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COMPLEXITY, PATTERNS, AND CREATIVITY

The title of this chapter suggests three distinct yet tightly intertwined ideas of complexity, patterns, and creativity. These ideas have been deeply embedded and intertwined patterns throughout my teaching and academic career. As Catherine Bateson (1995) has described them, these ideas have become major thematic helical patterns that have submerged and re-emerged for many decades. I relate this brief personal history not so much as a description of my background, but as a description of complexity, patterns, and creativity themselves. These three themes became part of my set of complex systems of learning. In this chapter, I explore the dynamics of these and related ideas in the contexts of teaching, learning, and thinking. However, these ideas of complexity, patterns, and creativity are examined by aligning them to a context of natural systems. Gregory Bateson (Bateson, G., 1979/2002; Bateson, N., 2011) maintained that we have to examine how our thinking can be aligned with how the natural world works. At this point, we have reached a point where our thinking has diverged from the way nature works, which has led to dire consequences. As human beings, we have the capability to think in ways that are destructive to ourselves and to our environments. Yet, we are biological beings that have arisen through evolutionary processes. In many if not most traditional tribal societies, people thought and lived in ways that were not self-destructive or destructive to their environments (Maybury-Lewis, 1992). There is no room here to explore the history of this divergence in human thinking. However, this idea of the connection between biological patterns and human cognitive patterns is a theme we need to keep in mind as we explore complexity, patterns, and creativity.

CREATIVITY

For most creativity researchers, the focus on creativity as a subject to study began quite recently. However, many Western philosophers dating back to Plato have explored creativity. Plato (-347 BCE/2007) spent significant time discussing creativity (for which there was no Greek word) in terms of poetry and poets. Interestingly, the Greek word for poetry is poiesis or "making," which is the root of the word that describes one of the key features of complex systems: autopoiesis or self-making that has been expanded to include concepts such as self-generating, self-organising, self-regulating, self-maintaining, self-transcending, and so forth (Capra, 1996).

Contemporary interest in creativity as a subject of investigation began in the middle of the 20th Century as our enthrallment with positivist and behaviourist approaches

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to understanding our world began to wane. Although much of Guilford's (1950, 1967) work was behaviourist and positivist in nature, he may have been the first contemporary psychologist to examine seriously the nature of creativity. He, along with Meeker (1969), who applied his work to education, may have been the first to distinguish between convergent and divergent thinking in creativity (Spendlove, 2012). Certainly, these two cognitive processes of production are consistent with the biological patterns of convergent and divergent evolution. During this same period of time, Koestler (1964/1969, 1967) stood out as another investigator of creativity, not just as a cognitive activity, but as part of larger patterns of living systems.

Since the 1950's, creativity research focused on ways of (a) measuring creativity, such as the Torrance Test of Creativity (1974) I used in my early days of teaching, (b) dissecting and categorising creativity, (c) discriminating between creativity as an acquired trait or as a genetic trait, and (d) exploring creativity as a cognitive tool for specific benefits, all of which are reviewed by Spendlove (2012). Although interesting, much of this work was embedded in positivist, reductionist, mechanist, utilitarian, and determinist assumptions. Even the ideas in the "underground book," *Synectics* (Gordon, 1961), that was popular in my college days was embedded in such assumptions that are still influential. I do not want to dismiss such work, which has extended our understanding in both depth and extent. However, I do think we need to keep in mind this history and its influence. Throughout the rest of this chapter, I will be setting up the context for a perspective of creativity that is situated in the complex biological systems of which we are part.

COMPLEXITY AND COMPLEX SYSTEMS

Our everyday use of the word *complexity* does not mean the same thing as "complexity" in the context of complex systems. We often use "complexity" interchangeably with "complicated," but within the context of systems it may or may not be complicated. Fundamentally, complexity describes the nature of systems that are autopoietic (Maturana & Varela, 1998). In other words, complexity describes the ways in which various systems maintain some degree of continuity. As living organisms, each one of us is a complex system. Our bodies maintain themselves for relatively long periods of time, hopefully. Our cognitive and creative capacities are part of this complex system as well. In fact, our survival as individuals and as a species is dependent upon our cognition. At the same time, human beings are part of even larger complex systems such as various social groupings, cultures, ecosystems, and the biosphere as a whole. Fundamentally, we live in a world of systems within systems and of interacting systems and sets of systems.

For a complex system to function in ways that allow the system to survive and thrive, there are *patterns of organisation* or networks of non-linear pathways and feedback loops through which information and materials flow. These are the autopoietic processes. In the human body, an example of a *complex structure*, our neural pathways, lymphatic systems, circulatory systems, RNA molecules, hormones, and other substances as well as many of the organisms that live on and within our bodies all function to help maintain the system as a whole. These patterns of organisation and complex structures are generated and maintained by *processes of production* that require some sort of energy production and storage such as photosynthesis and cellular respiration where energy is stored and utilised in the binary of ADP—ATP or adenosine diphosphate—adenosine triphosphate. Although cognitive systems still require the biochemical energy to function, they also require emotional energy, passion, or curiosity to function. While the biological functions of the system operate in relationship to one another, our whole beings are more than just our bodies. The self-transcendent quality of such a complex system creates a whole that is greater than just all of the parts working together. Even a simple mechanical system, such as a bicycle, can become a part of a larger complex system as the bike and rider interact. The bike becomes more than just a mechanical system. It becomes part of the rider's identity in the social and cultural context in which he or she rides. A cyclist in the United States may have a very different bike-rider identity from the bike-rider in a village in India.

Such an idea of a system that goes beyond the rider to the bike suggests a notion of mind that extends beyond the skull and even the body. The concept that mind is more than what exists in the human skull was proposed by early Buddhists (Sangharakshita, 1957; Nisker, 1998) and Western philosophers as early as Anaxagoras in the early 400's BCE (Russell, 1945) and more recently by phenomenologists (Hegel, 1910) and others (e.g., Bertrand Russell). However, in the beginning of cybernetics during the late 1940's and early 1950's, Gregory Bateson (1972/2000) formulated a cybernetics explanation of how mind transcended the limitations of the biological body. For Bateson, mind was a cybernetic system of information flow and feedback loops. From this perspective, our interactions with the contexts within which we live are part of the information flow. For instance, as we drive a car, we respond to a variety of sensory information from the steering wheel, the seat, the brake pedal, the accelerator pedal, various sounds, and the visual field. This information comes from the car, the road, and from objects and events in the surrounding context. We respond to this information by moving the steering wheel, stepping on the brake, or pushing on the accelerator. In turn, that information flows back to the brake pads, wheels, engine, and so forth. With any luck, we manage to move around without getting into an accident or getting a traffic ticket, both of which also are extensions of the information pathways. Viewing mind as extending beyond the individual is critical to understanding the power of context and social interactions in thinking and creativity as suggested by the thinking and behaviour of bats and meerkats (Perony, 2013).

As human beings, one of the major problems we face is that we do not see ourselves as complex systems or as parts of even greater complex systems. We reduce ourselves to isolated individual "things" with no real connection to anything else. From that point of view, we can give the finger to someone else, dump toxic waste into the environment, over-fish a lake or ocean, and bomb other cultures without seeing the consequences for the well-being of ourselves, of others, and of the very environments of which we are a part. The same basic idea holds true for classrooms and schools. The politics of schooling perpetuates a fundamental pathology in the systems of classrooms and schools that isolate and disconnect students and teachers. As the focus shifts to specific content acquisition (which in itself is decontextualised and sanitised) and to conformity in approaches to teaching and learning, we further disconnect children and teachers from themselves, one another, their biological and physical contexts, and the world of ideas.

THE IMPORTANCE OF DIVERSITY IN COMPLEX SYSTEMS

The approaches of schooling and society value ideas of conformity and devalue the notion of diversity that serves to isolate, fragment, and disconnect knowledge. Such approaches and ideas are dangerous. The biosphere and its ecosystems, the survival and continuity of species, evolutionary speciation, and the welfare of societies and cultures are dependent upon diversity or variation. Gregory Bateson (1972/2000, 1979/2002) maintained that the diversity of ideas was essential. His notion of *idea* as information extended from that of mental construction to that of a DNA sequence. From such a perspective, the dualistic separation of mind and body and of *us* from our environment is artificial. The patterns of ideas and this broader perspective of mind and cognition operate in similar ways across contexts and levels of scale. In all cases, creativity is evident when ideas interact, change, and give rise to new ideas. Without diversity, the emergence of new *ideas*, new forms, new species is greatly limited. Without diversity, adapting and adjusting to new conditions are hindered or prevented. Without diversity, complex systems have no material for change.

Bateson (1972/2000, 1979/2002, 1991) suggested that the essential or core characteristic of diversity is *difference.* In fact, difference is the unit of mind. Building on Korzybski's idea that the "map is not the territory," Bateson (1972/2000) suggested that nothing will appear on the map if there is no difference (p. 455). In this argument, the territory may be considered the world in which we live, while the map is comprised of our mental representations of this world. My idea of a bicycle is not the bicycle. My idea of a cup of coffee is not the cup of coffee as suggested by Keanini (Bateson, N., 2011). So, the idea of difference suggests that if there is no difference, we cannot even perceive some *thing* in order to create a representation or our idea of some other *idea*.

Last year, I had an MRI of my head. The difference between lying outside of the MRI tube to lying inside the tube was dramatic. My initial reaction to moving from a visual field of differences to a visual field of no differences was one of claustrophobia. I had no sense of how far away anything was from my head. I was in a white field with no differences. Although there was a difference between in and out, the *in* situation was disorienting. As Bateson would have suggested, there was no news of difference.

Without a fundamental difference – from nothing to something or from one to two or more *things* – there is nothing. As we expand the differences, a world based on diversity is created. Simple and complex systems require difference and diversity. A particular situation comprised of differences makes up a context of some sort. A classroom is comprised of some structural situation that could be a forest for an outdoor *classroom* to a human-made *box* with four walls, a floor, and a ceiling. Inside the classroom, there are various other *things* (like desks, tables, chairs) and people. This physical context can be fairly limited and simplistic to more elaborate and complicated. The context also can include the individual, social, and cultural variation among students as well as the philosophical manifestations of the teacher and his or her approach to teaching and learning. A teacher-controlled classroom management approach creates a different context than a classroom community based on distributed and shared control. The teacher-controlled context tends to be like a simple, mechanical system that verges on collapse while trying to maintain conformity and minimise difference. Whereas, the distributed control approach is more of a complex system that adjusts to variation and, in fact, requires difference and variation to thrive. At the same time, "differences are the things that get onto a map" (Bateson, G., 1972/2000, p. 457) or get into cognitive representations.

The fabric of a world of difference and diversity is relationship. Everything is in relationship to something else. In Nora Bateson's film (2011), Gregory Bateson contends that we "live in a world that's only made of relationships," which suggests that a world made of differences is a world made of relationships among these differences. A tree is comprised of relationships, such as a cell in the phloem is in sets of relationships to other cells in the phloem, in the roots, and in the leaves. The function of the phloem is based on binaries of high-low pressure and high-low concentrations of sugar. These binaries draw the food (sugar) across cell membranes and throughout the tree and its roots. The xylem or tubes that transport water and minerals up from the roots to the leaves are driven by the evaporation of water from the stomata or pores on the under-surface of leaves. Furthermore, the tree does not exist in isolation but in relationship to other trees, plants, bacteria, fungi, animals, protists, human beings, industries, pollution, and so forth.

RELATIONSHIPS AND SYSTEMS

At this point in the discussion, we have some sense that difference, diversity or variation, relationship, and context are essential to understanding how complex systems function, while pointing to the basis for how creativity manifests in complex systems. However, we also need to develop an understanding of the nature and dynamics of relationships. Although the previous discussion treated systems as being comprised of relationships, many if not most relationships themselves are systems (Bloom, 2012b). The flow and exchange of information and/or materials occur within systems, much as they do between those *things* or beings within a relationship. In fact, as Kelso and Engstrøm (2006) suggest, nothing happens without two or more *things* interacting in some sort of relationship. The work of Kelso and Engstrøm focuses on coordination dynamics across scales of relationship between what they refer to as complementary pairs in brain function, an expanded sense of mind, and well beyond to the fundamental nature of the universe.

Everything arises out of relational dynamics. From an earlier study of children's discourse (Bloom, 2001), in which I examined an argument about density through the lens of complex systems, I began to suspect that not only did all arguments arise out of conflicting binaries, but that all systems are initiated and maintained by tensions within various types of binaries. Bateson identified three fundamental types of relationships that describe and address relational tensions in different ways. Complementary relationships are offset pairings that are oppositional. Examples of complementary relationships include dominant-submissive, leader-follower, strong-weak, and outgoing-withdrawn. Symmetrical relationships tend to be equivalent pairings such as dominant-dominant and follower-follower. Dominant-dominant relationships are characterised by competition. In the follower-follower case, the relationships have difficulties functioning. In contemporary western societies, both complementary and symmetrical relationships are difficult to maintain over time. They often descend into conflict and resentment or into dysfunction. However, there are situations where such relationships are necessary. Law enforcement, the military, fire and rescue operations, and people in emergency situations need to work within complementary relationships where someone has to be in control and others need to follow. In other situations, it may be beneficial to be in a symmetrical relationship, at least momentarily, such as competing in some athletic event. Engaging in an argument may be necessary to develop deeper understandings and make any kind of meaningful gain in knowledge or a relationship. However, the third type, reciprocal relationship, is characterised by negotiation and compromise. These relationships tend to be durable. Although such relationships may become complementary or symmetrical from time to time, they return to reciprocity (Bateson, G., 1972/2000).

On the other hand, some relationships are intensely problematic. In such cases, the messages of one type of relationship are permeated with conflicting messages. In the 1950's, Gregory Bateson along with his colleagues Jackson, Haley, and Weakland developed the idea of double bind to explain certain dysfunctional traps in interactions and communications in certain relationships (a report in a 1956 issue of *Behavioral Science* is reprinted in *Steps to an Ecology of Mind*, 1972/2000). The double bind is a binary trap, where there appears to be no viable alternative or answer to a specific situation. A simple double bind may consist of an animal running from a forest fire. When this animal comes to a cliff, it is faced with the alternative to go over the cliff, in which case there is a high likelihood of dying, or to stay at the cliff's edge, in which case there also is a high likelihood of dying. We all face decisions like this, but usually not as dire. However, more intensive double binds not only involve specific traps in interaction or communication, but also are embedded in contexts that support and promote double binds.

A parent who continually treats and communicates with his or her child with double binding actions and communications creates such a problematic context. The parent may tell the child not to do something, but when the child tries to do the right thing, he or she is reprimanded. The parent may even say to the child that some action is "okay," but the body language and actions may contradict what is said. And, when a child comes home late from school or from playing with friends and confronted with double binding questions, such as: "Why are you always coming home late?"—there is no room for a "correct" response. The question recipient is wrong no matter what response is offered. As difficult to deal with as double binds are, they do provide opportunities for transcending the context and responding with creative solutions (Bateson, M. C., 2005; Gibney, 2006). There are no formulas for creative solutions to double binds or creative solutions of any kind. However, the sense here is that potential solutions cannot arise from the double binding context, but can arise from transcending the contextual rules or from jumping across contextual boundaries.

PATTERNS

The fundamental organisation of just about everything involves patterns. From the binary attractions within atoms to the ways living things are organised and function to vast galaxies and to mind and culture, patterns underlie, comprise, and connect every *thing*. Within complexity theories, patterns of organisation are ubiquitous and permeate all aspects of our world including actual forms, processes across scales and dimensions, manifestations of mind and culture, and metaphors (Ball, 2011a, 2011b, 2011c; Bloom, 2004; Bloom & Volk, 2007; Bloom & Volk, 2012; Bloom, Volk, & Richards, 2007; Volk, 1995; Volk & Bloom, 2007; Wilber, 1995). In fact, patterns also characterise the processes of production and the structures of systems. Returning to the previous discussion of relationships, patterns are the manifestations or expressions of relationship.

Gregory Bateson (1979/2002) coined the term *metapatterns* as a way to capture the power and scope of patterns including his ultimate question that he posed for others to find the "pattern which connects." The question: "What is the pattern which connects?" was not meant to be answered definitively but was meant to be a stimulus for a continual quest for understanding the connectedness of everything (Bateson, N., 2011). The prefix "meta" in metapatterns suggests such an overarching or higher level of pattern or of a pattern of patterns. In 1995 while trying to describe a number of specific functional metapatterns that arise from evolution, Volk examined Bateson's idea of metapatterns. These specific patterns include (a) specific forms or shapes, such as sheets, tubes, and spheres; (b) organisational elaborations, such as various layers of form and function, centres, binaries as the beginning of complex sets of relationships, and borders with regulating pores; and (c) temporal patterns of relationship, such as breaks (branches and transformations), arrows, calendars, and cycles. Volk's work is specifically connected to the work of Bateson.

However, for over a century a number of people have explored the importance of various patterns and their functions, including Thompson's (1942/1972) groundbreaking examination of the physics of biological form and function, Carroll's (2005) extended examination of forms in evolution, Stevens' (1974) examination of universal patterns in nature, McHarg's (1969/1971) examination of urban design that is consistent with patterns in nature, Kapparoff's (1991) mathematical exploration of patterns as connections, Wilbur's (1995) spiritual and scientific exploration of universal patterns, Campbell's (1972/1993) examination of myths as patterns of culture; Lakoff and Johnson's (1980) explorations of metaphoric patterns in mind and culture, and Barabási's (2010) explorations of networks and bursts as fundamental patterns. Coward's (1990) seminal work in pattern thinking has extended our understanding of cognition as a pattern-based process. Although interest in and understandings of patterns and metapatterns have increased, as any Internet search will show, patterns as a serious domain has not taken hold in schooling, cognitive studies, and many other contexts.

The power and scope of patterns are significant. For instance, binaries, which are the beginnings of complex relationships, appear to be the basis of the universe. Pairs of eyes, nostrils, ears, and legs or sets of legs not only are the expression of bilateral symmetry, but also are functionally significant. One eye, nostril, or ear is not particularly useful for survival. However, two of these organs provide an exponential leap in their advantages. However, three or four are not significantly more helpful, especially considering the energy and material "costs" to produce more than two. The binary of positive-negative atomic forces along with the predominantly ignored issue of attraction-repulsion (why electrons do not collapse into the proton) is the very building block of the material universe. Binaries are just another way of discussing relationships. We can extend this view of relational binaries to other patterns. A border is a binary of in-out. A tube is a binary of directional flow while an arrow is a binary of directionality. Binaries and sets of binaries tend to drive cycles, such as with evaporation-precipitation in the water cycle.

Pattern thinking is part of the built-in capacity of various cognitive systems, including those of human beings (Coward, 1990). We recognise patterns and use patterns to make sense of our perceptions. However, we do little to promote and develop this capacity throughout schooling. In part, this may be due to our limited view and understandings of patterns and how this capacity can be used in learning, analysing, designing, and creating. We are made of patterns that have emerged divergently and convergently throughout biological evolution. We think in patterns that have roots in these same evolutionary processes. We create cultural and technological constructs based on these same patterns (Volk, 1995; Volk & Bloom, 2007). In fact, the entire physical world is constructed on physical principles that involve these very same patterns (Kappraff, 1991; Stevens, 1974; Volk, 2013).

Thinking in patterns can provide us with cognitive tools to develop deeper and more complicated *understandings* of our world that actually tap into the very complex nature of multiple interacting systems (Bloom, 2004, 2012a, 2013;

Bloom & Volk, 2007, 2012). For example, we can examine an earthworm as being comprised of a number of interconnected, functional patterns. They are tubes within tubes as layers of functionality. As tubes, earthworms can penetrate the soil, transport materials and information from one end to the other, and separate the functions of various tubes as holons or layers of functionality—such as the digestive tract, nervous system, circulatory system, and muscles. The tube within a tube design allows distribution of functionality much in the same way the human body is designed as tubes within tubes. Earthworms utilise a binary of muscles for movement with a secondary effect on circulation. Each individual contains a binary of sexes with pores connected to tubes and spheres of sex organs. They move and maintain their individual survival through complex systems of non-linear cycles at various levels of scale. The same functional patterns exist in all life forms. We can continue with other specific earthworm patterns, but this treatment is just an example of how functional patterns both comprise an individual organism and share functional patterns across organisms and beyond such as the tubes-within-tubes structures of communication wires, computer circuitry, highways and tunnels, ship and airplane construction. Then beyond the individual organism, we can find cycles of reproduction or replication for maintaining the continuity of the species much in the same ways that cycles of information exchange maintain the continuity of cultures. In addition, the patterns of earthworm life and survival in individuals and species interact with the survival of ecosystems, like that of gardens and agricultural systems. But, rather than investigate such sets of interacting patterns and systems in schooling, we reduce *learning* to discrete, disconnected bits of information.

Pattern thinking also can be used for the *analysis* of systems, situations, objects, and events (Bloom, 2004, 2012a, 2013; Bloom & Volk, 2007, 2012). As with the earthworm example we can zoom in to look at parts of more complicated objects or events, then zoom out while examining scales of interactions among the parts up to actions of the whole and then up to interactions among different wholes. We can examine a government as a holon (a whole functional layer) comprised of clonons (individuals within the government) but also see how governments become hierarchical layers that set up a variety of binaries or relationships, some of which can become quite pathological in terms of binary-based double binds and complementary and symmetrical power relations. We can delve even further into the nature of these patterns of relationships by looking at the arrows and webs or networks that describe power structures and the hegemony of particular contexts.

We also can use patterns and pattern thinking for *design* (Bloom, 2004, 2012a, 2013; Bloom & Volk, 2007, 2012). Artists use these patterns all of the time by juxtaposing binaries of light and shadow and utilising various patterns of form. Musicians use cycles of repetitions of beat and cycles of sound frequencies within binaries of sound and silence. Such examples are endless as we explore all kinds of endeavors from those of scientists and mathematicians to those of writers and artists. We also can use such functional patterns in the design of various technologies and structures, as well as in the design of a classroom space and the functionality of a classroom community.

Pattern thinking recognises patterns, analyses their functions and meanings, analyses multiple perspectives, situates patterns in contexts, evaluates, models, organises, and categorises in ways that exemplify transcontextual and transdisciplinary thinking (Coward, 1990; Volk & Bloom, 2007). Pattern thinking also provides for creativity in insight and production. A significant aspect of this creativity lies in the nature of patterns as fundamental to our living and non-living worlds. However, the creative power lies in our ability to see and use patterns across disciplines and contexts. Peirce (Frankfurt, 1958; Burks, 1992; Kapitan, 1992) described this ability as abductive thinking, which became a significant way for Bateson (1972/2000, 1991) to describe rigor in ways that did not fall into the traps of measuring things that are not measureable. However, the ability to abduct or to use, apply, test, and explore how particular functional or metaphorical patterns connect across diverse contexts is a source of creativity. We can see examples of such abduction in the development of Velcro from de Mestral's "accidental" insight of his dog picking up burrs from a walk through a field in 1941 (Velcro, 2014) or the development of airplane wings from the patterns of structure in birds' wings. Poets, novelists, and artists borrow their insights from diverse contexts as well. At the same time, the evolution of various structures and processes have arisen from the various processes that are based in stochastic or random systems as well as what might be more directed creativity of the larger complex system (Margulis, 1998).

COMPLEX CREATIVITY

From within complex systems, creativity arises from non-linear pathways of information flow, diversity or variation, and the dynamics of relationships, including double binds. At the same time, creativity in complex systems relies on random or stochastic processes, as well as on processes that are more directly concerned with specific outcomes or problems. The patterns that arise or emerge from various processes and that are embedded in the systems are also critical components of creativity. In cognition, each of these characteristics and processes come into play along with our ability to think across contexts and disciplines.

In the biological world, emergence—the arising of something new—is creativity. However, as Wilber (1995) noted, emergence describes a process but does not explain anything. What is this creative process of emergence? A novel idea emerges. A new species arises. A groundbreaking technology is invented. A song is composed. A painting is completed. A poem is scratched out in a notebook. Each of these emergent objects is creative. In biology, a single-celled organism can divide into two clones of the original. A binary split occurs in much the same way as our skin cells split into two, then four, then eight, and so on. Unless some event occurs that modifies the DNA, such replication is not particularly creative. No new form or variation occurs. Although such non-creative replication is essential for survival, such as repairing damaged tissues or creating more individuals when in dire circumstances, the very foundation of life on Earth is based on the variation imbued in sexual binaries.

Random variation provides a source of genetic material that can lead to emergent new properties or species. As mentioned earlier, binaries seem to be essential for initiating and maintaining systems.

However, another source of creative emergence has to do with relationship binaries or symbiotic binaries, as suggested by Margulis (1998). In early evolutionary history, certain bacteria worked their way into single-celled organisms. Both organisms benefited, but after a while, the relationship became a permanent one. The bacteria lost much of their individuality, but played an important role in cellular physiology and energy production in what we now call mitochondria. Interestingly, the mitochondria still hold onto a certain degree of individuality in their own DNA. And, such individuality within the whole can now allow us to track maternal lineages passed on directly through the female mitochondrial DNA.

There are many other examples of relational binaries between wholes and parts of wholes that serve as sources of creativity, such as with John Lennon and Yoko Ono (Tracy, 2014) and with Patti Smith and Robert Mapplethorpe (Smith, 2010). The dynamics of these relationships created wholes that were larger than the individual parts. They also provided for the emergence of new forms of art, photography, poetry, and music. The creativity that arises from various relationships involves some sort of tension that sparks such creative emergence. These tensions may involve a variety of differences between the parts or may involve more intense double binding tensions. In either case, there is some sense of self-transcendence or transcontextuality that provides new perspectives and new pathways to creativity.

But what are the dynamics of binaries that lead to creativity? In Bateson's (1972/2000) three types of relationships – complementary, symmetrical, and reciprocal – there are particular tensions that are part of these relationships. In fact, these three categories are descriptive of the ways in which the tensions are addressed, rather than explanatory. Coordination dynamics may at least provide some insight into the nature of binaries. Kelso and Engstrøm (2006) suggest that oppositional pairings are necessary for the functioning of the human brain and of pretty much all living things. However, the way in which oppositional binaries coordinate is variable. Each system has its own rules, but they all involve non-linear, recursive patterns of information exchange. Pairs of "things" come together and move apart, then come together again in various ways. There is no steady state, which is characteristic of chaotic and complex systems. They always need to be far from equilibrium (Capra, 1996). If they are in equilibrium, they are most likely dead. Living systems are always in flux, and dealing with tensions of various kinds.

Bateson (1979/2002) described this flux in terms of cybernetic feedback loops that operate in ways that minimise, maximise, or optimise the conditions. For example, our body temperature operates in a way that optimises the conditions. At 35° C or 98.6° F, our physiology works in a way that does not maximise or minimise enzyme and other physiological activities or efficiency. If we get sick, our physiological systems raise the temperature in an effort to kill off the invaders. At 106° F, our enzymes and those of the invading bacteria (at least that's the *hope*) are working at peak efficiency, but they decay rapidly. The idea is to kill off the invaders before you kill yourself. Such an approach is the body's version of chemotherapy. On the other hand, our bodies can minimise the temperature in an effort to save the system, as well. However, the same sort of save-or-die risk occurs. These sorts of non-linear information and control patterns occur throughout the biosphere and at all levels of scale. And, I am suggesting that creativity as a process involves these same patterns of non-linear information flow. However, how is creativity different from mere replication or repetition? Changing body temperature in an attempt to survive in and of itself is not creative. However, the initial evolutionary development of this ability was creative. Throughout our living world are examples of the results of evolutionary creativity. The use of the sheet metapattern for the development of wings was a creative leap. But, was the first use of wings or each separate introduction of wings also creative? Insect wings were developed separately from the wings of birds. The use of wing-like features on maple seeds is an entirely separate lineage of sheet usage. Was the development of planes and their use of wings a creative act?

At this point in my thinking, I believe such separate innovations are creative acts. They are leaps that transcend the initial situation. They may use existent patterns in new ways or combine sets of patterns to create new forms. In human creativity, these forms may be ideas, images, and insights. But, do they have to be useful as suggested by Robinson (2006) and others (Beghetto & Kaufman, 2007; Runco & Jaegar, 2012; Spendlove, 2012)? Throughout evolution, some emergent forms and species appeared but did not significantly add to the ability of an organism to survive. Were these creative acts? Maybe the emergence of these new forms was just poorly timed. Or, maybe the conditions changed too rapidly. In the same way, is a novel idea, image, or insight creative if it is never acted upon? If I generate a haiku in my head but never write it down or if I write it down, but never share it, is it creative? As autopoietic systems, pathways for creativity are built-in. These pathways allow for creative paths to self-transcend (as a specific aspect of creativity from Koestler's [1964/1969] work), self-maintain, self-generate, and self-regulate. Creativity does need to be useful, but maybe the patterns of creative generation without specific utility is just *practice*. We generate ideas to keep the pathways working.

Play is just this sort of practice. Young children move in and out of fantasy worlds and fantasy play in ways that are indicative of creative complexity. Such creative complexity is evident in the work of Paley (1990) and Singer, Golinkoff, and Hirsch-Pasek (2006). As children grow older, schools tend to suppress their creativity, but they find other outlets in various gaming worlds and other contexts. However, on occasion, teachers can provide fantasy worlds that replicate relevant and meaningful real-world contexts and issues. Such approaches can be powerful ways to encourage creativity in more relevant situations, as with Hunter's (2011, 2013) World Peace Game. In this game, 4th grade children tackle some of the most pressing problems facing humanity within a long-term simulation. Hunter refers to the outcomes of this game as moments of spontaneous wisdom and spontaneous acts of compassion that are not predictable. The children find themselves in double binds and other untenable situations but find creative solutions often by transcending the specific situation.

IMPLICATIONS AND DISCUSSION

Spend any time around young children and one is bound to see how boundless creativity is expressed in their talk and play as evident in my early studies of children's contexts of meanings (Bloom, 1990, 1992a, 1992b). They generate fantasy situations and characters. They make leaps across contexts and what we call subject matter disciplines. They see patterns and make connections in sometimes unusual and insightful ways. They are, in very important ways, using non-linear, autopoietic pathways of creativity. They are practicing the ways of thinking that could be beneficial for future thinking, problem-solving, and even survival. However, schools not only devalue these processes, they undermine them. Drill-and-practice, teaching-to-the-test, and other rote memory and superficial approaches to *learning* take the place of helping students develop and refine the very thinking processes that are part of their biological make-up. The Common Core has gone to the extent of emphasising reading and writing about content at the expense of reading fiction and creative writing. Block (1997) published a chilling examination of how schools promoted and enacted psychological violence against children. Block's critique was written before the Common Core Standards and before No Child Left Behind legislation. The scope of psychological violence has now been pushed far beyond what Block critiqued 17 years ago.

There are many approaches we can take in schools that can help foster creativity and creative thinking. We can engage children in inquiry where, with the help of teachers' they design investigations, collect data, formulate explanations, and communicate their knowledge claims. In such an approach, children's creativity can be used in the design of investigations. They could use understandings of patterns to help in this process in the way they juxtapose binaries of variables and layer or situate layer, sequence, or cluster observational or experimental designs. Their formulation of explanations can involve abductive and creative connections across contexts. Seeing how the tubular shapes in earthworms function in similar ways to tubes in other organisms and technological objects may allow them to develop creative insights into the structures and functions of the world within which they live. They also may develop creative representations through models, works of art, or poetry. Such thinking also models and promotes the very core nature of transfer of knowledge (Bloom, 2012a; Bloom & Volk, 2007, 2012). And, communicating can involve creativity as well. Rather than a formulaic "lab report," children may communicate their knowledge through drama, visual arts, music, film, and poetry. They also can examine how the knowledge they have created in one context is connected to other contexts. A science investigation may lead to understandings of one particular living system, but children can see how that living system is affected by society or social systems, by economic systems, by political systems, and so forth.

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