team discovered that in the real living cells, the chromosomes and nuceoli were always connected by flexible strings, made of DNA, Ingber described it as an 11 on a heretical scale of 1-10. The clean separation of chromosomes seen previously was probably a product of sample preparation (Glanz, 1997, p679). This work emphasizes "how we will never be able to fully understand cellular control if we only analyze individual molecules in isolation" (Ingber, 1998b, p236). He believes the future in this area lies with biomimetics rather than genomics, by structures and mechanics rather than chemistry alone. It could make functional genomics look primitive. Of course, like all new discoveries, this systemic approach has stirred the more orthodox into protest (Brookes, 1999).

Far from the genes determining the shape of life and its development, tensegrity has “allowed us to comprehend better how cellular shape and mechanical forces...influence the activities of genes”. “How living things form has less to do with chemical composition than with architecture” (Ingber, 1998a, p31), changing geometry could “even alter genes...and thus the proteins that are made” (p34). “Genes are a product of evolution, not its driving force” (p38). Indeed, in the same issue of *Sci Am* and in a spate of other recent scientific articles, there is accumulating evidence that genes and other so called fundamental building blocks are far more malleable and mobile than previously believed, shades of ‘jumping genes’. They, like all else in nature, respond to changes in their environment (Rayner, 1997).

Genotypical Patterns and the Design Principles

Figure 1 illustrates the basic modules of the structures flowing from the two genotypical design principles and a third non-structure called laissez-faire (Lippitt & White, 1943 & 1947; deGuerre, 2000). These design principles have also been discovered independently by Riane Eisler (1995, p105) who calls the systems flowing from them 'androcracy' and 'gylany'. She also recognizes they are extremely powerful and affect most aspects of organizational life as well as male-female relationships.

These design principles are not human constructs or concepts in the normal theoretical sense. They are the realities of life operating in all forms of organization including families, voluntary organizations and governments. They are also legal realities within industrial relations. The first design principle is embedded in individual job specifications, duty statements or contracts and is enforceable. The failure of a supervisor to adequately supervize, i.e. control the work and behaviour of an employee and coordinate the work of the section such that the specified goals are met is punishable.

To change the genotypical principle from the first to the second in a formal, employing organization requires an agreement signed in the Industrial Relations Commission so that the second design principle is now the legally binding reality behind the organization structure. Without a legally binding agreement, the structure is still built on DP1, whatever its superficial appearance, and everybody who works there knows it. This is the main reason that so many experiments with so called 'self managing' groups are short lived. While the results may be good for a short period, they are unsustainable because sooner or later people realize that nothing has really changed. Supervisors may have their names changed to coaches or trainers but they are still legally responsible for the coordination and control of their section. People may have been told they are 'empowered' but the power structure remains unchanged.

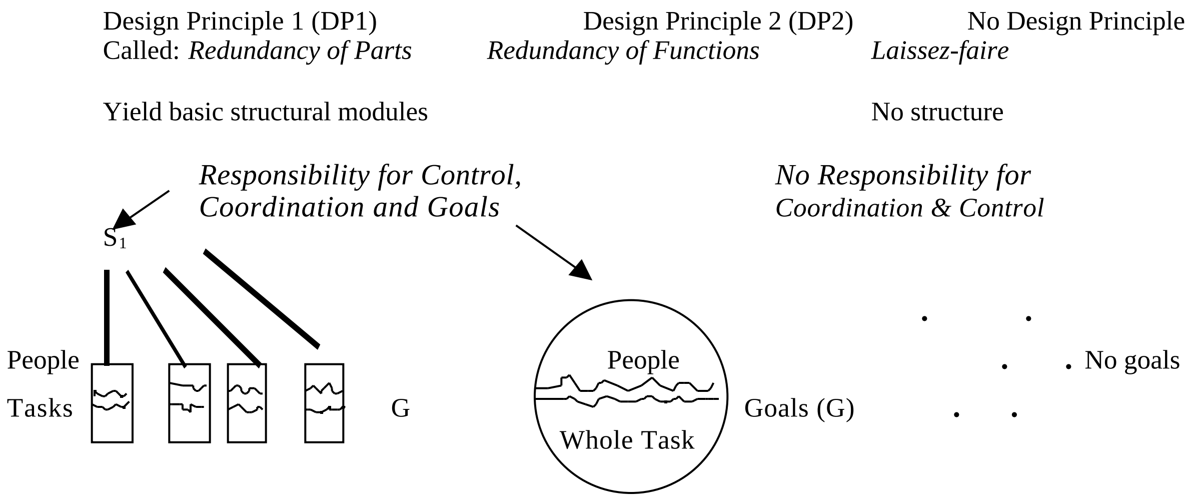

Figure 1. The Genotypical Organizational Design Principles

Figure 1 shows that the basic module flowing from the first design principle called DP1 for short, is a section of an organization with a first line supervisor (S1). The technical name of DP1 is ‘redundancy of parts’ because there are more parts, that is people, than are required to do the productive work at any one given time (Emery F, 1967a). DP1 yields a supervisory or dominant hierarchy. A dominant hierarchy or hierarchy of personal dominance is one where the people, at least one level above where the work is being done, have a legal right and responsibility to tell the people below them what to do and how to do it.

Its second critical feature is that responsibility for coordination and control is located at least one level above where the work, learning or planning is being done (Emery & Emery, 1974). In DP1 structures, responsibility for control, which is the vertical line, is vested in S1. It is S1's responsibility to ensure that each person does his or her job on time and up to specifications. It is also S1's responsibility to ensure that coordination, the horizontal line, is adequate, that all the outcomes of the separate jobs plus all the interdependencies between them, add up to the section's goals.

Figure 1 also shows that the basic module flowing from the second design principle, called DP2 for short, is a self managing group, without a first line supervisor. The technical name of DP2 is ‘redundancy of functions' because there are more skills and functions built into each individual person than they need to do the productive work at any one given time. DP2 yields a non-dominant hierarchy of functions or a functional hierarchy. A hierarchy of functions acknowledges that different types of work need to be done at different levels of the organization, certainly in large organizations. For example, in large organizations, there is considerable productive work that needs to be done everyday at the overall organizational, strategic or policy level. Similarly, no organization can survive without having people working at the operational level, the level at which the core work or business of the organization is performed. In a DP2 structure, nobody has the right to tell others what to do and how to do it. All communications are conducted as negotiations between equals. DP2 structures are open information systems and because all staff have adequate skills and knowledge to operate in their group, there cannot be discrimination on this basis.

The second critical feature of DP2 structures is that responsibility for coordination and control is located exactly where the work, learning or planning is being done. In DP2 structures where multiskilling is possible, responsibility for both coordination and control is vested in self managing groups at different levels of the functional hierarchy. It is the group's responsibility to manage themselves as people, and to ensure that the group's goals are met on time and up to specifications. Once the goals are drafted, negotiated and agreed with whoever is the authorizing group within the organization for this, it is up to the group to decide how to allocate different pieces of the work to different people at different times.

The design principles and their basic modules form very different organizational structures with extremely different modes of operation. The overall form of DP1 structure is a larger replica of the basic module, well known and recognized. There are different forms of DP2 structures and we examine these below when we compare them with structural forms in other realms.

Before we can effectively make the comparison and judge whether there is a real parallel in biological and social arrangements, some differences must be made explicit. Obviously people are not bridges, nor are they cells or bees or dogs. Within the conceptual framework called open systems theory within which the design principles lie, people are taken to be open purposeful systems, who may under certain circumstances become ideal seeking (Emery F, 1977; 1998). They differ from the rest of the animal kingdom in so far as they have consciousness. By consciousness I do not mean the word in the sense that we have awareness, an ability we appear to share with other creatures, nor do I mean it in the sense of 'altered states of consciousness'. I use the word strictly in the sense of Chein's rigorous (1972, p95) definition which means that humans can be aware of their awareness. This definition can be expressed as a directive correlation (Emery M, 1999, pp70-77) which gives an operational definition.

Isomorphisms in the Biological, Mechanical and Social Realms

In translating from the biological and mechanical realms to the social and pyschological I will draw the parallels at two levels, the relation between individual and group within an organizational structure and the relation of intrapersonal to individual psychology. This is sufficient to suggest that tensegrity functions exactly the same way in the human and social realms as it does in the mechanical and also biological fields.

Fuller (1975, p360) stated that "compressionally dominated functions of structural systems are inherently self-diminutive in overall aspect. Tensionally dominant functions of structural systems are inherently self-enlarging in overall involvement". Self-diminutive translates into variety reducing and Emery (1977) discovered that structures built on the first design principle (DP1) are variety reducing. Those structures built on DP2 are variety enhancing. Here we see the first parallel between compression and DP1 on the one hand, and tension and DP2 on the other.

Tensegrity structures offer a maximum amount of strength for a given amount of building material. The geodesic form is one type of tensegrity structure which relies on frameworks made up of rigid struts each of which can bear tension or compression. The second type of tensegrity encompasses structures that stabilize themselves through a phenomenon called ‘prestress’. Here structural members that can bear tension are distinct from those that bear compression. “Even before one of these structures is subjected to an external force, all the structural members are already in tension or compression - that is, they are prestressed (Ingber, 1998a, p31).

These two types of tensegrity structures are contrasted with other buildings that derive their stability from continuous compression because of the force of gravity (Ingber, 1998a, p32). These do not share the critical feature of tensegrity which is that tension is continuously transmitted across all structural members. An increase in tension in one member results in increased tension in members throughout the structure, and this total increase in tension is balanced by an increase in compression within certain members spaced throughout the structure. Those that rely on continuous compression do not have the same capacity to withstand stress. Let us call the compression only structure 'type 1' while we will call these tensegrity structures 'type 2A' (geodesic) and 'type 2B' (prestressed).

The *first level* of translation involves the individual, the group and their relationships within an organizational system. The parallel is with the relation of individual nodes, hexagons and struts in a geodesic dome, or the nucleus, microfilaments and microtubules in the cytoskeleton of a cell. The overall body is the organized system.

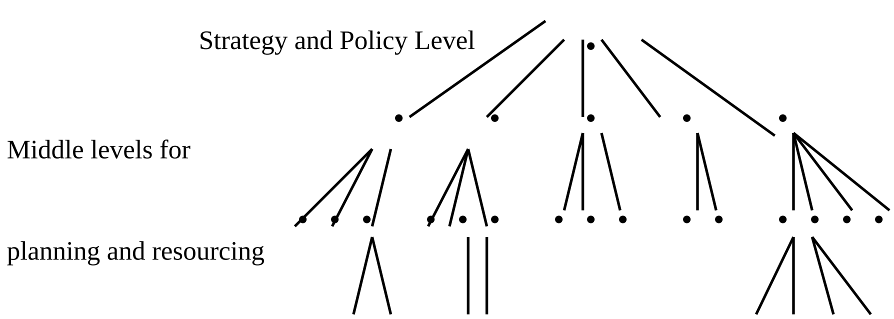

Figure 2. Small DP1 Structure

The major clue to the isomorphisms is given by the response of the structures to external forces. DP1 structures (Figure 2) are notorious for their inability to respond to external forces such as changing values in the external social field or environment. Changing customer requirements, or complaints, are either simply ignored or messengers are shot, or one or two operators are put under increased pressure to change their behaviour, which can result in increased absenteeism, turnover, accidents, etc. Unfortunately, many organizations say this continues to be true even after major efforts to introduce methods such as TQM.

As Figure 2 shows, tension in a DP1 structure is not transmitted across the whole structure as there are no lateral relationships to produce counteracting forces to the compression coming down from above. Individuals are continually compressed in their range of behaviours and purposefulness. If supervisors are doing their jobs properly, those beneath them have less than adequate levels of autonomy in decision making, goals setting and the other psychological requirements for productive work (Emery & Thorsrud, 1969; Emery & Emery, 1974). Mutual support and respect which could exert an indirect effect also often tends to be low in these structures. There are simply no other forces to bring the compression into balance with tension.

DP1 can, therefore, be described as producing a type 1 compression only structure. The relationships between different levels of the dominant hierarchy are rigid, struts, but there are no lateral structural relationships that could carry the tension across the structure. Communication is down and up the line and because DP1 structures encourage competition, has the characteristics of asymmetry, egocentrism, and 'them and us' (Emery & Emery, 1976). While communications sent down the line are typically instructions, communications to be sent up the line may be forgotten, may contain information or may contain misinformation. External stress or force is, therefore, continuously compressed down onto individuals with the resulting breakdowns in physical and mental health that have been documented as characteristic of DP1 structures since Trist and Bamforth (1951).

In contrast, DP2 structures contain two distinct entities, individuals and groups with the individuals arranged into groups. They also can appear in three forms, two with stable self managing groups. Figures 3 and 5 show the models for stable work while Figure 4 shows the appropriate model for unstable work. In all cases, there is a lattice of both horizontal and lateral structural relationships for communicating stresses across the whole structure. In addition, these relationships or struts are under the joint control of the people, so that they also can be continuously redesigned so that they continue to be capable of bearing both tension and compression.

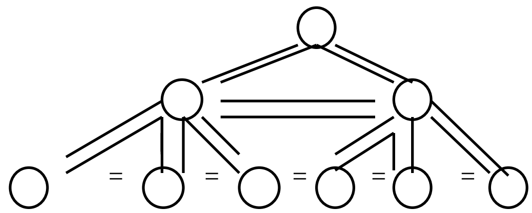

Figure 3. Medium to Large Organization where All Groups are Multiskilled

The first case with stable multiskilled groups shown in Figure 3 is the equivalent of the Type 2A (geodesic) model in which both individuals and groups can both bear tension *and* compression. In this case, individuals can bear tension because they have supporting relationships within the group, as well as the groups having supporting relationships with other groups. These supporting lateral and horizontal relationships are also flexible as they are constantly under implicit negotiation within the dynamic, responsive whole.

The double lines in Figure 3 indicate that all change is negotiated between peers throughout the organization, from its initiation at any point. We note here that purposeful, and creative, people are also a source of tension within DP2 systems as they generate ideas which result in changes, which because of the above network of relationships, are transmitted and cause change across the system. Here the group acts to compress, as the individual's bright idea must first go to the group for consideration. If the group decides to act on the idea, it will then function to increase tension within the whole system. This will then be spread up and down and across the structure as the idea is given wider consideration through the whole. Hence there is an automatic balancing of tension and compression which functions in the best interests of the whole system as no individual can act unilaterally in such a way as to introduce maladaptive change.

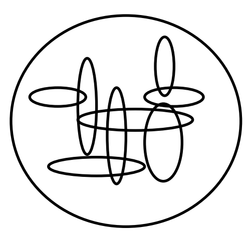

Figure 4 Small So-called 'Knowledge Work' Organization

Figure 4 shows a small one level organization where the whole is the decision making body, composed of temporary, overlapping project teams. This is the appropriate form when the work is unstable, that is, it comes in as projects where every project is different and needs to be addressed by different mixtures of skills and knowledge. It is a highly flexible dynamic form with extremely high responsiveness. As with the full multiskilled model, there are forces acting both to compress and spread tension, keeping them in equilibrium.

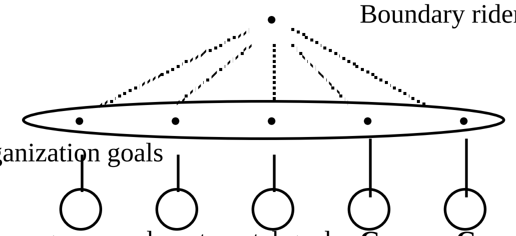

Figure 5. Small to Medium-sized Organization with Specialists at the Strategic Level

In the variation of DP2 shown in Figure 5, there is a mixture of individual and group responsibilities depending on whether control can be practically shared by a group. This is a preferred model when specialists are present and when there are legal or other demarcations operating within the organization. In Figure 5 the specialists are at the senior level of the organization but the model may be used at any level. There is also a 'boundary rider' who works across the boundary of the organization and the environment but is not a supervisor. The boundary rider and the senior team work together when required. In these cases, control and coordination are split with control remaining with the individual specialist while the specialists still share responsibility for coordination and goals. This model is appropriate for transdisciplinary research and some long-lived, stable project teams.

This model of DP2 is the equivalent of the Type 2B (prestressed) model where the tension bearing components are the groups and individual specialists with control have the compression function. The counteracting forces of tension and compression are present but we would expect that the specialist individuals who carry responsibility for controlling some functions or particular aspects of the work would be more subject to forces originating from inside or outside the system. This would be the case because their network of supporting relations is somewhat reduced by their partial individual responsibility.

We can see that “tensegrity structures are mechanically stable not because of the strength of individual members but because of the way the entire structure distributes and balances mechanical stresses (Ingber, 1998a, p31). Now substitute ‘DP2’ for ‘tensegrity’ and ‘psychological’ for ‘mechanical’ and we can see immediately how DP2 structures achieve greater stability and adaptation than do DP1 structures (Emery F, 1977; Emery M, 1999). Because DP2 structures better produce the six psychological requirements for productive activity, the intrinsic motivators, (Emery & Thorsrud, 1969; Emery & Emery, 1974) they have shown much better organizational statistics from the birth of socio-technical systems (Trist & Bamforth, 1951) through the experimentation that followed (Rice, 1953, 1993; Trist et al, 1963, 1993) to the Norwegian Industrial Democracy Project (Emery & Thorsrud, 1976) to such ongoing sites as Syncrude Canada Ltd (deGuerre, 2000). Australia has also produced notable statistics from sites such as ICI Botany, CIG (Roberts, 1995) and Karadoc Winery (Roberts, 1996a) but unfortunately, few of these have been formally published. Apart from the six psychological requirements, DP2 structures also provide better possible conditions for their people as one of the changes involved is a shift from positional based pay to pay for skills and knowledge held. This allows employees to choose their rate of increased skilling and pay without the inflexibility of having to move from chosen areas to administration or management.

One of the implications of these improvements in motivation and conditions is that the massive amount of time and money spent attempting to select the right people for various positions in organizations is mostly a waste as DP2 structures do not rely on having the very ‘best’ people. Individual ‘strength’ or resilience as measured by psychological tests is not a fixed entity in any person. Like other behavioural characteristics, it varies depending on the ecosystem within which the person is embedded. What bothers one person will be very different from what bothers another and as we know from using the six requirements, individuals will rate their scores on the same criterion differently from day to day according to variations in other aspects of their life inside and outside the workplace (Emery & Emery, 1974).

At the level of the whole organizational system the analogy works well with complex structures such as the human body. As Ingber describes it, the body is a non dominant hierarchy of functions with systems within systems. As we know from the work of Edelman (1992), that appears to be the nature of the organization of the human brain and central nervous system more generally. At the social organizational level, we have purposeful systems within groups that act as purposeful systems within a purposeful organization. And the more complex the organization, the more it relies on the counterbalancing forces of tension bearing and compression bearing components for coordinating production and marketing as the body relies on these for the coordination of the systemic functions of digestion, intellectual activity etc.

Tensegrity also informs us about the possibilities of other functions within DP2 structures. Researchers have experimentally modified the shape of cells. When cells were spread flat, they became more likely to divide. When round cells were prevented from spreading, they self activated apoptosis - a cell death or suicide program. When cells were neither too extended nor too retracted, they neither divided nor died. Instead they merely got on with their work with whatever normal skills they possessed, i.e. “differentiated themselves in a tissue-specific manner: capillary cells formed hollow capillary tubes, liver cells secreted proteins that the liver normally supplies to the blood” etc (Ingber, 1998a, p34). [The analogy is not complete here because the cells with which they experimented were more specialized than most people.]

“Very flat cells with their cytoskeletons stretched, sense that more cells are needed to cover the surrounding substrate - as in wound repair - and that cell division is needed” (Ingber, 1998a, p34). When a group of people is stretched to the limit, they too realize that they need either more members or need to set up another group to better get the work done. “Rounding indicates that too many cells are competing for space...and some must die” (Ingber as above, p35). We can translate this into groups or individuals who are so restricted or constrained in their scope or abilities that they finally self destruct, either organizationally, in terms of group dynamics (Bion, 1952, 1961; Emery M, 1999, pp115-1230) or psychologically as individuals. This would indicate that they were not part of a genuinely DP2 structure where they could exercise judgement over the matters of numbers and scope. Pseudo-teams or the attempt to graft teams onto the DP1 structure have been all the rage for some time now but constantly fail over time (Roberts, 1996b).

We can also make the translation at a *second level* and this involves the relation of intrapersonal to individual psychology rather than individual to group. Here we take autonomy and homonomy as an example of our counterbalancing forces. Autonomy, meaning governed from the inside (Angyal, 1965), if allowed to run wild results in highly disturbed people who can play out their disturbances in the community arena with random violence and other dissociated and antisocial acts. This can be seen as the result of excessive levels or surges of high voltage tension. Homonomy, the need to belong (Angyal, 1965), if overdominant, results in highly conformist behaviours and levels of psychic death as measured by affectual flatness and lack of creativity. It can be seen as over-compression and it also has transfer effects to the broader community. However, it is the individual who firstly and predominantly suffers from the intrapersonal imbalance of these countervailing forces. We know that the balance of these forces and personal behaviour does change through a person’s life as their ecosystems and panoramas of social ties change (Greco, 1950). There is no need to labour this analogy further. The point has been made.

“The geodesic structure found within the cytoskeleton is a classic example of a pattern that is found everywhere in nature (Ingber, 1998a, p36). “It is visual evidence of the existence of common rules for self-assembly” (as above, p37). Is there any good reason to assume that we are not intrinsically adapted to organize ourselves by these common rules? As Fuller put it (1975, p408) "We thus discover that tensegrity structuring and its omnirationally constituted regularities are cosmically *a priori*, disclosing that Universe is not redundant", i.e. is not built on redundant parts, not DP1. It is only humanity's being born ignorant that has delayed all of humanity's escape from the self-annihilating effect of the omniredundance now characterizing most of humanity's activities". Ingber (as above, p38) restated this as “tensegrity is clearly nature’s preferred building system”. He then continued to explain it “as a local force (that) can change the shape of an entire tensegrity structure” and “these conformational changes...trigger a cascade of molecular restructuring (reorganization of which individuals are primarily doing what) inside that cell (group)”. The isomorphism is clearly the rebalancing of autonomy and homonomy within the individual. Given this, why should DP2 not be the preferred genotype for social organization? It is documented to be the “most economical and efficient way to build”, both at the level of tensegrity (Fuller, 1975, p533; Ingber, 1999. p38) and at the social level.

While our experience, and particularly our consciousness of it, gives us a choice of genotype for organizing our social structures, perhaps we would be wise to firmly make the decision to go with nature’s preferred form. When Volk (1995) recognized that DP2 did appear to be Nature’s major preference, he began to reflect on human history. Have we as *homo sapiens*, the “planetary brain species” become the center? “Indeed, we have taken the icosahedron of dispersed nature and molded it into a centered vector equilibrium...this act has entailed our removal of a number of original relations, expanding the parts into an unstable, new geometry, then stabilizing them in this position by our own radiating relations to all” (Volk, 1995, p119).

But have we really achieved stability, and if so, to what end? I think only in our imagination or hubris, as everyday new evidence comes to light that our dominance over the Earth is a myth. Bacterial, viral and insect resistance to our amoury of weapons has been growing apace. We cannot control the myriad of subsystems from weather to viruses and we know not what we have done. The planetary pollution by accumulating and persistent chemical groups such as PCBs, dioxins and nonyphenols is taking its toll on human reproductive and central nervous system functioning to the point where it may threaten our long term survival (Colborn et al, 1996). Where is the new stability?

We are not queen bees and our consciousness does not change our status as biological creatures embedded in the Earth. It does not confer dominance or the right of dominance. We have proved we cannot escape from the hierarchy of directive correlations in which we find ourselves. All our consciousness can validly do is to help us understand and exercise our responsibilities towards the Earth. Our experiment with DP1 appears to have failed badly. As we are only one species and there is only one Earth, it is time to design a DP2 system where responsibility for coordination and control is located where the action and the actors are, at each appropriate level of system, from our smaller local units up to the planetary wide governance system. Then we may start moving towards a genuine active adaptation that includes ourselves.

The Design Principles in the Animal World

The more one delves into this world of other than humans, the more extensive and inescapable becomes the discovery that the design principles are deeply embedded in nature. As many such as Fuller discovered, mathematical forms and 'new technologies' already exist in the natural world. "The principle of the jet was invented by the squid and the jelly fish long ago" (Fuller, 1975, p6). Moreover, even a superficial or anecdotal study of the animal world reveals that the design principles may operate in different situations in the same species. There are plenty of species that use a DP1 structure when mating (Alpha males and females) but a DP2 structure when hunting (the cooperative pack). The major difference between these animals and humans is that humans always have a choice - if they know about the design principles. Otherwise they may assume, as many appear to assume today, that organizations must be structured on DP1.

However, even in the animal kingdom, there appear to be vast misunderstandings. As Gordon (1999, p25) points out, stories about totalitarian societies and inexorable armies abound in relation to ants but "ants have no dictators, no generals, no evils masterminds. In fact, there are no leaders at all." Gordon spent seventeen summers studying harvester ants in a small patch of the Arizona desert and makes it clear that rather than structured on DP1, the ants work strictly within a DP2 structure with specialization of function in some cases and multiskilling in others.

The tasks in a harvester colony are many and varied and change in importance depending on what is happening in the environment. "Task allocation is a process that operates without any central or hierarchical control to direct individual ants into particular tasks. The queen exercises no authority; she merely lays eggs and is fed and cared for by the workers. No ant can assess the global needs of the colony, or count how many workers are engaged in each task and decide how many should be allocated differently. Yet there is abundant evidence throughout physics, the social sciences and biology, that simple behavior by individuals can lead to predictable patterns in the behavior of groups" (Gordon, 1999, p26).

Gordon conducted a series of simple experiments to determine the dynamics of task allocation in these ants. She discovered that the ants changed task in response to environmental demand. When for example, toothpicks were placed near the entrance, more ants went on nest maintenance rather than foraging. This finding that ants switched tasks was "in contrast to earlier work which had postulated that an individual ant would carry out a single task throughout its life" (Gordon, 1999, p27). In other words, the previous postulate had been an extrapolation from the researchers' beliefs and views of the nature of DP1 structures, e.g. one person-one task. But while an ant may specialize for a short time, it often does several tasks. The number of ant workers that perform a task is not a simple function of the number of ants of that task group.

Which ant does what appears to be determined by the patterns of interaction and simple rules. Meeting too few successful foragers returning leads to fewer ants leaving to forage. The rate as well as the number of contacts is important. While colonies must respond to changing environmental conditions, task allocation does not need to be perfect. But there is nothing clockwork about these operations. It is not "an army, each unit snapping into place so that the entire system ticks on without a hitch" (Gordon, 1999, p28) - although it is extremely doubtful that this is what actually happens in a human army. "*The most difficult thing to grasp about task allocation is that it is not a deterministic process* even at the individual level. An ant does not respond the same way every time to the same stimulus; nor do colonies. Some events influence the probabilities that certain ants will carry on certain tasks, but those regularities lead to predictable tendencies rather than to perfectly deterministic outcomes" (Gordon, 1999, p28, my emphasis). The allocation process results in approximately the right number of ants engaged in the appropriate task.

I have emphasized the above because it illustrates the belief of many, however implicit, that DP1 is the only principle for organizational structuring. It also illustrates how this has effected our assumptions of determinism everywhere and how, as she says, it creates difficulties when one is confronted with DP2 although she does not use this term. Resistance to accepting the efficacy, or even workability, of DP2 is often the visible result of this difficulty.

Gordon has conquered her difficulty after seventeen years of empirical results and makes the implications of them very clear. After stressing that it is the *pattern of interaction*, not a signal in the interaction itself, not a bit of chemical information, nor any other of the reductionist guesses about the causes of such effects, she speculates that "such a process might operate in brains, immune systems, or anyplace where the rate of flow of a certain kind of unit, or the activity level of a certain kind of unit, is related to the need for a change in the rate of flow. Perhaps ants have something general to teach us…about how nature works…Ants…show how simple parts make complex living systems, and how those systems connect to the outside world. By looking at ants in colonies, and looking at colonies in populations, one can begin to see how the layers of a natural system fit together" (Gordon, 1999, p28).

Indeed. Perhaps we can go further in realizing the implications of this dedicated piece of research. Perhaps we need to rethink the statement above that plenty of species use different design principles when organizing themselves for different functions such as mating and hunting. Clearly they are organized on DP2 when hunting, that seems indisputable. But perhaps, when mating, they are simply exercising specialization for good evolutionary reasons. It is simply a temporary episode of DP1embedded within the dominant DP2 structure. At a particular time, a particular male or female may have the best or required characteristics to produce the next year's offspring. Remember that at various times within human DP2 groups, seemingly DP1 structures may exist temporarily. In extreme or dangerous circumstances, e.g. when a fire breaks out in a chemical plant and few have experience of how to deal with it, the most experienced person will be called upon to give orders. The others follow the orders for good evolutionary reasons: they want to survive. In this case, we have an illustration of a temporary episode of DP1 and specialization, embedded within a long term DP2 structure. When the fire is out, the group returns to its normal operating mode.

The extension of this knowledge of the asymmetricality of the design principles to animal organization has not been fully explored. Frequently the research assumes that the dominant organizational form is that seen in the mating patterns (DP1) and that a special case is made for hunting (DP2). That assumption could, as we have seen above in the words of Gordon, be culturally determined. It may just as well be the case that the basic unit is based on DP2 and that for reasons of specialization, intimate family, group, pack or troupe life takes on DP1. Apart from the research data, I have watched a dominant male dingo bring food to a (non pregnant) female when she was too sick to get her own share. This is actually a common observation in 'pack animals'. This also argues for the view that cooperation for the good of all may be dominant, not competition or the 'boss takes all' syndrome.

The Problems with Phenotypes

We have looked at these isomorphisms at the genotypical level. Let us now look at the confusions that are engendered when the phenotypical approach is taken. Volk (1995, pix) follows Bateson in defining a ‘metapattern’ as a pattern of patterns, “functional universals for forms in space, processes in time, and concepts in mind”. He includes in these metapatterns many forms such as calendars and arrows as well as spheres, borders, layers, cycles, etc. His chapter on centers is most relevant to my purposes here.

Volk as does Ingber, begins from the analogy between many biological forms and the structures of Buckminster Fuller, namely the icosahedron which is ‘leaderless’ as are bacteria because they do not have nuclei or centers, and those stabilized forms in the ‘vector equilibrium’ model. These latter forms have centers and Volk compares them with atoms, cells and monarchies. From this taxonomy into ‘dispersed’ and ‘centered’, Volk derives some features of centers. These include:

- a center is singular
- in physical systems such as cells and the solar system, “the centre is of unique substance” (1995, p105)
- “center is often particularly resistant to change” (Volk, as above, p105) as for example, when cells rapidly repair DNA damage, or the sun remains after planets change
- centers affect the whole system and are most directly tied to the nature of the whole, radiating relations

This seems clear enough as a description of what we call a dominant hierarchy or DP1 system with instructions down affecting relations between the centre and the parts and between the parts themselves. The fact that there is no known evidence that people who hold center (or top) positions in a dominant hierarchy are any different from anybody else and are certainly not composed of unique substances, although as Volk points out some kings and emperors have claimed different coloured blood or partial divinity, the lack of correspondence would lead us to believe that such centered systems may not be appropriate for people.

On his first point of singularity, he then goes on to say that "Systems with a multitude of essential parts could be called multi-centered systems, implying the possibility of a dispersed systems of centers and thus going beyond the probably too rigid binary of dispersed and centered" (Volk, 1995, p104). This is where we begin to see that simply describing systems with semantics and without clear operational definitions such as those given by the genotypical design principles is not going to work, as a multi-centered dispersed system is no longer a system with a center.

This confusion worsens after he says "it is to life that the search must turn...[because] only in adaptive systems - those in which evolutionary processes channel design possibilities towards utility - can we look for wide-ranging patterns...as design attractors" (Volk, 1995, p106). When he does this he finds mainly the dispersed pattern but he seems to want to find centers. He acknowledges that plants are complex organisms but seem to lack a center, sponges also have no centre but these creatures are immobile. Hence, "mobility called for a global network of communication and control. A new center was born: the nervous system" (Volk as above, p107). However, plants do have nervous systems and they communicate through chemical messages, for example when warning of advancing predators. And describing the nervous system of plants and animals as central, flies in the face of much evidence that the nervous system merely takes its place in the whole as do other systems such as the endocrine system etc. Such subsystems are mutually influential whereby damage to the endocrine system can change the nervous system and learning potential (Colborn et al, 1996).

Taking this further, he finds that organisms with nerves as centers made possible the novelty of *social systems* but again the evidence for centers is elusive. "Flocks of birds, schools of fish, and migrating herds of wildebeest or caribou consist of a large number of nearly identical beings. They are dispersed systems" (Volk, 1995, p109). He explores the phenomenon of 'alpha' individuals in some mammalian species but "in some ways the case for the mammalian centers is weaker than for many of the other examples presented thus far...the alpha mammalian center is not a specialized individual [such as a queen bee] but a role. Perhaps because this role embodies a greater degree of whatever metaphysical substance makes up the network of dominance and cooperation, mammal societies with dominance hierarchies should be considered more dispersed than centered" (Volk as above, pp111-112).

With the precision given by the design principles, we can clearly differentiate between DP1 structures such as those allegedly found in bee hives and ants nests, and the DP2 structures found in mammalian structures. Also we know that DP2 structures contain the possibility of DP1 structures for certain functions and in certain circumstances. However, DP1 does not contain the possibility of DP2 within it for short periods of time. The design principles are asymmetrical (Herbst 1990). We do not need to revert to non scientific speculation about metaphysical substances.

To escape from this problem of metaphysics, Volk speculates that "the DNA, the code, is perhaps echoed in human society in the laws of the land" (Volk, 1995, p114) but again this level of argument is far removed from the observable distinct arrangements between individuals that constitute structures. When finally he arrives at the ecological level he again forces the argument for centers beyond the evidence. "The closest ecology gets to a centered system is the concept of key-stone species" and the example he uses of 'key-stone species' is that of a cow in USA where the cow is key-stone only from the economic, not the ecological perspective. Finally he acknowledges that 'Nature breathes freedom as an ideal dispersed projection - no bosses" (Volk as above, p119).

Throughout this fascinating but confused book, we see that the confusion arrives because Volk lacks the precision of concept afforded by the genotypical organizational design principles. Only at the genotypical level can there be precise validation of these principles in other realms of life and greater confidence in their power to explain and predict human behaviour.

Conclusion.

In this paper we have looked at multiple instances of structural corroboration (Pepper, 1942) of not only open systems but also of the genotypical design principles. Over and over again, we see that people have recognized them all in different areas of life and given them different names. There would appear from this brief survey to be sufficient structural corroboration of the occurrence of these design principles for them to be viewed as fundamental and ubiquitous principles producing building blocks in mechanics, in biology and in human and social affairs.

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