Chapter 1

Today's information towards Aristotelian form

New perspectives on information in mathematics, physics and biology

In this first chapter we intend to introduce some elementary notions about the increasingly meaningful role of *information* in the context of the *biological sciences,* starting from the early decades of the 21st century.[1] A role which seems to involve both the question on the evolution of species and the matter of the emergence of life. In a wider sense information is playing a significant role in *order emergence* (self organization) of the *structure* and the *dynamics* of physical and biochemical complex systems.

Nowadays we can see biologists, non-linear systems physicists, computer scientists and philosophers collaborate in a same research group in order to investigate new simulation models and theories about emergent life, organ formation in a body and mutations of species. Most of these topics involve relevant philosophical problems related to the possibile and unavoidable quest for an ontological interpretation of such theories beside to suggest heuristic paths orienting the research.

People are now especially interested in proposing some definition of *information* which is more fundamental and relevant than the traditional one arisen in the field of noise free communication engineering. Significant steps have been carried out thanks to the analogy recognized between *information* and *negative thermodynamic entropy,* when non-equilibrium thermodynamics of open systems exchanging matter energy and information with the environment was developed by several authors. In the latter context the emergence of *ordered structures* within the physical open thermodynamic systems, governed by a sort of theleonomic dynamics, has oriented the researches to test how such thermodynamical systems could provide models for biological organisms and life emergence. Meanwhile the non-linear mechanics of dynamic systems discovered the existence of the *attractors, i.e.* solutions towards

[1] I dealt with this subject for the first time in the last chapter of my book [7] to which the present chapter is largely inspired.

which all the trajectories, the initial conditions of which belong to a suitable *basin of attraction*, tend for time increasing values. Such attractors may be *stable* or *unstable* depending of the parameters characterizing each of them and may switch from stability to instability in correspondence to the parameters value switching. A comparison between a similar behavior and and the change from life to death of a living system was considered as straightforward. Moreover some properties of a non-linear system appeared as *global* (holistic) and not reducible to a sort of summation of more elementary *local* (reductionistic) properties.

So the idea that some *information* characterizing the *structure* and the *dynamics* of the *whole*, which is not deducible starting from the properties of its single *parts* as if they were independent of the whole, suggested quite naturally to compare our contemporary notion of *information* with the ancient but always fascinating notion of Aristotelian *form*.

Those ideas have been applied also to the *species* of living beings and not only the *individual* and the question

– if a sort of *information* may somehow orient the evolution of species, involving *attractors* and *repellers,* even if the initial conditions are determined by chance

– or if only chance and natural selection are enough to explain evolution.

At present two schools of thinking are in competion:[8]

– The former school defends a neo-Darwinian position according to which the only *random genetic mutations* are enough to explain an evolution improving the qualities of species by spontaneous emergence of *new information*.

– The latter, on the contrary, suggests that chance may not be enough to explain a gain (evolution) in the level in species, since an adequate *cause* is required in order to activate the emergence of *new information* from the *potentiality of matter*[2] as, in a greatly different historical and cultural context Aristotele proposed.

Therefore an increasing interest in Aristotelian doctrine of *form* appears today no more so peregrine as it was only until some decades ago.

Surprisingly *experimental investigations* and mainly *computer simulations* provide relevant results supporting the ideas of the second stream of thinking.

– In fact simulations show that the great majority of random mutations are not of advantage for the species since they do not improve the ability to survive of the mutant individuals and only very few do. Moreover a sort of increasing *genetic entropy* accompanies mutations which destroys information rather than increasing it. A situation resembling the behavior of thermodynamic entropy the increasing of which, according to the second principle, decreases the power of heat in order to be transformed into mechanical work. Random genetic mutations cause more *disorder* (loss of information) than *order* (organization).

[2]See[8] *General Introduction*, pgs XIII-XIX.

– Moreover the mutations result not to be genetically permanent, since they disappear in the descendants after few generations. In practice it has been shown that a *threshold* (minimum number of mutant individuals) exists under which the effect of mutations (either damaging or improving) extinguish after few generations.[9]

– Computer simulations, at least until now,[3] has provided results which seem not to be favorable to a *merely random mechanism* of a process improving the species.

Then the researchers have been induced to examine in more depth the notion of *information* as a new *immaterial factor* playing an essential role, even if not yet well understood, either in governing the evolution of species and the birth of life and the emergence of an ordered structure in complex systems. In this framework at least two main problems arise.

– How to *define* information and how to try to provide a *model* of information behavior?

– Which is the *cause* of emergence of information in material systems (*i.e.,* systems carrying mass and energy)?[4]

The *reductionistic* and materialistic approach attempting to explain *information* as a mass-energy phenomenon, identifying it with its material carrier, has been just universally recognized as inadequate to describe experience. As a matter of fact we experience every day how information can be transferred from some material support to any other one, without alteration of its informational content. Since the early times of telecommunications and cybernetics it appeared as an evidence what Norbert Wiener (1894-1964), one of the fathers of information theory, said:

> Information is information, not matter or energy. No materialism which does not admit this can survive at the present day ([12] pg 132).

1.1 Heuristic operative definitions of information

We can easily recognize an increasing progression along the history of the attempts to achieve a proper definition of *information.* Starting from the early purely *descriptive* definitions, based on a physical and statistical approach as it was suggested by a comparison with thermodynamics and statistical mechanics, further steps were made in order to formulate more abstract and *causally explicative* definitions. In literature we may find references at least to the following kinds of theories of *information* and related definitions:

– *the classical theory of information*;

– *the theory of specified complex information*;

[3]For instance we may mention computer programs like *Tierra, Mendel* and *Avida* simulating random mutations involved in species evolution.[10] [11]

[4]According to an Aristotelian way of speaking we could say: *which is the adequate cause of the eduction of the form from matter potency?*

– *the algorithmic theory of information*;

– the *universal theory of information*;[13]

– la *the pragmatic theory of information* which is concerned to the cost of the machineries and networks required to process information.[14]

Here we will examine some of the previous definitions which seem to be more relevant even for their philosophical implications.

We remark that none of those definitions appear to be exhaustive. So their approach to the notion of *information* is to be considered as heuristic, operative, in progress, in oder to attempt to reach a more deeply *essential*[5] definition. Together to all those efforts it proves to be useful and somehow clarifying to take into account also the notion of Aristotelian *form*.

1.1.1 The classical theory of information

The classical theory of information, originally own to Claude Shannon (1916-2001) is based on the statistical mechanics with the engineering purpose of softening as possibile undesired signals (*noise*) emphasizing, on the contrary, the carrier of the relevant information to be transmitted by a sender to a receiver. For this aim it proves to be enough and very efficient to restrict the object of investigation to the *syntactic* statistical analysis of the material *symbols* required to data transmission, *e.g* along cables or aether, their storage into physical memories and their processing.

The basic original idea of Shannon was that of relating the notion of *information* to the probability of some event to happen or not, the behavior of which seemed to him very similar to that of the *negative thermodynamic entropy*. So he conjectured a definition of *information* as:

$$I = -\log_b P, \tag{1.1}$$

I being interpreted as a measure of information, P the probability of the event occurrence and b the basis of the numeric code employed.

If a very likely event happens we gain a very law information. On the contrary if it does not occur (or its contrary happens) we are more informed and almost compelled to a deeper investigation about that phenomenon. The formula is assumed to be the same as that which characterizes the thermodynamic entropy, except for the minus sign ([15] §IV).

1.1.2 The theory of complex specified information

The *theory of complex specified information* proposed by William Dembsky (b. 1960) adds to the classical information theory a sort of *finality criterion* orienting chance to reach some

[5] When we say *essential* we mean a definition catching what information is properly in itself and not only when it is related to aspects coexisting with it, like the string by which it is coded, the different kinds of memories on which it is stored, the costs required for it to be processed, and so on.

result at the end of a process. The main problem a similar approach is the lack of a mathematical or symbolic formalization of that theleonomic factor which remains an extrinsic philosophical conjecture. Therefore such a theory is often evaluated as non-scientific as the entire approach of the so called *intelligent design* ([13] pg 17).

Finality may enter legitimately within a scientific theory if it results to be a part or a consequence (*e.g,* as a mathematical solution) of the laws (equations) governing a complex system (physical, biological or other, [16] §VI, 1). In any case, the existence of an element external to a theory needs to be demonstrated as a logical consequence of the internal axioms of the theory itself, which is required to avoid internal contradictions.

1.1.3 The algorithmic theory of information

At present it seems to me that the approach of the *algorithmic theory of information,* adequately enriched by a *semantic* interpretation and content, is the most promising one, for the development of a mature scientific theory of information contributing to physics of complex systems and biology, and even to philosophy.

The *theory of algorithmic information,* proposed and enriched by Ray Solomonoff (1926-2009), Andrej Nikolaevi Kolmogorov (1903-1987) an Gregory Chaitin (b. 1947), is concerned with *complexity* – as it is suitably defined within the theory itself – of the *symbols* involved in data and object structures.

First of all a definition of *algorithm* is required.

> An *algorithm* is a sequence of operations capable of bringing about the solution to a problem in a finite number of steps ([15] §V).

Such definition is enough wide to host different kinds of algorithms involving different levels of information, progressively approaching to the Aristotelian notion of *form.* We will examine, by means of some examples, the methodological and epistemological relevance of the corresponding different levels and some implications for biology, foundation theory and even philosophy.

1.2 Some examples of algorithms

We limit ourselves to three simple well known examples of algorithm emphasizing the different *level of information* involved in each one.

- The *first level* consists in a simple *sequence of operations* to be executed in order to solve some problem. In this case the kind of information involved is merely *operational* and does not involve any sort of definition of some entity. On an Aristotelian-Thomistic point on view it looks like the description of an *accidental mutation* of some entity built as a cluster (aggregate) of substances which is not endowed of a unique *substantial form.*

- The *second level,* as we will see, is ontologically more relevant, since it actually *defines an entity* determining its *structure.* Philosophically we can say that the *information* involved in the algorithm properly defines the *essence* of an entity, just as an Aristotelian *form*.

– The *third level* also *defines* an entity characterizing the *dynamics* which generates its *structure,* rather than defining immediately the *structure* as a *whole.* According to the Aristotelian-Thomistic terminology we say that the *information* involved in the algorithm specifies the *nature* of the generating information.

Let us now examine those examples.

1.2.1 Algorithm to exchange the liquid contained in two different glasses

Let us consider two glasses, say A and B, filled respectively of water and wine. We want to transfer the water from A into B and *vice versa.*

$$A, B \to B, A$$

The problem is easily solved with the aid of a third empty glass C. Then the required algorithm is the following:

1) pour the water contained in A into C:	$A \to C,$
2) pour the wine contained in B into A:	$B \to A,$
3) pour the water now contained in C into B:	$C \to B$

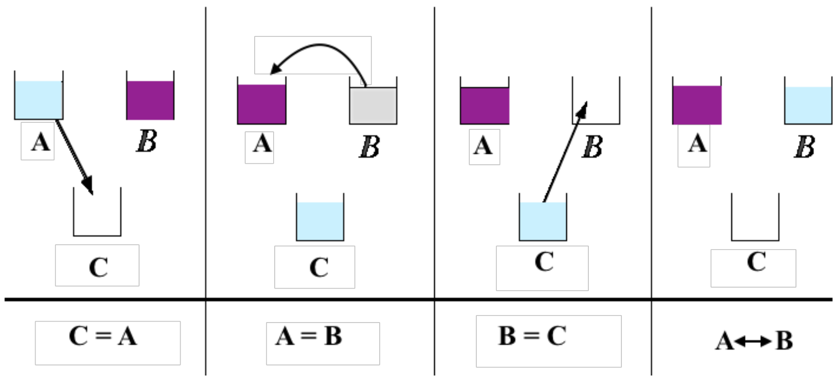


Fig.1 - Exchange the liquid contained in two glasses

At the end of the procedure the desired exchange will result. The water which was into A will have been transferred into B and the wine originally in B will be now in A.

The algorithm, simply, describes an *operative* procedure which provides a mutation (*becoming*), while it does neither define nor give consistency (*being*) to an entity.

Let us now examine a second kind of algorithm which, on the contrary, is actually able to *define* the structure (*essence*) of a new entity.

1.2.2 Algorithm to generate a *fractal*

Roughly speaking we can characterize a *fractal* as an infinitely rippled curve or surface the level of complexity of which is preserved at any magnification scale.[6]

What is remarkable is the circumstance that the mathematical computation generating a fractal, beside providing an operational procedure, properly *defines* and in the same time *actuates* constructively its entity.

Among all fractals we choose here, as an example, a typical *Julia set* (the *dragon*). The algorithm is the following.

- We consider a complex number:[7] $z_0 = x_0 + i\,y_0$ the real part (x_0) and the imaginary part (y_0) of which run inside a suitable interval: $[-l, l\,]$;

- we choose another complex number $c = a + i\,b$ which is maintained constant along the whole procedure, as an identifier of the *Julia set* itself. In the example of fig. 2 we have set $c = 0.27334 + i\,0.00642$;

- we define a sequence of complex numbers $z_n = x_n + i\,y_n,\ n = 0, 1, 2, \cdots$, the initial term of which is just z_0 and each next number is obtained adding c to the previous one squared. We have so the recurrence rule:

$$z_{n+1} = z_n^2 + c, \tag{1.2}$$

- we take the sum of a significantly high number of subsequent terms of the sequence;[8]

- At the end we evaluate the absolute value h of the sum obtained:[9].

$$h = \left| \sum_{k=0}^{n} z_k \right| > R. \tag{1.3}$$

  If h is greater than a suitable value R, before established, we paint on a computer display a pixel of co-ordinates (x_0, y_0) with a precise color (or respectively a gray level) of a suitable color map (or grayscale).

Manifestly the algorithm beside providing an operating procedure *defines* essentially the *structure* of a new entity, namely a *Julia set,* while constructing it.

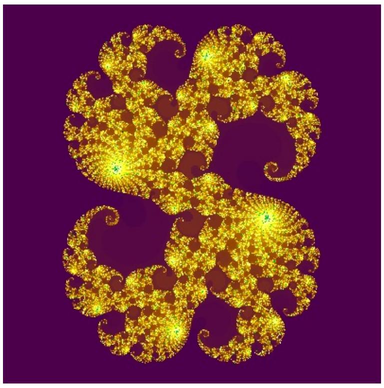
[6] Fractals are more precisely classified considering their *fractal dimension,* a measure of the fraction of plane or space they fill when they are considered as wholes. One may see, *e.g.,* my *Fractal Gallery* (www.albertostrumia.it/?q=content/galleria-di-frattali-fractal-gallery) beside several papers and books with astonishing pictures of fractals.

[7] We remember that a complex number has the general form $z = x + i\,y$ where x, y are two real numbers and i is the imaginary unit, *i.e.,* a number the square of which is, by definition, -1.

[8] In principle the infinite series of all the terms of the sequence should be taken. In practice, on a computer a finite number of terms can be added. The greater is the number, the better will result the details in the picture.

[9] We remember that the absolute value or *modulo* of a complex number $z = x+iy$ is given by $|z| = \sqrt{x^2 + y^2}$.

$$\begin{array}{ccccccc}
 & & & & & & z_0 \\
 & & & & & & \downarrow \\
 & & & & z_1 & = & z_0^2 + c \\
 & & & & \downarrow & & \\
 & & z_2 & = & z_1^2 & + & c \\
 & & \downarrow & & & & \\
z_3 & = & z_2^2 & + & c & & \\
\dots & & \dots & & \dots & & \dots
\end{array}$$



$c = 0.27334 + i\,0.00642$

Fig.2 - Generation of a Julia set

1.2.3 Algorithm to determine a fractal *basin of attraction* of a chaotic magnetic pendulum

Our third example is provided by physics rather than mathematics. It consists also in a fractal set the *structure* of which results as an effect of the chaotic *dynamics* governing a magnetic pendulum driven by three magnets located in the vertices of an equilateral triangle.

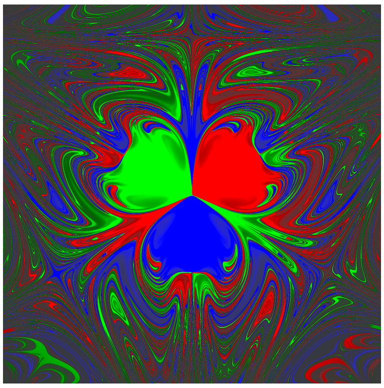


Fig.3 - Fractal basin of attraction of a chaotic magnetic pendulum

The motion of the pendulum appears to be *random* at all when it is observed at some time interval and with no regularity or order. Each trajectory seems to end onto one of the magnets without any choice criterion. That notwithstanding the *dynamics* is driven by a precise *information* arising from the laws of physics, since the arrival magnet depends exactly on the starting point from which the pendulum is initially released.

The pendulum dynamics being *complex* – determined by *non-linear* laws – it results to be strongly *sensitive to the initial conditions*. The starting point being even slightly displaced,

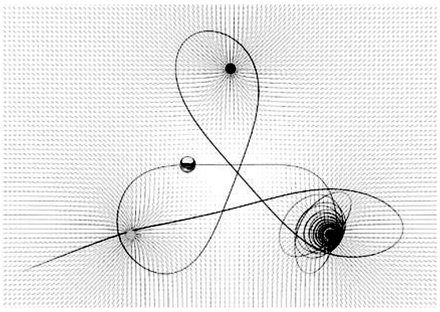


Fig.4 - A chaotic trajectory of a magnetic pendulum

the arrival magnet may change. So the *basin of attraction* (set of the initial conditions) related to the dynamics of the pendulum, exhibits a quite precise fractal *structure*.

We point out that, in the present example the *information* which determines the fractal *structure* of the *basin of attraction* is determined through the *dynamics* of motion.

Graphically the fractal basin is painted assigning distinct colors (or gray levels) dependent on the arrival magnet of the pendulum.

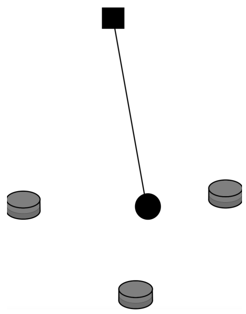


Fig.5 - Sketch of a magnetic pendulum

1.2.4 Remark

We want to emphasize, now, that people investigating *algorithmic information* are generally interested in defining the *quantity of information* involved into a computer program algorithm, which is viewed simply as a *code string.* Therefore a string program which solves some problem is considered as more rich of information as shorter is its code string. A matter involving a pragmatic instance of efficiency, minimizing time machine and then costs of program running.

But it is known that not any problem is *computable,* since a string including an infinte number of characters, in many cases, cannot be *compressed* into a shorter one. Moreover also strings including a finite number of characters often cannot be compressed into a shorter one.

In the language of set theory a similar circumstance arises because only a class of sets may be defined by a *law* (*shorter string*) according to which their elements are generated, thanks to the *replacement axiom*. All the remaining sets can be defined only listing their elements one by one (*incompressible string*).

Within the frame of Gödel's theorem we can see the same problem as a matter of *decidable propositions* which correspond to a computable Gödel's number and *undecidable propositions* which are related to non-computable Gödel's numbers. This is what one means when says that not all numbers are *computable,* since it does not exist a formula (*shorter string*) enabling us to evaluate all their digits avoiding to list them one by one.

As a consequence, attaining physical dynamical systems, and especially biological and cognitive ones, we know that not all their activities are computable. So the irreducible *qualitative* and properly *ontological* aspects of their behavior has acquired a great relevance even on a scientific point of view beside their philosophical importance.

Many of those non computable aspects concern *information* and related *algorithms*. A *semantic* approach seems now to be required beside the purely *syntactic* one developed in the classical information theory. Because the algorithm, as here is intended, is no longer simply identified with the *string* on which it is coded – sum (*whole*) of the characters (*parts*) of which it is composed – rather being a *definition,* actualizing the *dynamics* of some resulting new *entity*.

Rather such a definition is a *logical law* defining an entity and a sort of *ontological form/information* actuating its *structure* (*essence*) and its *dynamics* (*nature*).

We emphasize that such a notion of algorithm, together with the previous *philosophical* interpretation seems to reveal a first but non-trivial rigorously scientific attempt to approach the *definition/essence* of the entity the *structure/organization* and the *dynamics/nature* of which are generated by the algorithm itself. We remember, in fact, that according to the Aristotelian-Thomisitic ontology the *nature* is just the *essence as principle of acting*.[10]

So an *algorithmic information* involves more of philosophical content than some mere *quantitative measure* of information. Scientific investigation on information has become aware of this semantic exceeding contribution and is just attempting to grasp it with more and more suitable definitions. Information is recognized to be more than the length compression of a string of code.[11] In the frame of the mathematical physics of non-linear *dynamical systems,* for instance, a relevant approach to *form/information* has been developed following a methodology which is known as *qualitative analysis* of motion. Similar models are applied even in a biological context, in order to model the evolution of species or the emergence of self-organization during the transition from non-living matter to living organisms.

All these research exhibit some non-trivial philosophical relevance since they investigate, as a matter of fact, the *essence/nature* of some entities by means of constructive definitions. Most likely more refined mathematical instruments will be required in order to formalize

[10] "Acting depends on nature, which is the principle of acting (*actio dependet a natura, quae est principium actionis*)", Tomas Aquinas, *In I Sent.,* Lib. 3, d. 18, q. 1, a. 1co; "the word *nature*, so considered, appears to mean the *essence* of something, in order to its proper action (*nomen autem naturae hoc modo sumptae videtur significare essentiam rei, secundum quod habet ordinem vel ordinationem ad propriam operationem rei*)", *De Ente et Essentia,* chap 1 (See[1]).

[11] Among the first mathematicians who approached in a rigorous way the problem of characterizing the *information,* according to a careful comparison with the Aristotelian *form,* we have to mention René Thom (1923-2002), of whom we cite his famous book[17].

adequately *information* as a sort of algorithm and mathematics itself will widen as a true *theory of entities* (*formal ontology*). So information could involve both computable aspects and non-computable ones.

1.3 Main characters of information

It is now relevant to show which are the main characters of *information* which have been caught by the different theories, as they have been developed in science. In particular we will be able to recognize a progressive approaching between the scientific definitions of *information* and some aspects of the Aristotelian-Thomistic notion of *form*.[12]

In particular we are able to identify some of its proper elements (*formally* defining characters) and some other elements required to its carriers, *i.e.,* material supports ([13] pgs 13-17).

i) *Code and syntax*: at a first level of *Shannon's communication theory*[18] we find, first of all, the presence of a code, a symbolic *alphabet* allowing to tie (*i.e.,* to write) information onto some *material support* which is needed for it to be carried. Moreover, since any alphabet requires to be governed by suitable rules, a *syntax* is to be added so that the alphabet becomes useful to code information.

So we will have:

– a set of conventional *symbols* called the *alphabet*;

– a set of conventional *rules* which must be enough to state what is allowed in organizing the symbols, which we call the *syntax*.

That not withstanding information, in itself, is independent of the matter medium across which it is traveling, which only allows to it to be carried. Any carrier can be exchanged with another carrier of just the same information. And the carrier, as it is, cannot produce any information by itself, neither as *efficient* cause, nor as *formal* cause, nor as *final* cause.

ii) *meaning*: meaning is the essential attribute of information as it is coded into a language in order to its *communication* (*i.e.,* transfer and interpretation).

– The *words,* either they are written or spoken, may be used used to symbolically represent entities of any kind: events and/or concepts, *i.e.,* everything.

– Moreover (this is the relevance of symbols) the signified entities need not to be physically present together with the words, since they take their place, representing them and communicating something about them just as if they were actually present.

[12] In Aristotelian-Thomistic view by *form* one means an immaterial principle acting in such a way that an entity is what it is and nothing else. On a *logical* viewpoint it identifies the so called *metaphysical definition* of an entity; on a *metaphysical* viewpoint it identifies the *structure* and the *dynamics* of an entity so determining its *nature*.

– Experimentally it has always been observed, until now, that chemical and physical (*i.e.,* purely material) processes, as such, are unable to perform any symbolic substitution. We mean, here, material processes which are not driven by some external control system informing the behavior of the process itself.

iii) *Expected action*: information appears as something which is sent by a *sender* in order that a *receiver* executes a precise operation to achieve some goal.

– The *receiver* starts operating soon after reading and decoding the message. In some situations the sequence of the operations may be even very long and difficult to be executed.

– The *receiver* may be required to *decide* if the operation is to be executed or not, completely or only partially. If the decision is "yes", the operation will be executed as required by the *sender.* In particular two kinds of receivers are to be distinguished, *i.e.*:

= an *intelligent* and *free* receiver, who is able to understand the *meaning* of the message;

= or a *machine* which is unable of understanding and freely choosing.

The former, being intelligent, can answer the sender's request according to a freely choice among several different strategies. The latter, being an *automatism,* is totally driven by the control program. In both cases machines may be necessary to perform the required operations.

iv) *Intended purpose*: before the message is sent the sender needs some internal mental process motivating him to formulate and send the message as such.

– This process is generally highly complex and involves some need, motivation and will that something is received and executed by somebody/something else.

– in particular, when the operation is so hard that it could not be executed by any receiver, the sender must carefully evaluate if the chosen receiver is adequate to perform the duty.

– If the whole process is successfully performed the sender's intent will be achieved satisfactorily.

– So the sender's intent appears to be essentially at the origin of the message.

– The receiver's success in executing the sender's intent is the result of the entire operation of communication of information.

The previous four attributes seem to be required to characterize unambiguously the notion of *information.* Therefore a possible formal definition of *universal information* (UI) must include them all. Here is such a kind of definition: ([13] pg 16)

> A symbolically encoded, abstractly represented message conveying the expected action and the intended purpose.

In order that a similar definition may become scientifically employable we need to formalize it, in turn, into a suitable *symbolic language,* so that we are able to use it in *computations* (as for *computable* matters), or in the frame of a *qualitative analysis* (as for *non-computable* matters).

It is interesting to follow Stuart Kauffmann's (b. 1939) remarks on a progressive deeper approach to the notion and the theory of *information.*

> I begin with Shannon's famous information theory. Shannon chooses, on purpose, to ignore any semantics, and concentrate on purely syntactic symbol strings, or messages over some pre-chosen symbol alphabet [...].
>
> It is clear that Shannon's invention requires that the ensemble of all possible messages [...] be stable head of time. Without this statement, the entropy of the information source cannot be defined. Now let's turn to evolution. We saw above that we cannot pre-state the adjacent possibilities of the evolution of the biosphere by Darwinian preadaptations. Thus, we cannot construct anything like Shannon's probability measure over the future evolution of the biosphere [...]
>
> The same concerns arise for Kolmogorov, who again requires a defined alphabet and symbol strings of some length distribution in that alphabet. Again, Kolmogorov uses only a syntactic approach. Life is deeply semantic with no pre-stated alphabet, no source, no definable entropy of a source, but unpre-statable causal consequences which alone or together may find a use in an evolving Kantian whole of a cell or organism.
>
> In summary, standard information theory, both purely syntactic and requiring a pre-stated sample space, is largely useless with respect to evolution. On the other hand, there is a persistent becoming of ever novel structures and processes that constitute specific novel and integrated functionalities in the [...] wholes that co-create the evolving biosphere. [...]
>
> We need a new theory of embodied functional information in a cell, ecosystem or the biosphere.[19]

1.4 Emergence and evolution of biological information

The relevant interest in the role of *information* in biology raises at least three main questions in the context of scientific research.

- The first question is related to the *emergence*, or the *origin* of *biological information.*

  According to an Aristotelian terminology we should talk of *eduction* of the *form* from the potency of matter. So the problem for the search of an adequate *efficient cause* in order to obtain such an eduction arises each time a *substantial mutation* transforming some entity into another one happens in a stable way.

In the contemporary scientific context this matter is often viewed as the problem of *information production* or *information increment* within some system (physical, biological, etc.). There is a tendency to guess that information may be produced or increased *spontaneously,* without an adequate causation, thanks to self-organization capability of the system itself, arising by a sequence of random events.

- A second question, which is strictly tied to the previous one, is related to the *evolution* of information, *i.e.,* its mutation in time. In particular its spontaneous increment within some system, especially a living system.

- The last question attains the problem of *coding* and *copying* biological information. Clearly biological information is no longer considered as residing only in the *DNA* code. Rather it appears as layered at several levels, even on the same biochemical, electrochemical or, generally, physical medium.

The assumption that life complexity is only a spontaneous result of *non-linearity* of *chaotic systems,* has been shown to be incompatible with the numerical mathematical simulation models implemented on a computer, starting from their governing equations ([20] and related bibliography).

> The explosion in the amount of biological information [. . .] requires explanation ([22] pg 204).

The useful *non-ambiguous beneficial mutations* (*i.e.,* non-damaging at any level) arising from natural selection, result to be extremely rare. Chance seems not to be enough to generate improvements without an adequate cause.[21]

On the contrary a process of *loss of information* (*genetic entropy*) is revealed, because of *deleterious mutations* which result to be the most likely mutations. So a sort of defensive barrier, conservative of complexity stability appears.[11]

As to biological information coding scientists has observed that the *genetic units* consist in very precise instructions, coded in such a rich language that "any gene exhibits a level of complexity resembling that of a book" ([22] pg 203). More languages (*genetic codes*) are present in the same genoma, with multiple levels (even three-dimensional), coding biological information, forming a network with several layers.

Computer simulation models did not succeed in attempting to explain neither the emergence nor the increment of information, not withstanding both computer programs and the human genoma exhibit very resembling repetitive code schemes.[23]

Information is responsible of *organization* and *order* emergence within the structure of a system, so that information increasing implies order increasing. What numeric simulation – based on statistical mechanics and non-equilibrium thermodynamics – show, on the contrary, is that order is not spontaneously generated within the system, even if this latter is *open* (being able of exchanging matter and energy with the external environment). Information appears in a system, only in presence of a *causal agent* external to the system acting on it.

> If an increase in order is extremely improbable when a system is closed, it is still extremely improbable when the system is open, unless something is entering which makes it not extremely improbable ([24] pg 174).

The process of *self-organization* is activated thanks to the action of such an *efficient/formal cause,* which resembles to what, according to the Aristotelian-Thomistic theory is called *eduction* of a *substantial form* from the potency of matter.

Starting from our recent knowledge on the physics of non-linear systems and the thermodynamics of non-equilibrium governing open dissipative systems, attempts are made in order to model the process of *information emergence* form matter (emergence of an organized structure in matter) by means of stable *attractors.*

The dynamics of those attractors, not withstanding it appears chaotic and dominated by chance, is able to construct ordered structures. In fact the phase trajectories, solutions to dynamics, even starting at random from different initial conditions belonging to a *basin of attraction* (which may be even fractal), tend to fill precise regions of the phase space. So a *whole* arises from a confluence of *parts,* which are only apparently separated, being on the contrary non separable from the whole they are building, thanks to an information governing the structure and the dynamics of the process.

Kauffmann's intuition that a new kind of notion of information, which is not merely statistical and syntactical, but involves also the semantic aspects seems to drive research towards the right direction.

In particular the idea that some *asymptotically stable attractor* may be a good information carrier:

- on one side ensures the presence of some information leading to *structured order* emerging within a system;
- on the other side allows that chance play a wide role in the *dynamics* of the system, since the choice of initial conditions of the evolutive trajectories, within the *basin of attraction,* is left to chance without preventing that they all reach asymptotically the attractor itself.

So there does not exist any law in the arbitrary choice of the initial condition of the trajectories with the basin of attraction – the behavior of which may result even unpredictable if the attractor is *chaotic* – but some law exists within the dynamics of the system, involving some finality in its attractor solution. Such a finality (*intended purpose*) is typically a character of *information.*

In principle several *analogous levels* of organization and finality may be obtained *nesting* several attractors into a hierarchy, so that some level of attractors is attracted in turn by a level of higher degree, until some *first universal attractor* is reached, which by definition cannot be attracted further, in order to prevent the occurrence of a logical paradox like that of the *universal set.*

i) A lower *level of organization* could be, *e.g.,* provided by a set of stable attractors representing the *molecules,* the dynamics of which is governed by

ii) an immediately higher level of attractors organizing *e.g., cells,* the dynamics of which is ruled

iii) by an higher level of attractors representing the *organs* of a living system;

iv) a fourth level of attractors shapes the structure and the functionalities of *individual living beings* of different species;

v) a fifth level of attractors will organize the *species* of living beings, and so on.

In principle one could guess, according to such a model of *nested attractors,* the existence of a chain starting at the level of the *elementary particles* and reaching the level of the *universe as a whole.*

The chain is broken when some attractor flips from *stability* to *instability,* because of the occurrence of some accidental *cause* modifying the values of the parameters involved in the law of its level of dynamics. Then it happens that the *second principle of thermodynamics,* locally overcomes with the result of increasing *disorder*: the ordered organization of the system is partially damaged or fully destroyed.

The whole scheme of chained attractors reminds a sort of *fractal structure,* even if it is not necessarily self similar in all its properties. We will be concerned with fractals in some of the next chapters, at least in relation to the aspects involved in our investigation.

At present research is open on these topics and a widened mathematics appears to be required resembling, at some levels, a sort of new version of *ontology,* suitably formalized.