

## A Ten Point Guide to Open Systems Theory

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### one

The study of open systems began in earnest in the 20<sup>th</sup> century after 19<sup>th</sup> century innovations in thermodynamics and related disciplines. Classical, Newtonian physics had based its study of natural phenomena on the analysis of the behavior of closed systems, which is now considered an artificial and misleading way of finding out about nature. An open system is a system that changes and evolves according to information continually being received from its environment. It shows characteristics that are known as nonlinear, because they are dynamic, unpredictable and open-ended. Crucially, open systems are self-organizing systems.

### two

Nonlinear dynamical theory has been applied to many kinds of systems, from ecosystems to economic systems, from chemical maps to urban networks. Nonlinear mathematics provides ways of mapping clouds and nervous systems. It is most effective in describing patterns.<sup>1</sup> Patterns cannot be measured and weighed: to understand a pattern a configuration of relationships must be mapped. The structures that emerge from such mapping have certain crucial characteristics. They are revealed as 'interactive webs' or 'differential networks' characterized by large numbers of highly mobile components that are linked to one another by various modes of communication.<sup>2</sup>

### three

In the 1960s the Nobel prize-winning chemist Ilya Prigogine developed his influential theory about self-organization while studying systems under conditions of non-equilibrium. He realized that systems that are far-from-equilibrium must be described by nonlinear equations. He discovered that as a system moves further away from equilibrium it reaches a point of critical instability, at which a new pattern emerges. This he called self-organization. It is a characteristic of what he termed 'dissipative structures.'<sup>3</sup> Prigogine introduced the concept of dissipative structures to emphasize the paradoxical close relationship between structure and order on the one hand, and dissipation on the other. In classical 19<sup>th</sup> century thermodynamics the dissipation of energy was regarded as waste. Prigogine changed this view by showing that in open systems dissipation becomes a source of order.

### four

According to Prigogine, dissipative structures (or nonlinear systems) not only maintain themselves in a stable state far-from-equilibrium, but may even evolve. When the flow of matter-energy through them increases, they may go through new instabilities and transform themselves into structures of increased complexity. Prigogine showed that, while dissipative structures receive their energy from outside, the instabilities and jumps to new forms of organization that characterize them are the result of fluctuations amplified by positive feedback loops.<sup>4</sup> The so-called runaway feedback, which had always been regarded as destructive in cybernetics, appeared as a new source of order and complexity in the theory of dissipative structures.

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<sup>1</sup> Capra, F. (1996). *The Web of Life*. London, Flamingo. pp.83-117.

<sup>2</sup> Davidson, P., D. Bates, et al. (1997). "Future Generations University." *AD Architecture After Geometry* 67(5/6). p.32.

<sup>3</sup> Prigogine, I. and I. Stengers (1984). *Order Out of Chaos: Man's New Dialogue with Nature*. New York, Bantam Books.

<sup>4</sup> It is the sudden move across levels of organisation that inspired the title of Charles Jencks's book, *The Architecture of the Jumping Universe*.

## **five**

Feedback is a characteristic of any system in which the output, or result, affects the input of the system, thus altering its operation. Put another way, information generated can influence the generation of further information. Positive feedback, or autocatalysis, is a property of open systems. An autocatalytic process is one that catalyses or accelerates itself. Classical physics did not have the tools for finding this out. Newton could predict the moon's orbit from the laws of gravity, but did not have the equations to describe the nonlinear feedback produced if another moon is introduced into the system, when orbits become chaotic and linear prediction impossible. For the first time in history, the study of feedback loops enabled researchers to distinguish between the pattern of organization of a system and its physical structure.

## **six**

An open system is part of its environment. While this means that its future behavior is not able to be determined, it can nevertheless attain a structure and maintain it in far-from-equilibrium conditions. This undermines the traditional view that systems must be examined as if they were isolated from their environment. Instead they are seen as embedded, or nested within an interactive 'cascade' of mobile networks. For this reason scale is critical in the consideration of landscape systems. In landscape studies space is dynamic, flexible, relative. It is not an absolute, not a container for form. Within a watershed or a city we can observe spatial changes at different scales. As a whole a city does not seem to change much in a week, but at the level of the street the change in one week can be radical: buildings vanish, families move on, crushing accidents occur. What is most crucial is that we can see different relationships depending on the scale at which we look. At the scale of Oceania, we can observe economic flows between Pacific islands, and this causes us to understand these islands in certain ways, as part of a global system. At the scale of the bay we see different aspects of these economic flows, and understand their relationship to landscape conditions: harvest, management and husbandry; weather patterns, kinship influences and so on. In fact, scale itself is a framing device that separates and isolates systems that are in reality connected.

## **seven**

The flow of energy in open systems allows them spontaneously to self-organize by developing novel structures and new modes of behavior. Self-organizing systems are therefore said to be 'creative'. They are adaptive, and actually require conditions of instability and disturbance in order to evolve to new levels of order and vigor. This characteristic, known as emergence, has given rise to disturbance theory in ecology, and is perhaps the most interesting development in landscape architectural terms. Emergence theory, akin to the philosophy of becoming, suggests that matter-energy, and its flows and coagulations, is the basic subject-matter of landscape architecture. The regulation of these flows and coagulations as a design strategy is described by Zaera-Polo as a way to 'permit organizationally complex landscapes to emerge through the production of topographies artificially generated by a mediated integration of rigorously modeled orders.'<sup>5</sup>

## **eight**

Open systems are complex. Their parts are so numerous that there is no way a causal relationship between them can be established. Instead, their components are connected by networks of feedback loops operating at different levels, different scales and different rhythms. Landscapes work like this. This is why it is not necessarily useful to think of them in terms of types. As complex adaptive systems their 'higher order' patterns are the result of their continual interactions within and without, of their ongoing openness and responsiveness to quite specific, changing conditions. We should think of landscapes as generated by, and therefore imminent to, the specific conditions they comprise. How we remodel landscapes is a question how we gather and direct these forces and, indeed, this is just what gardening is: the production of difference through the husbandry of natural processes.

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<sup>5</sup> See Alejandro Zaera-Polo's chapter in Reed, P., Ed. (2005). Groundswell: Constructing the Contemporary Landscape. New York, The Museum of Modern art. p.23. Zaera-Polo is a designer with Foreign Office Architects.

## nine

Once open systems theory got going it seemed as if differential, nonlinear structures were everywhere. By the 1990s open systems theory was being applied to cities. It turned out that chaos theory had developed into a tool for devising new strategies in urban development. Urban systems, too, were open-ended and unpredictable. Writers such as Salingaros,<sup>6</sup> De Landa<sup>7</sup> and Kwinter<sup>8</sup> began to explain urban processes in terms of dissipative systems. De Landa, staked out the urbanistic territory of the rhizomatic process.<sup>9</sup> High-profile practitioners like Allen,<sup>10</sup> Corner<sup>11</sup> and Koolhaas<sup>12</sup> drew explicitly on the work of scientists and science popularizers<sup>13</sup> to develop urban landscape design strategies that took account of the unpredictable and open-ended character of urban systems, and used it to generate design proposals that were time-based and adaptive. Despite their emphasis on structures of organization, and transformation over time, the ground-breaking work both of Ian McHarg and Christopher Alexander lacks a sense of the propulsive character of change and the recognition of the ability of systems to self-organize without recourse to external agency. As Batty notes, early systems theories of the city 'were structured around parts adding up to wholes in terms of an equilibrium which could not cope with any form of change.'<sup>14</sup> A city, as Holland says, 'is a pattern in time.'<sup>15</sup>

## ten

The transition from static to dynamic models has been reflected in the science of ecology. Early ecologists saw ecosystems as homeostatic. They are now seen as homeorrhetic.<sup>16</sup> Odum, for instance, wrote in 1971 that 'Homeostasis ... is the term generally applied to the tendency for biological systems to resist change and to remain in a state of equilibrium.'<sup>17</sup> In 1997 by contrast, he wrote: 'Organization and function at the ecosystem level are [not] tightly regulated [and display] more pulsing and chaotic behavior ... in other words they exhibit homeorrhesis as opposed to homeostasis.'<sup>18</sup> Pulliam and Johnson explain the paradigm shift in ecology in terms of two major changes: a shift from the equilibrium point of view to a disequilibrium perspective, and a shift from considering ecosystems as closed or autonomous systems to a consideration

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<sup>6</sup> Salingaros, N. (1998). "Mathematical Theory of the Urban Web." *Journal of Urban Design* 3: 53-71.

<sup>7</sup> De Landa, M. (1999). *The Nonlinear Development of Cities. Eco-Tec: Architecture of the In-between*. A. Marras. New York, Princeton Architectural Press.

<sup>8</sup> Kwinter, S. (1992). "Emergence: or the Artificial Life of Space." *Anywhere* 2: 162-171. Kwinter, S. (1994). "the Complex and the Singular." *Anyway* 3: 186-197. Kwinter, S. (1998). "Leap in the Void: A New Organon?" *Anyhow* 7: 22-27.

<sup>9</sup> De Landa calls rhizomatic structures 'meshworks'.

<sup>10</sup> Allen, S. (1997). "From Object to Field." *AD Architecture After Geometry* 76(5/6).

<sup>11</sup> Corner, J. (1999). *Recovering Landscape: Essays in Contemporary Landscape Architecture*. New York, Princeton University Press.

<sup>12</sup> Koolhaas, R. (1995). *The Generic City. S.M.L.XL*. R. K. a. B. Mau. New York, Monacelli Press: 1248-1264.

<sup>13</sup> For example, Capra, F. (1996). *The Web of Life*. London, Flamingo. Also Gleick, J. (1998). *Chaos: The amazing science of the unpredictable*. London, Vintage.

<sup>14</sup> Batty, M. (2000). "Less is More, More is Different: Complexity, Morphology, Cities and Emergence." *Environment and Planning B: Planning and Design* 27(2): 167-8.

<sup>15</sup> Holland, J. (1995). *Emergence: From Chaos to Order*. Oxford, Oxford University Press.

<sup>16</sup> 'Homeorrhesis' refers to the self-organising attributes of an ecosystem, including its ability to move through far-from-equilibrium conditions to higher orders of complexity.

<sup>17</sup> Odum, E. P. (1971 (revised from 1953)). *Fundamentals of Ecology*. Philadelphia, W T Saunders and Co. p.34.

<sup>18</sup> Odum, E. P. (1997). *Ecology: A Bridge Between Science and Society*. Sunderland, Sinauer and Associates. p.72.

of ecosystems as open and strongly influenced by the flux of material and individuals across their borders.<sup>19</sup> Keller and Golley describe this movement – from essentialism to probabilism – succinctly. ‘Ecology has been dominated by the entity (Being) approach at the expense of the process (Becoming) approach.’<sup>20</sup> Reflecting this change, the work of many contemporary landscape architects emphasizes the generative nature of systems modeling, and accordingly places an emphasis on agency and transformation.

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<sup>19</sup> Pulliam, R. H. and B. R. Johnson (2002). *Ecology's New Paradigm: What Does it Offer Designers and Planners? Ecology and Design: Frameworks for Learning*. B. R. Johnson and K. Hill. Washington, Island Press. p.51.

<sup>20</sup> Keller, D. R. and F. B. Golley, Eds. (2000). *The Philosophy of Ecology: From Science to Synthesis*. Athens and London, University of Georgia Press. p.31.

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