The Evolution of Life

According to the law of syntropy

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Abstract

The theory of syntropy suggests that the underlying mechanism of macroevolution is characterized by attractors and retrocausality, but it does not contradict the theory of evolution which would remain valid within microevolution.

1. The naturalist view of evolution

Naturalism was born in the nineteenth century in opposition to the spiritualistic ideology of the Romantic period and is based on the premise that all natural phenomena can be explained using causality. However, the energy/momentum/mass equation shows that classical causality is governed by the law of entropy, i.e. the tendency to dissipate energy and matter to be distributed randomly.

Albert Szent-Gyorgyi (1893-1986), Nobel Prize for Physiology and discoverer of vitamin C, stated:

> *It is impossible to explain the qualities of organization and order of living systems starting from the entropic laws of the macrocosm. This is one of the paradoxes of modern biology: the properties of living systems are opposed to the law of entropy that governs the macrocosm* (Szent-Gyorgyi, 1977).

While entropy is a universal law that leads to the disintegration of any form of organization, Szent-Gyorgyi concluded that syntropy is the universal law of life, which is demonstrated constantly by the existence of living systems. For Gyorgyi syntropy is symmetrical to the law of entropy and leads living systems towards more complex and harmonious forms of organization. The main problem, according to Gyorgyi, is that:

> *We see a profound difference between organic and inorganic systems ... as a scientist I cannot believe that the laws of physics become invalid as soon as you enter the living systems. The law of entropy does not govern living systems.*

The biologist Jacques Monod (1910-1976) described the paradox between life and the properties of entropy which lead towards an increase in disorder, disorganization, and homogeneity, with the following words:

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> *Man must at last finally awake from his millenary dream; and in doing so, awake to his total solitude, to his fundamental isolation. Now does he at last realize that, like a gypsy, he lives on the boundary of an alien world deaf to his music, indifferent to his hopes, his sufferings, his crimes* (Monod, 1971).

Naturalism is based on cause-effect explanations, governed by the law of entropy, and leads to a vision of the universe governed by laws that deny life, in which life is just a highly unlikely episode.

Naturalism tries to overcome this entropic vision by providing negentropic properties to chance, random mutations. According to naturalism life originated and evolves thanks to chance, that is without any apparent cause. Einstein used to say that the use of chance shows the incompleteness of a theory. "*God does not play dice!*" he exclaimed trying to emphasize the fact that a scientific theory must make use of causality and should avoid resorting to chance. The use of chance puts naturalism in contradiction with its fundamental premise, namely that all natural phenomena can and should be explained using causality.

The theory of syntropy extends causality to retrocausality and supercausality and shows that the negentropic properties, that naturalists attribute to chance, are typical of retrocausality and supercausality. By doing so, the theory of syntropy extends causality to those aspects of life, organization, order and complexity that today are explained using hypothetical negentropic properties attributed to chance.

Albert Szent-Gyorgyi suggested the existence of a force symmetric to entropy:

> *A major difference between amoebas and humans is the increase of complexity that requires the existence of a mechanism that is able to counteract the law of entropy. In other words, there must be a force that is able to counter the universal tendency of matter towards chaos and energy towards dissipation. Life always shows a decrease in entropy and an increase in complexity, in direct conflict with the law of entropy.*

- *The concept of species*

Cataloging and classifying living organisms is one of the oldest and main objectives of biology and is referred to as "taxonomy". The term comes from the Greek word *taxis* (ordering) and *nomos* (rule). In biology, a taxon (the plural is taxa) is a taxonomic unit, a group of real organisms, morphologically distinguishable and / or genetically recognizable from others as a unit with a precise location within the hierarchy of the taxonomic classification. Carl Linnaeus (1707-1778), the father of taxonomy, based the classifications mainly on the external features of living things and this procedure is sometimes referred to as "Linnaean taxonomy". Only later taxonomy was expanded to anatomy, i.e. the skeleton and soft parts, and molecular and genetic information. Morphological taxonomy attempts to classify living beings according to their similarities, using neutral and objective descriptions.

Taxonomy is an empirical science which uses ranks, including, among others: kingdom, phylum, class, order, family, genus, species. In zoology, the nomenclature for the more important ranks is strictly regulated by the ICZN Code (International Commission on Zoological Nomenclature), whereas taxonomy itself is never regulated, but is always the result of research in the scientific community. How researchers arrive at their taxa varies. It depends on the available data, and resources and methods can vary from simple quantitative or qualitative comparisons of striking features to elaborate computer analyses of large amounts of DNA sequence data.

For this reason, researchers can produce different classifications due to a series of subjective choices. For example:

- Depending on which features we choose to consider, the classifications can change.
- The similarity values used in statistical analyses can be changed, and this can lead to place individuals into taxa that are close to the critical values of similarity.

To overcome the limitations of subjective choices genetic taxonomy was developed. Genetic taxonomy is based on the idea that couples that produce fertile progeny belong to the same taxa. The genetic approach classifies species according to their ability to produce fertile offspring under conditions of natural life. If organisms produce fertile offspring only when artificially crossed, in captivity or breeding, they are counted in different species. For example, a mule is the product of a horse and donkey, and is barren. The genetic approach therefore leads to catalog horses and donkeys as different species.

Biological taxonomy is therefore divided mainly into morphological taxonomy, which takes into account the external features (morphospecies) and genetic taxonomy which takes into account fertility (genospecies). Depending on whether the emphasis is put on the genetic (fertility) or morphological (features) the boundaries between species can vary. In the case of donkeys and horses there are two genospecies and one morphospecies, since they are indistinguishable on the basis of their external features, and therefore belong to the same morphospecies, but do not produce fertile offspring, and therefore do not belong to the same genospecies. To overcome this discrepancy, the base type classification was introduced which takes into account both classifications: the reproductive behavior and the morphological features. However, even the base type classification has not managed to produce generally accepted taxa. The geneticist W. Gottschalk says "*Despite decades of research, the definition of species as a biological unit presents great difficulties. To date there is still no single definition that meets all the requirements*." The common definition of species, genospecies, morphospecies and base type, are imprecise, since they do not permit a clear and always valid delineation among taxa. By applying different definitions of species, inevitably the boundaries change. This raises the question whether it is possible to define higher taxonomic units that encompass the concepts of both genetic and morphological species.

- *Microevolution*

Charles Darwin (1809-1892), in *The Origin of Species* (1859), described the variability among species and the fact that in the long-term population size remains constant, despite the overproduction of progeny. Darwin concluded that only the best and fittest individuals survive and become the parents of the next generation. This process of natural selection would be enhanced by genetic drift, i.e. the tendency of alleles, which are responsible for the particular ways in which the hereditary features manifest, to randomly combine during reproduction. Positive combinations would increase the chances of survival and would be therefore selected, becoming a common feature. Only random variations (mutations) which directly or indirectly benefit the possibilities of survival and contribute to evolutionary progress are selected whereas deleterious mutations are mostly eliminated. This mechanisms favors advantageous mutations and plays an important positive role in the evolutionary process. For Darwin, natural selection and genetic drift are the key elements of the evolutionary process.

However, it is generally accepted that the mechanism of natural selection and genetic drift operate only within the context of microevolution.

The terms microevolution and macroevolution were introduced in 1927 by Philiptschenko, where:

- *Microevolution* indicates the selection of features within the same species, for example: quantitative changes of organs and structures of existing bodies.
- *Macroevolution* indicates the evolution of new features, for example: the development of organs, structures and forms of organization with qualitatively new genetic material.

The function of microevolution is to optimize existing structures, while the function of macroevolution would be to develop for the first time, or from scratch, structures with new functions.

An example of microevolution is provided by seeds carried by wind, which fail to germinate in soils polluted by heavy metals. In landfills in Britain it was observed that a minority of seeds can germinate, grow and make seeds that can colonize soils polluted by heavy metals. These offspring show the inability to re-cross with their parental plants growing on normal uncontaminated soils. Based on the definition of genospecies, one can therefore say that a new species is born. Can this processes be used as evidence of the development of a new specie with new information? Genetic analysis shows that these new plants, that can grow on contaminated soils, have not developed a new character, but the tolerance to the high content of heavy metals derives from the fact that the absorption of minerals from the soil is limited. The genetic information has been limited, and it is not an evolutionary progress due to new information. The example of plants colonizing mine landfills, as well as other examples of this type, proves that the process of microevolution should not be considered a development towards higher forms, but an impoverishment of the genetic information. It is a specialization the creation of a race with depleted genetic information. These plants are more tolerant to heavy metals, but are less adjustable to environmental changes and are more at risk of extinction. When this process of selection is repeated, it results in massive depletion of the genetic information. These new breeds are more suited to specific environments, more specialized, but also less flexible.

Another example of microevolution is provided by the cheetah, the fastest mammal on the planet. The depletion of the genetic information, due to specialization, is not reversible and tends to bring this specie to extinction. Despite its extraordinary abilities as a predator, the cheetah is endangered because of its very low genetic variability and information which makes the species all very similar. This specialization leads to illnesses, a high percentage of abnormal sperm, the fact that after hunting these predators are so tired that they become unable to defend their prey from other competitors, such as lions, leopards and hyenas, and an insufficient capacity for adaptation that increases the risks of extinction.

Speciation, i.e. the formation of new species, observed to date is limited to microevolution processes of specialization governed by natural selection which selects the genetic potentials of species. Observations suggest that species start from a condition in which large quantities of genetic information and potential is available; gradually this potential is reduced as a result of natural selection, guided by events of colonization and isolation. This reduction of the original variability of genetic information allows the colonization of new habitats, but limits future possibilities of adaptability. Speciation, as it is known today, is based on the loss of genetic information due to particular environmental conditions and the processes of specialization.

An important role in microevolution is played by genetic drift, i.e. by the recombination of parental genes during sexual reproduction that leads to the formation of a virtually unlimited number of new combinations. The biological importance of sexual reproduction is explained by the fact that it enhances the possibilities of natural selection. But, since genetic recombination does not produce anything new, natural selection is confined only within microevolution. No new genetic material is formed, but only pre-existing genes and alleles are recombined, mixed and selected.

- *Macroevolution*

Unlike microevolution, which is based on genetic drift, natural selection and speciation which progressively reduce the genetic information, macroevolution requires mechanisms that can increase and produce new information. However, so far, only microevolution processes of specialization have been observed. Evolutionary factors such as natural selection, genetic drift and isolation do not seem to provide explanations regarding macroevolution. Consequently the term macroevolution has been understood and is understood in very different ways:

- Some authors use it to indicate mechanisms other than Darwin's gradualism which are insufficient to explain the development of new complex organs (such as the development of wings or legs, etc.).
- Others use it in a descriptive way, without any comment on the mechanisms.
- Some use it to indicate evolution beyond the species level. The difference between microevolution and macroevolution becomes the border between species.
- Sometimes a distinction is made by discipline: macroevolution is studied by paleontologists whereas microevolution by biologists.
- The boundaries between microevolution and macroevolution are considered to be fluctuating and it is not possible to distinguish between these two terms.
- Others reject the term macroevolution on the grounds that there is only one evolutionary mechanism.

Genetic mutations appear spontaneously in nature (without apparent causes) and can also be artificially induced or favored, for example by treatment with chemicals, radiation and temperature changes. However artificial mutations limit evolution to the field of microevolution. Empirical findings show that these mutations help explain the separation of a parental species into two or more species (speciation), but they do not explain the increase in information. Offspring specialize in different directions, but cannot increase their information.

One wonders then:

- if there are known mechanisms that explain macroevolution;
- if there are clues that suggest that macroevolution is possible;
- if the equation *microevolution + time = macroevolution* is correct.

A first consideration about the action of natural selection is that a series of mutations that should initiate the development of a new organism (macroevolution) would survive only if every single change causes a selective advantage or, at least, not a disadvantage. This means that the evolution of a new organ or structure cannot go through intermediate stages which are disadvantageous and would not survive natural selection. Living systems must be able to survive in each stage of the evolutionary process. For this reason it is difficult to explain the development of complex organs, since the intermediate stages would result in a disadvantage which would be eliminated by natural selection.

In the formation of new organs and structures, in general, a selective advantage is given only after their completion. The early stages of a new body represent a pure waste of material and until the process is completed do not offer any selective advantage. Therefore, incomplete intermediate forms would be eliminated by the mechanism of natural selection. The biological value of an organ is given only when the various functions can interact. Simulating the evolution of new organs using computer software, advantageous intermediate stages should be achieved in a very limited period of time; but neither the computational or biological models can account for these quick intermediate stages of evolution. Advantageous intermediate stages require information on mechanisms, rates of mutation and recombination, suitable and appropriate selection criteria and population size, which in simulations need to be introduced artificially (from outside) showing that the processes of macroevolution require good technology, good programs and software, but there is no known natural source that can provide these resources, programs and information. From the evolutionary point of view, the unsolved question is not about the existence of advantageous mutations, but the possibility of the development of new genetic material and new structures.

Darwin believed that similar features are hereditary, for example children resemble their parents, and for this reason he argued that similar species, such as chimpanzees and humans, should have common ancestors. This hypothesis requires the existence of numerous intermediate links which should testify the evolution between chimpanzees and humans, but these links are missing and have not been found so far. Occasionally there are fossils that are interpreted as links, but their interpretations have resulted fundamentally controversial. Phylogenetic theory cannot completely ignore the fact that these links are missing. Darwinists try to explain their absence by saying that evolutionary processes took place in marginal populations with a low probability of fossilization.

The theory of macroevolution also maintains that affinities should be interpreted as convergences. But, how can an evolutionary process without a tendency converge towards similar results? The convergence is usually explained by saying that evolution has been strongly channeled by similar selective processes. But fossils show that in regard to size, morphology, ecology, stages of development and reproduction, old species cannot be distinguished from recent ones, suggesting a substantial constancy of species.

While biology examines living species, paleontology studies the world of plants and animals which existed on our planet in the past and it is therefore considered to be a science of origins and evolution. According to the macroevolution doctrines, each type of organization would have developed gradually and links existed between and among different types, gradually developing in higher forms and organisms. But, paleontologists have failed to provide any evidence for the existence of these links. On the contrary, they have provided evidence of a substantial constancy of species. For example: the major groups of plants appear suddenly and not in a gradual way and species often appear in the wrong chronological order (the most complex and evolved appearing first). Within the same taxa, it is usually impossible to show a trend from simple to complex, for example, under the Psilophyton taxa, the oldest forms are the most complex in the stratigraphic sequence. In most cases, family trees can be reconstructed only if we admit the possibility of convergence and reversions (i.e. the return to original features). According to generally accepted studies, spores appear before macrofossils (wood, leaves, etc.). No one knows why this could have happened.

2. The syntropic vision of evolution

The interpretation of the energy/momentum/mass equation produces a representation of the universe based upon two polarities: the big bang and the big crunch. This representation is schematically outlined in Figure 1.

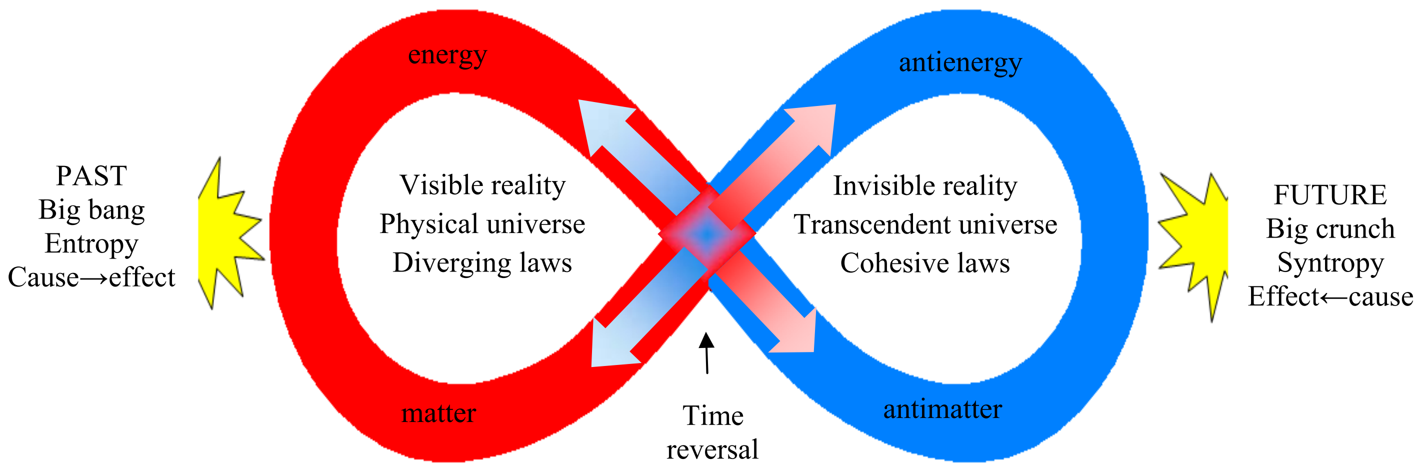

Figure 1 - Graphical representation of the cosmological interpretation of the energy/momentum/mass equation

Figure 1 schematically shows the cosmological interpretation of the energy/momentum/mass equation. In summary:

- On the left, the big bang from which matter, energy, the laws of mechanics and the visible universe governed by the law of entropy started.
- On the right, the big crunch from which antimatter, anti-energy and the transcendental universe governed by the syntropic laws of life initiate.
- The expansion rate of the visible universe would gradually decrease, under the effect of the gravitational forces. When it reaches zero the visible universe begins to implode and time is reversed. Similarly, the anti-universe, or transcendental universe, starts from the right with the big crunch, moves backward in time and, when it comes to the point of time reversal, starts to move forward in time.

The energy/momentum/mass equation states that during the big bang there was exactly the same amount of matter and antimatter. The question that physicists ask is: *why do we live in a universe* *mostly made of matter? What has happened to antimatter*? When the negative, backwards in time, solution of the energy/momentum/mass equation is accepted as valid, antimatter is described as moving backwards in time. At the moment of the big bang the same amount of matter and antimatter was created, antimatter immediately started to move backwards in time, while matter and energy started to move forward, avoiding any interaction and annihilation. According to this equation, the universe consists of the same amount of matter and antimatter, but these two aspect of reality move in opposite directions that come into contact only indirectly through the central point of time reversal (see figure 1). According to this interpretation all that is divergent is governed by the laws of entropy, whereas all that is convergent is governed by the law of syntropy.

Before we venture in the description of how the theory of syntropy explains the evolution of life, it is necessary to understand how the transcendental universe is organized. It is commonly accepted that the big bang was made of highly concentrated and undifferentiated energy that cooled down because of the expansion of the universe and slowly clustered into atoms, galaxies, solar systems and planets, through the action of cohesive forces such as gravitation. Similarly, the big crunch would be made of highly concentrated and undifferentiated anti-energy, which diverges backwards in time and slowly clusters thanks to the opposing forces. Similarly to what happens in the visible universe, it is assumed that the transcendental universe has a complex structure made of a central attractor which corresponds to the moment of the big crunch and smaller attractors increasingly complex in structure, the further one moves from the big crunch. Consequently, the energy that comes from the future (syntropy) would not be undifferentiated, but would be structured in the form of complex attractors hierarchically organized and articulated, with their starting point in the big crunch. Life would be a physical manifestation of these attractors and would represent the organization of the transcendental universe.

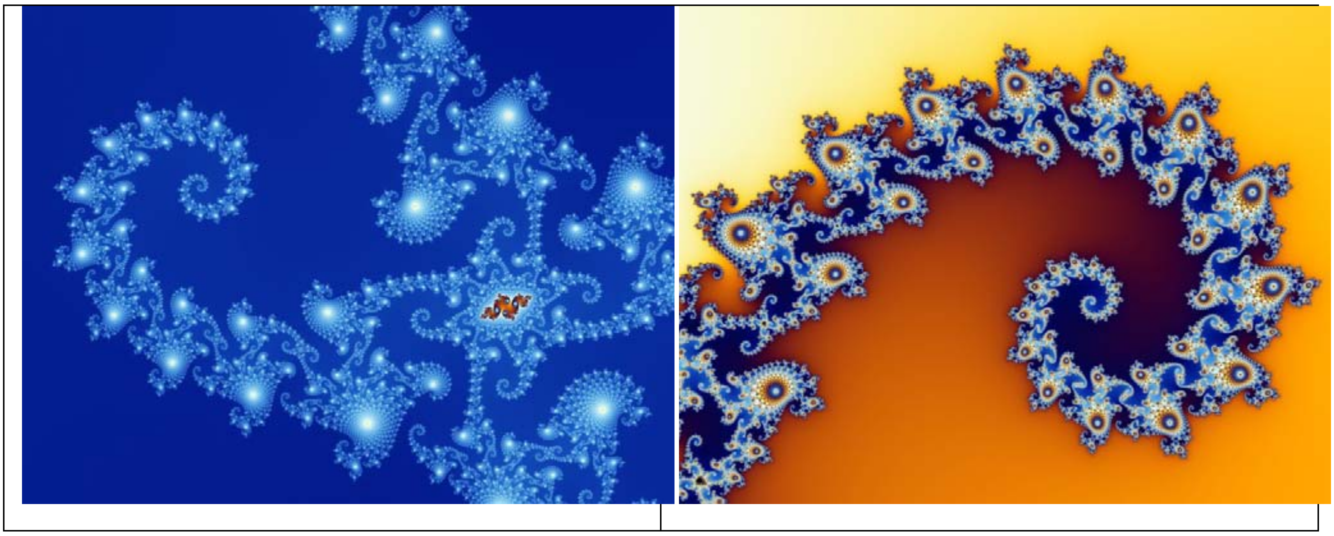

Figure 2 - Example of fractal figures (Images taken from Wikipedia).

When attractors interact with entropic systems fractal geometry is obtained. Fractal geometry is fascinating since it recalls the forms and structures of living systems. It is amazing the amount of fractal structures observed in the human body, for example (Vannini, 2005):

1. The coronary arteries and veins have fractal type ramifications. The main vessels branch into a series of smaller vessels which, in turn, branch into even smaller caliber vessels. It seems, moreover, that these fractal structures have a vital role in the mechanics of contraction and

conduction of excitatory electrical stimulation. Heart rate spectral analysis shows that the normal beat is characterized by a broad spectrum that resembles fractal geometry.

2. Even neurons have a structure similar to fractals: when observed at low magnification asymmetric branches (dendrites) connected with the cell bodies can be seen. At a slightly higher magnification there are smaller branches starting from the larger ones and so on.
3. Lungs resemble fractals generated on the computer. Bronchus and bronchi form a tree with multiple branches, whose configuration appears similar in both high and low magnification. By measuring the diameters of the different orders of branching, it is found that the bronchial tree can be described by fractal geometry.

Fractal geometry suggests that the organization and evolution of living systems, tissues, nervous system, organisms and species, is guided by attractors that retroact on living systems from the future, thanks to the properties of retrocausality and syntropy.

The biologist Rupert Sheldrake refers to the theory of René Thom (1923-2002) "*The theory of catastrophes*" which identifies the existence of attractors at the end of any evolutionary process (Thom, 1972). Sheldrake introduces the hypothesis of formative causation according to which morphogenesis (the development of the shape) is guided by attractors, i.e. retrocausal processes. The term comes from the Greek root *morphe/morphic = form* and is used to emphasize the structural aspect. Thom's work introduces the idea that shapes are caused by the future (attractors), i.e. by a mechanism identical to that of Fantappiè's syntropy.

Michelangelo stated that the skill of an artist is to bring out from stone the figure that is already in it. Similarly, the success of living species is to bring out the attractor which is already present in the body, thanks to continuous feedback loops with the future. The theory of syntropy thus leads to the hypothesis that the organization of living systems is guided by attractors that retroact from the future. According to this hypothesis, genes would have the function to receive information from attractors and not to encode information from the past. This would be the reason underlying the incredible stability of the species and their convergence towards common forms, and would also explain the strange results obtained by Driesch in his experiments on embryos of sea urchins, which show that if in a two-cell stage sea urchin a cell is killed, the remaining cell does not give rise to half of a sea urchin, but generates a small but complete organism. Living forms are guided by attractors. They acquire their form from these attractors, regardless of what happened in their past. Consequently, the most powerful way to manipulate living matter is to change its connection with the attractors, which means manipulating its genes.

Another anomalous experimental result, that can be easily explained in terms of attractors, is Sheldrake's discovery that members of the same group, such as animals of the same species, are able to share knowledge, without using any physical transmission. Experiments show that when a mouse learns a task, this same task is learned more easily by each other mouse of the same breed. The greater the number of mice that learn to perform a task, the easier it is for each mouse of the same bread to learn the same task. For example, if thousands of mice are trained to perform a new task in a laboratory in London, similar mice learn to perform the same task more quickly in laboratories all over the world. This effect occurs in the absence of any known connection or communication between the laboratories. The same effect is observed in the growth of crystals. In general, the ease of crystallization increases with the number of times that the operation is performed, even when there is no way in which these nuclei of crystallization may have been moved from one place to another infecting the different solutions.

In order to explain this strange results Sheldrake introduced the concept of morphogenetic field:

> *Today, gravitational effects and electromagnetic ones are explained in terms of fields. While Newtonian gravity rose somewhat unexplained by material bodies and spread into space, in modern physics fields are the primary reality and by using fields we try to understand both material bodies and the space between them. The picture is complicated by the fact that there are several different types of field. First there is the gravitational field, identified in the theory of general relativity as the geometry of space-time that is curved in the presence of matter. Then there is the electromagnetic field, in which electric charges are localized and in which electromagnetic radiation propagates in the form of waves. According to quantum theory, these waves consist of particles called photons which are provided with a field. Third, the quantum field theory (QFT) considers subatomic particles such as fields. Each particle has its own type of field: for example, a proton is a quantum field of proton-antiproton and an electron an electron-positron field, and so on* (Sheldrake, 1981).

Sheldrake's morphogenetic fields are a combination of the concepts of fields and energy. Energy can be considered the cause of change, the field can be considered the project, the way in which change is guided. Fields have physical effects, but are not themselves a type of energy, they act as attractors guiding energy in a geometric or spatial organization.

The theory of syntropy translates "*morphogenetic fields*" in "*morphogenetic attractors*" or "*morphogenetic retrocausality*" and agrees with Sheldrake's conclusions on morphogenetic fields, which would be at the basis of formative causation. Attractors are the cause of morphogenesis, evolution and the maintenance of the shape of living systems at all levels of complexity, not only on the surface, but also in internal processes.

The theory of syntropy shows that retrocausality, i.e. attractors that retroact from the future, explain in a causal way the mysteries of life. According to the theory of syntropy, life is guided by attractors, which causally act from the future, with properties similar to those described by Driesch's entelechy, and which follow fractal geometry. Attractors would drive the evolution and growth of living systems within morphogenetic fields. Even if attractors explain morphogenesis they are not the only cause. For example, in order to build a house we need building materials and a project (an attractor) which determines the shape of the house. If the project is different, the same building material can be used and produce a different house. When building a house there is a field that corresponds to the project. The project is not present in building materials, which can therefore be used in many different type of projects. The project gives stability and leads the building material to converge and cooperate together, despite individual differences. There is something that keeps parts together, something that contrasts the divergent forces of the law of entropy, and these are the cohesive forces of syntropy. This example can be extended to cells, organs, trees, and living systems in general. For each species, for each type of cell and organ there is at least one attractor which coincides with what is normally called a field. Each morphogenetic field would correspond to an attractor that drives the living system towards a specific form and evolution.

In 1942, Conrad Waddington coined the term epigenetics in order to describe the branch of biology that studies the causal interactions between genes and phenotypes, i.e. the physical manifestation of the body. According to epigenetics, phenotypes are the result of inherited genetic mutations. These mutations last for the entire life and can be transmitted to the following generations through cell divisions. However, the hypothesis that the features of life can be added by means of random mutations, such as described by epigenetics, contradicts the law of entropy according to which the spontaneous formation of the smallest molecule of protein requires at least 10^{600} mutations. It should also be noted that epigenetics imply that some mysterious mechanism has placed the properties of life in genetic programs and genetic instructions.

Attractors constitute the common denominator of a collectivity of individuals. For example, the attractor humanity is the common denominator of all human beings, the attractor mice is the common denominator of all mice. Attractors act as relays which transmit to all individuals connected to it the solutions to problems. This mechanism would explain the results obtained by Sheldrake which show that when mice in London learned to solve a task, automatically all the mice of the same species (same attractor), around the world solved the same task more easily. Individuals interact with the physical world and their experience reaches the attractor which relays it to other individuals. If this experience is useful it is reinforced by other individuals. This mechanism leads to select and reinforce only what is useful for life. When it is reinforced also by the experience of other individuals it becomes a common project to which the DNA can connect. Genetic information results as the sum of collective experiences shared through a common attractor. Genes would not store information, but would act as antennas that connect our cells, our body, to the projects stored in the attractor. When genes are broken the communication malfunctions, the project is not received correctly and diseases emerge.

The theory of syntropy suggests that the underlying mechanism of macroevolution is characterized by attractors and retrocausality, but it does not contradict the theory of evolution which would remain valid within microevolution.

References

Monod J (1971), *Chance and Necessity: An Essay on the Natural Philosophy of Modern Biology*, New York, Alfred A. Knopf, 1971, ISBN 0-394-46615-2.

Sheldrake R (1981), A New Science of Life: The Hypothesis of Formative Causation, Blond & Briggs, London, 1981.

Szent-Gyorgyi A (1977), *Drive in Living Matter to Perfect Itself*, Synthesis 1977, 1(1): 14-26.

Thom R (1972), *Structural Stability and Morphogenesis*, W. A. Benjam, (1972), ISBN 0-201-40685-3.

Vannini A (2005), *From mechanical to life causation,* Syntropy 2005 (1): 80-105.