# Principles of life

We will need to become ecologically literate in order to build sustainable communities, writes **Fritjof Capra**, who explains a new advanced theory of systems thinking that recognises that life is organised in networks and is inherently regenerative, creative and intelligent

ARTWORK BY CLAIRE BURBRIDGE

Mycelium Universe 2 (Fission), 2014, pen and ink drawing (48" x 48")

I was trained as a physicist and spent twenty years doing research in theoretical high-energy physics. I left physics in the mid-eighties and turned towards the life sciences, where a new conception of life has recently emerged. It involves a profound shift in perspective from seeing the world as a machine composed of elementary building blocks to understanding that it is a network of inseparable patterns of relationships.

Over the last few decades, I have developed a synthesis of this new understanding, a conceptual framework that integrates four dimensions of life: the biological, the cognitive, the social and the ecological. I have presented summaries of this framework, as it evolved, in several books. My final synthesis is published in a textbook entitled *The Systems View of Life*, which is co-authored with Pier Luigi Luisi (Cambridge University Press, 2014). I call my synthesis a 'systems view' because it requires a new kind of thinking – thinking in terms of relationships, patterns and context. In science this is known as systemic thinking, or 'systems thinking'.

## What is systems thinking?

Systems thinking emerged in the 1920s from a series of interdisciplinary dialogues among biologists, psychologists and ecologists. In all these fields, scientists realised that a living system – an organism, ecosystem, or social system – is an integrated whole whose properties cannot be reduced to those of smaller parts. The meaning of this statement is actually quite subtle and is often misunderstood. There is nothing wrong with saying that the *structures* of all living organisms are composed of smaller parts, ultimately of molecules. But this does not mean that their *properties* can be explained in terms of molecules alone. The systemic properties derive from the processes and relationships in which these molecules are involved. Systemic properties are properties of the whole, which none of its parts have. Thus systems thinking involves a shift of perspective from the parts to the whole. The early systems thinkers expressed this in the now well-known phrase 'The whole is more than the sum of its parts.'

In a more philosophical vein, we might even say that regeneration is the purpose, or the meaning, of life

Thinking in terms of relationships is crucial for ecology, because the word 'ecology', which is derived from the Greek *oikos* ('household'), means the science of the relationships among various members of the Earth household. I should also mention that systems thinking is not limited to science. Many Indigenous cultures embody profound ecological awareness and think of Nature in terms of relationships and patterns.

During the 1980s, systems thinking was raised to a new level with the development of complexity theory, technically known as 'nonlinear dynamics'. It is a new mathematical language, involving the use of high-speed computers, which allowed scientists for the first time to handle the enormous complexity of living systems mathematically. The new nonlinear mathematics is a mathematics of visual patterns – strange attractors, fractals, and so on.

During the last forty years, there has been a strong interest in nonlinear phenomena, which has generated a whole series of new and powerful theories that have dramatically increased our understanding of many key characteristics of life. They embody what I like to call 'advanced systems thinking', based on complexity theory rather than on the classical systems theories of the 1930s and 1940s. My synthesis of these recent theories is what I refer to as the systems view of life.

## Systemic principles of life

Naturally this synthesis involves quite a few technical concepts. However, I recently found a completely nontechnical way to summarise it in terms of four 'principles of life', which, according to the systems view, constitute its very essence. They are principles of organisation shared by all living systems, from the smallest bacteria through the wide range of fungi, plants, humans and other animals. In other words, these four principles are embodied in all forms of life, including social systems and ecosystems.

## Principle 1: life organises itself in networks

My first principle is that life organises itself in networks. This actually contains two ideas. One is that the network is the basic pattern of organisation of all living systems: wherever we see life, we see networks. This realisation originated in the early 20th century in ecology with the concept of food webs. Subsequently, network models were used at all systems levels, viewing organisms as networks of cells, and cells as networks of molecules, just as ecosystems are understood as networks of individual organisms.

A network, as everybody knows, is a certain pattern of nodes and links, of relationships. Therefore, in order to understand networks, we need to learn how to think in terms of relationships and patterns, and this is what systems thinking is all about. Please note also that networks are nonlinear – they go in all directions – and since all living systems are networks, this means that all living systems are nonlinear, or 'complex', systems.

In recent years, social networks have become a major focus of attention, not only in science but also in society at large and throughout a newly emerging global culture. Indeed, networks are the dominant social feature of our age. The profound change of metaphor from seeing the world as a machine to understanding it as a network lies at the very heart of the systems view of life.

The second idea implied in my first principle is that life organises *itself*: the network pattern is not imposed on a living system by its environment, but is created by the system itself. The concept of self-organisation originated in the 1940s and was used in many different contexts and with different meanings during the subsequent decades. Today, describing living systems as self-organising means that they create structures and processes organised by the internal rules of the system, rather than by external imposing forces.

This does not mean that living systems are independent of their environment. On the contrary, they depend for their survival on continual flows of energy and matter, or food, from the environment. In fact, these continual flows, known as metabolism, provide a key distinction between living and nonliving systems. The great microbiologist Lynn Margulis liked to say: "If it metabolises, it's alive; if it doesn't metabolise, it's not alive."

Sirens, 2021, pen and ink, watercolours (42.5" x 42.5")

## Principle 2: life is inherently regenerative

My second principle is that life is inherently regenerative. Living networks continually regenerate themselves by transforming or replacing their components. In this way they undergo continual structural changes while preserving their web-like patterns of organisation. This coexistence of stability and change is indeed a key characteristic of life.

The continual regeneration of life in Nature is, of course, well known. We only have to think of the turn of the seasons with new growth every spring. That's regeneration. The novel insight in the systems view is that regeneration operates at all levels of life, down to the molecular networks in cells. Regeneration is the very essence of life. When regeneration stops, life stops. In a more philosophical vein, we might even say that regeneration is the purpose, or the meaning, of life.

The continual process of regeneration, of transforming and replacing components of the system, is only possible with continual metabolic flows of energy and matter through the living network. Indeed, we all need to breathe, eat and drink to stay alive. In other words, metabolism – that defining characteristic of biological life – is an integral part of regeneration.

As I have mentioned, life in the social realm can also be understood in terms of networks, but here we are not dealing with chemical reactions: we are dealing with communications. Social networks, as everybody knows today, are networks of communications. Like biological networks, they are regenerative, but what they generate is mostly nonmaterial. Each communication creates information, ideas and meaning, which give rise to further communications, and thus the entire network continually regenerates itself.

As communications continue in a social network, they form multiple feedback loops that eventually produce a shared system of knowledge, values, and rules of conduct – a common context of meaning, known as culture, which is continually sustained by further communications.

## Principle 3: life is inherently creative

The fact that an organism's metabolism involves flows through networks of chemical processes has the important consequence that these metabolic flows include cyclical

The Quickening (detail), 2013, pen and ink drawing (42" x 48")

**All artwork by Claire Burbridge** www.claireburbridgeart.com
Claire's work will be exhibited at Nancy Toomey Fine Art, San Francisco in September
www.nancytoomeyfineart.com

pathways. These cycles can act as feedback loops. Because of that feedback, living organisms are able to regulate and organise themselves. Feedback loops can be either self-balancing, maintaining the organism in a state of dynamic balance known as homeostasis, or they can be self-amplifying, or 'runaway', which may result in the entire system becoming unstable.

At this point, the system may either break down, or it may break through to a new form of order. This spontaneous emergence of new order at critical points of instability, often referred to simply as 'emergence', is in my opinion the most important discovery of complexity theory. The process of emergence has been studied in great detail and has been recognised as the dynamic origin of learning, development and evolution. In other words, creativity – the generation of new forms – is a key property of all living systems. This is my third principle of life: life is inherently creative.

This means that, as human beings, we are creative not only if we happen to be artists or designers. All of us are creative simply because we are alive, because life itself is inherently creative.

## Principle 4: life is inherently intelligent

My fourth and final principle is that life is inherently intelligent. This is based on a new conception of the nature of mind, which is one of the most radical philosophical implications of the systems view of life, since it finally overcomes the Cartesian division between mind and matter that has haunted philosophers and scientists for centuries.

In the 17th century, René Descartes based his view of Nature on the fundamental division between two independent and separate realms – that of mind, which he called the "thinking thing", and that of matter, the "extended thing". Following Descartes, scientists and philosophers continued to think of the mind as some intangible entity and were unable to imagine how this "thinking thing" related to the body. The decisive advance of the systemic understanding of life has been to abandon the Cartesian view and to realise that mind is not a thing but a process, known as cognition (the process of knowing).

In the systems view of life, cognition denotes a particular way in which a living organism interacts with its environment. The organism responds to environmental influences with structural changes, and it does so autonomously, specifying which influences to notice and how to respond according to its nature and previous experience. Continual cognitive interactions with the environment are an essential part of an organism's metabolism, and thus life and cognition are inseparably linked: life is inherently intelligent.

This is a radical expansion of the concept of cognition and, implicitly, the concept of mind. In the systems view, cognition manifests at all levels of life, whether or not an organism has a brain and a nervous system. Plants, for example, and even bacteria, neither of which have nervous systems, are constantly engaged in cognitive activities involving their sensory apparatus and various self-organising processes.

Another way of describing this situation is to emphasise that all living organisms interact with their environment through sensory organs. To use an old philosophical term, living beings are sentient beings. In the systems view, their sentient interactions are identified as cognitive interactions. As the structures of the sensory organs become more and more complex in evolution, so do the corresponding cognitive processes. Eventually we have the evolution of brains, nervous systems and human consciousness, involving self-awareness, language and conceptual thought.

**Many Indigenous cultures embody profound ecological awareness and think of Nature in terms of relationships and patterns**

The ability to form abstract concepts, symbols and mental images is a key feature of our consciousness, and human intelligence today includes the abstractions we associate with mathematics and with computers – algorithms, mathematical models and the like. However, from the systemic perspective of life at large, these mathematical abstractions are peripheral to the intelligence inherent in all living organisms. Living intelligence is tacit and embodied. Its key quality is the ability to be in the world, to move around in it, and to survive in it.

With the recent rapid development of artificial intelligence (AI), we have overemphasised algorithms and other mathematical abstractions and have neglected our tacit, embodied, living intelligence. As a consequence, our ability to be in the world – in other words, our wisdom – seems to have diminished dramatically. Indeed, a civilisation that sees making money rather than human wellbeing as its main goal and in the process of doing so destroys the natural environment on which human survival depends can hardly be deemed very intelligent.

The critical question, in my view, is which uses of AI are helpful and appropriate, and which are inappropriate because, although they enhance the mathematical aspects of human intelligence, they may diminish our tacit, embodied intelligence or wisdom of how we should live.

In conclusion, I want to emphasise that advanced systems thinking will be critical in order to solve the major problems of our time, which are systemic ones – all interconnected and interdependent. In particular, systems thinking will be essential for building ecologically sustainable communities, designed in such a manner that their ways of life do not interfere with Nature's inherent ability to sustain life. The first step in this endeavour must be to become ecologically literate – that is, to understand the principles of organisation that ecosystems have evolved to sustain the web of life. These principles of ecology are grounded in the four principles I have introduced, and so – to summarise the new systemic conception of life – life organises itself in networks, and these living networks are inherently regenerative, creative and intelligent.

We urgently need to put life at the centre of our businesses, economy, technologies, physical structures and social institutions. As the political activist and author David Korten admonishes us, "We will prosper in the pursuit of life, or we will perish in the pursuit of money. The choice is ours."

Fritjof Capra is a physicist and systems theorist and the author of several international bestsellers, including *The Tao of Physics* and *The Web of Life*. He is co-author with Pier Luigi Luisi of the multidisciplinary textbook *The Systems View of Life*, on which his online course is based. www.capracourse.net