Living Systems Principles:	their dynamics and...	relevance for design
1. Organizationally open, self-organizing and ‘autopoetic’ Examples of open systems include an individual, our respiratory system, a social organization such as a community group, university or company, an ecosystem or the planet.	Living systems are: structurally closed, organizationally open and in a continual exchange of energy and matter with their environment. They are ‘self-making’ or autopoetic. They are self- determining and respond to perturbations from the environment through changes in their behavior and form. Open systems couple with their environment and co-evolve in symbiotic relationship with it. Change within open systems can be perturbed, but not predicted. The more freedom a system has to self-organize, the more creative forms of order will arise within it, and the more resilient it will be to radical changes in its immediate environment.	We design for and within open systems and must understand their dynamics to formulate meaningful solutions. Because these systems are self-determining, design solutions are essentially ‘perturbations’ from the environment; their outcome cannot be predicted. This calls for a slow, thoughtful design process of iterative, user-centered prototypes in which continual ‘feedback’ informs subsequent iterations. Designers must look for clues of solutions already present in the system (grassroots) and work to amplify them. Solutions designed out of context and ‘imposed’ upon an open system almost never work for long. They are unsustainable.
2. Operate in a state far from equilibrium In linear, closed systems, equilibrium is the point at which the capacity for change has been exhausted; it has run out of energy. In living systems, a state of equilibrium would be death.	Living systems maintain themselves in a state far from equilibrium due to their constant exchange of energy and matter with their environment. By importing energy from outside, these systems keep themselves off-balance, which results in growth and change. Dis-equilibrium is a necessary condition for life and evolution. In the face of external disturbances, living systems posses the ability to reorganize themselves and adapt through new forms of order and behavior. Therefore, dis-equilibrium can be a highly creative space for a system.	The context for most design solutions are open systems, which can appear chaotic and ‘disordered’. Traditional design process assumes designers will restore or impose order (equilibrium) within the system. However, ‘disorder’ is often a rich bed out of which new forms of order can arise. Instead of imposing order upon the system (design solution) designers can reconceive their role to that of ‘catalyst for change’. They can look for signs of new behavior/forms of order and help amplify them, or coax them into existence. This represents a new role and mindset for designers.
3. Have ‘emergent’ properties	Emergence refers to the unpredictable and new forms of physical and behavioral order within complex systems. These arise at critical points of instability in response to perturbations from their environment. Complex system structure evolves as nested and hierarchical ‘levels’, each of which exhibit laws and properties that do not exist at other levels. These new forms and behaviors are said to be ‘emergent’. Therefore, complex systems cannot be understood through reductive analysis in which the sum of the individual parts explains the behavior of the whole; the whole cannot be understood independent of the context within which it exists. Context is everything.	Designers need to look for signs of emergence within the systems they are designing for/within. To an extent, design is the antithesis of emergence. If a design solution is too rigid, too large in scope and/or does not take into consideration ‘local conditions’ (a ‘one size fits all’ solution), then sooner or later, new forms of behavior and physical order will arise in response/opposition to it. This is a sign that the solution is in ‘dissonance’ with the dynamics of the system (this can be physical or psychological). Designers must carefully study the dynamics of a system first, look for its emergent properties and design solutions that are in resonance with/leverage these tendencies.
4. Their structure is networed, holarchic, and fractal	Living systems are comprised of de-centralized, networked, interdependent parts connected through symbiotic relationships. They are holarchic; meaning they are comprised of systems nested within other systems (atoms, cells, organ systems, organisms, communities of organisms, ecosystems etc.). Individual parts form wholes that are themselves parts of greater wholes. As systems evolve, new forms of emergent order arise as new levels within the system are formed. These systems are often fractal, meaning patterns and forms of behavior repeat themselves at different levels of scale.	Framing design problems within appropriate contexts is crucial to developing appropriate solutions. If designers design for and within complex systems, then solutions will be implemented within multi-level, holarchic structures connected through webs of relationship. It is incumbent upon designers to look for these holarchic, networked relationships which form the context for solutions. This contextual structure should caution against design solutions that are centralized, rigid, linear and monolithic. Design solutions should focus on relationships at multiple levels as opposed to solutions based upon physical artifacts. Artifacts must support relationships.
5. Are sensitive to initial conditions	Living systems often display extreme sensitivity to initial conditions; small changes have the potential to create large variations in the long-term behavior of a system. Examples are global warming, weather patterns, a viral epidemic. This principle from chaos and complexity science posits that the deterministic nature of these systems (indicated by their initial conditions) cannot be predicted due to the chaotic behavior of the system over time as it is perturbed by small and large changes from its environment. Long-term predictions of its behavior are impossible. A commonly used metaphor is that a butterfly flapping its wings in the Amazon can give rise to a hurricane in southeast Asia.	Design solutions are almost always based upon a brief observation of the initial conditions of a particular situation (context). This is essentially a ‘snapshot’ in the life of a complex system. If design solutions do not take into account the system’s temporality (acknowledgement that it will evolve over time) and sensitivity to initial conditions, they may create changes in the system that will ramify exponentially, producing unexpected, often negative results. Designers need to consider that large scale solutions that incorporate powerful technologies can have unpredictable, disasterous consequences. Conversely, small changes in behavior and the introduction of new ideas, information and practices within complex social systems can ramify throughout the system to create sweeping powerful change on either a physical or psychological level.

Created for PIVOT: AIGA DESIGN CONFERECE, *Phoenix Arizona, October, 2011 by* TERRY IRWIN, *Head, School of Design,* CARNEGIE MELLON UNIVERSITY, *Pittsburgh. Sources: Augros & Stanciu,* The New Biology, *1987, Benyus,* Biomimicry, *1997, Briggs & Peat,* Turbulent Mirror, *1989,* Seven Life Lessons of Chaos, *1999, Goodwin,* How the Leopard Changed its Spots, *1994, Meadows,* Thinking in Systems, *2008, Rittel,* “On the Planning Crisis: Systems Analysis of the ‘First and Second Generations’”, *1972, Wheatley,* Leadership and the New Science, *2006, Capra,* The Web of Life, *1996.*

Living Systems Principles:	their dynamics and...	relevance for design
6. Are controlled/regulated through feedback	Within living systems, single events are part of circular, cause-and-effect chains which affect present and future functioning of the entire system. Negative feedback loops stabilize the system (an example in a closed system is a heating/cooling thermostat), while positive feedback loops amplify/exacerbate changes (feedback on a microphone). Living systems maintain their ability to survive and adapt through the presence of multiple feedback loops that restore balance to the system after a large disturbance. These same principles are at work in social systems and are at the heart of both static and chaotic situations. The more disturbances a system responds to, the greater degree of flexibility and resilience it develops and the more dynamic (creative) it becomes.	Once designers understand the principles of feedback loops they can become critical components of design solutions. If change/growth/evolution are the objective of a design soluiton, harnessing the power of positive feedback through the introduction of new information, behaviors, etc. can be a powerful strategy for success. If a greater degree of order or stabilizing behavior is required, then integrating negative feedback loops into the solution is desirable. Feedback loops are intrinsic to communication/social systems and are important to observe prior to designing solutions. For more on feedback loops see: Meadows: "Places to Intervene in a System"
7. When healthy, have high degree of diversity	In living systems, diversity refers to the multiplicity of relationships or variables with it. The greater the degree of diversity with a living system, the more flexible and resilient it is to pertrubations from its environment. The health of an ecosystem is almost always related to the degree of diversity found within it.	In their desire to bring order to chaotic or problematic situations, designers often impose 'uniformity' upon situations. Solutions are often mass produced with the assumption that one-size-fits-all. Such solutions fail to incorporate diversity and redundancy and are often not suited to local conditions. This suggests a design process that takes into consideration local conditions, incorporates a diversity of relationships/variables and which is designed for ongoing change. Homogeneity and uniformity are not the same as 'order'. Our modernist aesthetic may be at odds with embracing diversity in design solutions.
8. Comprised of non-linear relationships	Open, living systems are comprised of non-linear relationships in which causes do not produce predictable, proportional effects/results. Non-linear relationships are closely related to the concepts of feedback and sensitivity to initial conditions and explain why systems can behave in counter-intuitive ways. Non-linear feedback processes are the basis of the instability/disequilibrium in systems, which often give rise to new behavior.	Non-linear relationships can be leveraged by designers to introduce new information into a system (communication design) to create learning networks. The non-predictability of these non-linear, non-causal relationships also holds a caution for designers—the effects and ramifications of design solutions introduced into a system may have unexpected positive or negative results. This suggests a thoughtful, iterative approach to designing within complex open systems and a deep understanding of systems dynamics.
9. Whole and part relationships are non-hierarchical	Living systems are comprised of semi-discreet 'wholes' which exist at multiple levels of scale (holarchies). The whole has properties that are irreducible to those of its individual parts. Conversely, characteristics of the whole can always be found within its individual parts and provide a clue to the 'essence' of the whole. This is related to the principle of holarchic/fractal structure and emergent properties.	A fundamental key to design within open systems is drawing a boundary around/setting context for a particular problem. This principle tells designers that any boundary is artificial and to an extent, arbitrary; the 'whole' created by this boundary is, in a sense, 'counterfeit'. Design solutions will always exist within contexts that are at once wholes and parts of greater wholes. It is rarely possible to see or comprehend 'wholes'. The 'parts' designers examine and assess as context for a solution will provide clues to the greater 'whole' of which they are part and should be studied deeply. This ability to see context and understand that solutions exist and affect change within a system at multiple levels of scale, whose effects can never be entirely understood is key to the design of sustainable solutions.
10. Are full of interdependence and cooperation	Living systems, particularly ecosystems, are interconnected via a vast network of reciprocal relationships. These relationships enable the system to withstand perturbations from the environment and change in response to them (flexibility and resilience). The system can be seen as a part within a greater whole, and in this way, the health and evolution of part and whole are mutually determined; the human body works this way. Similarly, the parts within a system are connected to each other through webs of symbiotic relationship; a web of life.	This principle underscores the need for designers to focus on the webs of relationship that comprise the systems within which they are designing. Understanding the nature and interdependence of these relationships and being mindful of how small changes can ramify through a system, can influence the design of a solution. An objective of any design brief can be to create, foster and enhance symbiotic relationships between components/members of a system. Designers must also remember that the web of interdependent relationships within a living system is often so complex, that it is beyond the capability of a designer or design team to predict the outcome of a solution. This suggests sensitivity, humility and a highly iterative process in the design of solutions.