

What Is Life? A Systemic Approach

Pier Luigi Luisi^{*†}

Prof. emeritus ETH-Zurich, Switzerland

E-mail: luisi@mat.ethz.ch

In the systems view of life (in all biological, social, cognitive, ecological aspects) the fundamental properties of an organized assembly (be that of an organism, or a machine, or a social enterprise) are due to the mutual interactions of all components, and not so much to the properties of the individual components. What is then the difference between an organized mechanical system, also composed by many interacting parts, and a living organism? This question will permit to dwell on the theory of autopoiesis by Maturana and Varela, a theory which, within the general framework of system thinking, give the most exhaustive answer to the question "what is life?". The interaction of the living with the environment will be then considered, which brings to the important notion of cognition. This connects biology with cognitive science, which in turn is a concept related to evolution and the very origin of humankind. Consciousness appears as the most distinctive characteristic of humans – but if it is so, why man is the only animal which systematically destroys his own environment? The ecological problems of our time are then briefly discussed, including some of the proposals presented in the literature to possibly solve the crisis of our globe.

*XI Multifrequency Behaviour of High Energy Cosmic Sources Workshop
25-30 May 2015
Palermo, Italy*

*Speaker.

†A footnote may follow.

an integrate whole, we have a picture of fragmentation. Death is fragmentation, the lack of the concerted unity. And what is true for a body is also true for a social system: if in the aforementioned hospital the doctors do not speak with each other, nor with the nurses, or with the administration, and each part is isolated and independent, then this is a dead social system, and so is for a political party, for a city or for the European Union. And going to the very small, this is true inside a single cell: the cell metabolism is based on the interaction among thousands of compounds with thousands of reactions and this is so also for a small bacterium. This complex situation can be schematized in the cartoon of fig. 2, showing the spherical (in cross section) cellular compartment limited by a semipermeable membrane. Inside, the myriad of chemical transformations, but, despite this, a cell maintains its own individuality: a liver cell remains a liver cell, the amoeba remains the amoeba, and so on – at least during the homeostasis period.

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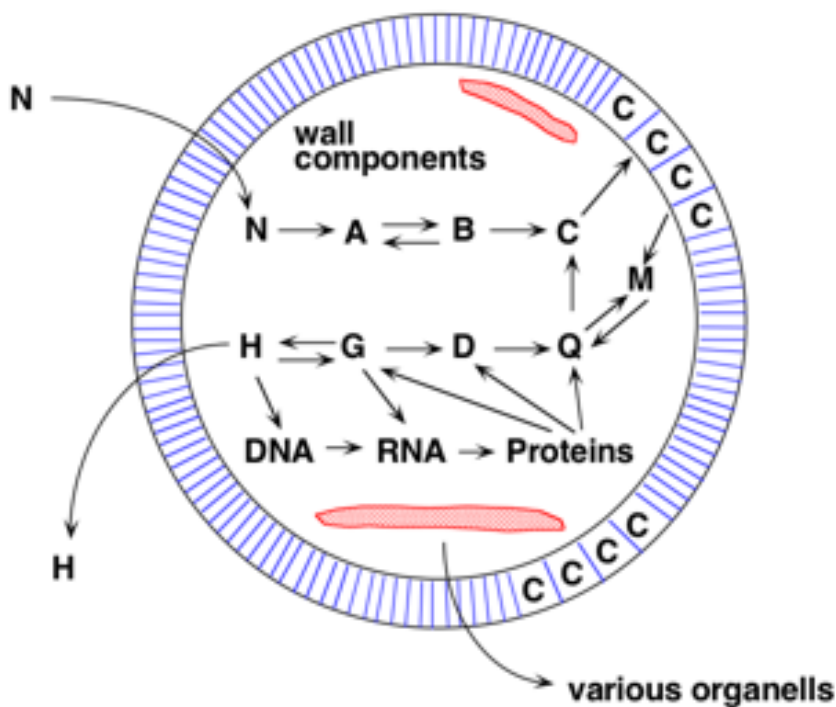


Figure 2: Schematization of a cell, characterized by a myriad of internal reactions, (here only a few are indicated, for simplicity) and limited in space by a semipermeable membrane which permits the entrance of certain nutrients N.

There is then an apparent contradiction between the large and continuous number of chemical changes, and the maintenance of the individuality. And here is really the important point: the basic tenet of each cell, and by inference of every living organism, is the self-maintenance despite the myriad of internal transformations; and this is possible because the cell re-generates from its interior all what is being destroyed in the chemical transformations. The cell, and each living organisms, can be seen as a factory that re-makes itself from the inside. This of course at the

expenses of energy/nutrients coming from the outside, as we will see more specifically in the next section. All this is the basis of the theory of autopoiesis, as developed by Maturana and Varela in the early seventies of last century (for that, see Maturana and Varela, 1998).

The take-to-home message from this, is that the interaction among all components -as the general landmark of life- forms a dynamic system whose main function is self-maintenance, namely the support of individual life itself. And this holds both in the biological as in the social life. Also notice from fig. 2 that the complex network of reactions- actually in reality something thousands of time more complex than that- does not have a localization centre, namely one particular reaction or compound which dominates and/or is responsible for the working of the entire ensemble. In this systems view, is the interacting whole ensemble that should be considered in its totality: life is a complex system without a centre of localization.

3. The interaction with the environment as a cognitive interaction

Living organisms are thermodynamically open systems, in the sense that they, as typical dynamical non-equilibrium systems, have to receive a flux of energy/nutrients from the outside. This brings us to the very important item of the interaction with the environment. Each organism, in order to remain alive, has to interact with its specific environment. The term "specific" is very important: it indicates that each organism is characterized -thanks to evolution- by a specific set of sensorial tools to recognize its own environment and interact positively with it. Thus, the fish has a sensorial apparatus which permits its existence in water; quite different is the sensorial apparatus of the earth warm, and that of the bat is again different, and very specific. In this sense, we can say, with Maturana and Varela again (Maturana and Varela, 1980) that each organism is a cognitive organism. Also the bacterium is cognitive, and the term cognition in this field should not be taken with an anthropomorphic meaning.

Thus, the question posed at the beginning of this article, "what is life?", cannot be exhaustively answered only on the basis of the biological, autopoietic structure. It must also contain the dimension of the environment, and the interaction between the living and the environment is made possible by the act of cognition – see fig. 3.

4. Arriving at the notion of consciousness

The complexity of cognition increases with the sophistication of the living, and at the level of man we have the five senses, and then the mind. All this is also the product of evolution, the particular evolution which has characterized the appearance and development of humankind. A couple of general considerations about evolution are important at this point. The final point we have today is the general tree of life, shown in the next figure, (Fig.4), with the three main domains of life, bacteria, eukaryotes, and archaea.

We have millions of different species in our planet, with a wonderful display of microorganisms, fish, insects, flowers, birds.... But we have to add that, according to the modern view of evolution, none of these species was programmed: nature, evolution, works without a predetermined plan. It works according to the vagaries of contingency-see about this point Capra and Luisi, 2014; Luisi 2006), which among other things, states that the forms of life might have been different; or

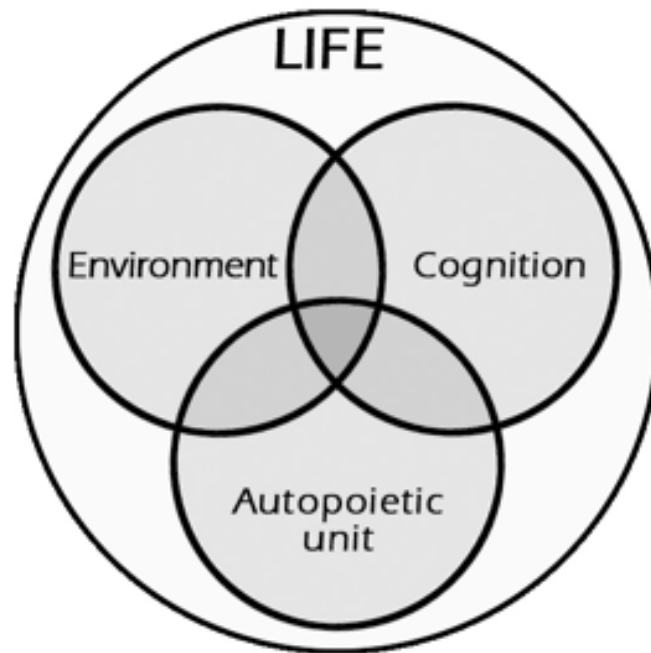
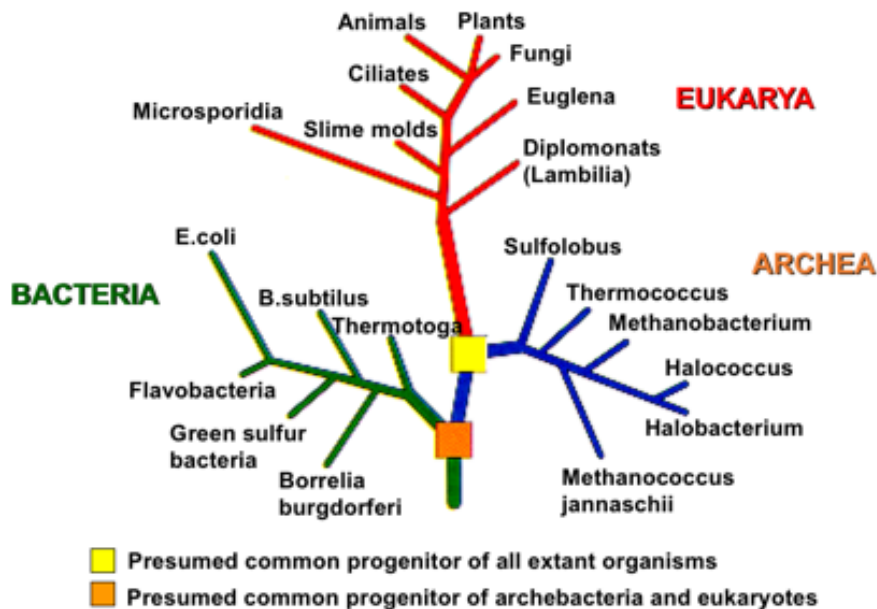


Figure 3: Life as a trilogy of the biological structure, environment and cognition (from Capra and Luisi, 2014. With modifications).

The three kingdoms of organism are related through sequences of their ribosomal RNAs.



(from Molecular Cell Biology, 4th ed.)

Figure 4: The three of life, the product of 3.5 billions years evolution, as divided in the three main kingdoms.

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that they might have not existed. There is no particular reason why the banana tree must have arisen, and if bananas were not existing, nobody of course would miss them. Stephen Jay Gould, one of the main voices in the theory of contingency, examines in one of his books (Gould, 1989) the flow of life from the beginning – 3.5 billions years ago – till the present; and points out that for the first two billion years our Earth was populated only of unicellular organisms; and that only with the Cambrian explosion, about one billion years ago, were the most important multicellular organisms originated-from which eventually came out Man). And considering the arising of the Cambrian revolution, he wrote his famous sentence: "run the tape again.... and it might have taken 12 billions instead of two billions years". This implies nothing less, that mankind might have not appeared as it did, namely, the arising of mankind is also due to the erratic pathway of contingency, and – just like the banana tree – might have not come out. And our globe would be still occupied only by unicellular organisms- a very peaceful landscape, even though not very exciting. And there are several examples of contingency all over our life history: take the famous case of the asteroid that 65 million years ago stroke our Earth, provoking among other the extinction of all dinosaurs – and thus permitting the arising of small mammals, which eventually evolved into humankind. If the inclination of the falling asteroid would have been a few degrees different, or if the Earth would have been in a slight different position, the impact would not have occurred – and then probably these dinosaurs which had dominated the Earth for over 100 million years, would be still here, but without us. Again a quite different, and peaceful, possible scenario for our Earth. But Man begun to spread around the Earth already 4–5 million years ago, till the point of eventually becoming the dominator of the planet. An animal characterized by many skill, and, most importantly, the mind skills-intelligence and creativity. And also, a quality that is distinctive human: consciousness. The origin of life is still a mystery for science: And the mystery which adds to this mystery is the fact that the very particular product of life on Earth, Man, is capable of consciousness. This term has various aspects, and the relation between brain–mind–consciousness is still the subject of debate (Capra, Luisi 2014). One aspect of consciousness is the subjective feeling of being, the knowing to know, the knowing to be. The other complementary aspect is the sensory level of consciousness, linked to our perception senses, and to the brain activity. In this part, we have consciousness in the sense of discriminating the level of the moral ethical values, including the sense of responsibility for our own action. Mankind as the crown of evolution and consciousness then as the highest pinnacle of this creation?

5. The global warming, and related problems

Despite its consciousness, man is the only animal who systematically destroys his own environment. This is also one chapter, and an important one, of the big chapter "what is life?". The destructivity of humankind, also towards itself, is very sadly documented by thousands of years of war and atrocities – non sense of listing them here, perhaps is sufficient to point out that in the last recorded 4 thousand years of history we didn't have a single day without war or without blood shed. Here, in order to see the negativity of human action on its own planet, we can simply jump to contemporary time, starting from 1950, for example. The next table – reported in Fig. 5 – (taken mostly from Capra and Luisi, 2014) gives a simplified list of our actions.

It is really an impressive series of insults to our own environment – a situation against which also Pope Francesco took clear position with his recent Enciclica "Laudato si", where, referring to the words of S. Francis about "nostra sora madre terra" (our sister mother Earth) had to write (my translation): "This sister protests for the illness we provoke in her, due to the irresponsible usage and misuse of the wealth that God posed in her. We have been growing thinking to be her owners, dominators, authorized to ransack her"

FROM 1950 TILL TODAY

- WE HAVE DESTROYED ONE HALF OF THE EARTH FORESTS**
- INSERTED IN THE ATMOSPHERE LARGE QUANTITIES OF CO₂, METHANE AND OTHER**
- WITH A GLOBAL INCREASE OF TEMPERATURE OF 0.5° C; WHICH CAN GO UP TO 2°C**
- WE CREATED A LARGE OZONE HOLE**
- 65% OF LAND, ONCE GOOD FOR CULTIVATION, NO LONGER AVAILABLE TO FARMERS**
- AND ONLY 12% OF EARTH SURFACE LEFT FOR THE CONSERVATION OF NON HUMAN SPECIES**
- A LOSS OF BIODIVERSITY ABOUT THOUSAND TIME HIGHER THAN NORMAL**
- WE CONTINUE TO PRODUCE NUCLEAR WASTE**
- ALMOST ONE THIRD OF THE WORLD POPULATION LIVES WITH LESS THAN A DOLLAR/DAY**

Figure 5: What Humanity has done since 1950.

The situation is dramatic, also because all the problems we are facing represent a systemic reality, they are all connected and related to each other: global warming depends on pollution which depends on the exaggerated consumption of fossil energy, which also induces loss of biodiversity, whereas the fossil oil/carbon production is dominated by multinational corporations, which bring about the accumulation of wealth in the hands of a few and the consequent poverty in the majority of people—a situation which in turn produces emigration of large masses of people, with political and military consequences. And the problems of deforestation, of neglect of small farmer houses, are interrelated problems. This is indeed a complex systemic situation, but it is also clear that there is a root to all this. Reporting from Capra-Luisi' book (see Fig. 6).

From this situation of quantitative, unlimited growth, we should move to a situation of a qualitative, sustainable growth. This is also "what is life" – at a global level. The way of this transformation appears to be hard, given the tendency of the great corporation for a policy of "business as usual". However according to several authoritative economists, there are solutions, and the books of Castells(1996), Lester Brown (2008, 2009), Amory Lovins (2011), Jeremy Rifkin (2011), offer a series of possible solutions to the question of energy, poverty, overpopulation, ecological farming, deforestation.... They generally add the budget for each solution they propose, as they are not new-age dreamers, but economists fully in touch with the ground reality. It is not the place here to discuss all that, it is important to stress that we are in the middle of a battle against a new type of global, institutionalized capitalism which may destroy our planet, and that the result depends on

The fundamental dilemma underlying the major problems of our time seems to be **the illusion that unlimited growth is possible on a finite planet.**

The obsession of politicians and economists with unlimited economic growth must be seen as one of the root causes, if not **the root cause, of the global multifaceted crisis. ...**

the goal of virtually all national economies is to achieve unlimited growth, even though the absurdity of such an enterprise on a limited planet should be obvious to all

Capra and Luisi p.363,367

Figure 6: The fundamental dilemma for the humanity.

the engagement of each of us.

6. Concluding remarks

We have looked at the question "what is life" within the framework of the systemic approach and spacing from the human body and its cellular structure, till the entire planet, noticing the complexity of each system as made by an ensemble of various components. In all cases, the common denominator is the interdependency of these components, the fact that the comprehension of the whole system can only be interpreted in terms of the mutual interaction of the parts, whereby has no much sense to consider one of these components in isolation, as it were an independent entity. And all this is true also for the social levels of life- families, corporations, hospitals, political parties, churches, where again the vitality is given by the positive interaction among the constituent parts, or members of the community. Important in the systems approach is also the notion of cognition, identified here as the capability of the system to interact with the environment, and the observation that due to this co-emergency, actually a new entity springs out- see the example of the spider and its web. The environment provides the energy and material for the dynamic interactions among the parts, but it is never to be considered an inert framework to be used passively by the living. The trilogy of biological structure, environment, cognition, provides the systems view of life. Speaking about cognition in humans has brought us to the notion of consciousness, and when this is meant as awareness and responsibility of human actions, we have outlined the basic, almost incomprehensible contradiction with the destructive activity of mankind towards his own environment. Those are all problems that we have caused, and we should have the means to repair them. And this is the direction to go, in order to give a healthy answer also in the future to the question: what is life.

Acknowledgments I would like to thank Professor Dr Franco Giovannelli for giving me the opportunity to expose the delicate issue of the meaning of life in a scientific context seemingly far away. Many thanks also to the LOC for the hospitality.

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