Systemic issues on the intelligence of matter, intelligence, and life. The game of *acquired* intelligent life.

GIANFRANCO MINATI
Italian Systems Society
Via Pellegrino Rossi, 42
ITALY

Abstract: - We consider, elaborate, and present formalizations for some concepts and phenomena characterizing the science of complexity (i.e., logical openness, theoretical incompleteness, quasi-ness, self-organization and emergence, and models of dynamical coherences), which are used in the following sections. Such concepts are combined with the fact that the issues of life and intelligence are inevitably systemic in nature, as are their constituent and evolutionary processes. We then deal, as topics of complexity, with the themes of possessed or acquired properties such as the intelligence of matter, intelligence of the living, and life. We consider consciousness from self-reflexivity and self-memory. However, because life recognizes life (i.e., itself) and intelligence recognizes intelligence (i.e., itself), it seems there is a closed, self-referential loop. We then present some consequential systemic issues suitable to consider new inquiring, less self-referential approaches as based on logical openness and theoretical incompleteness for further research. Is it possible to figure out a related game for a logically closed environment, and how can this reductionistic prevalent attitude be broken: through internal interventions or necessarily external, different in nature interventions? We may call it the game of acquired intelligent life. Can it be Turing complete as in Conway's Game of Life?

Key-Words: - Coherence, Consciousness, Emergence, Incompleteness, Intelligence, Life, Openness, Quasi-ness.

Received: May 31, 2022. Revised: March 4, 2023. Accepted: March 24, 2023. Published: April 27, 2023.

1 Introduction

The concept of a system relates to the peculiarity of some sets of items, termed systems, when items are suitably interacting between them, of acquire properties, whether they are pre-established (functioning) or only partially foreseeable, and according to the level of description considered. The systems can also be autonomous within their allowed degrees of freedom as studied by complexity science. Starting from a review of some crucial concepts and approaches of complexity science, the purpose of this paper takes shape. The complex systems concepts are considered to elaborate and review the topics of intelligence and life. We then present some consequential, almost original, issues suitable to consider new inquiring, less self-referential approaches for further research.

In the first part of section 2, we outline and present profiling definitions of some complex systemic concepts useful to set the conceptual context in which we will consider intelligence and life: logical openness, theoretical incompleteness, quasi-ness, self-organization and emergence, and models of their dynamical coherences.

In the second part of section 2, we focus on the intelligence of matter. We outline the concept of matter considered here, the intelligence of matter distinguishing between possessed and acquired intelligence, and outline human intelligence.

In section 3, we present systemic research issues related to intelligence, life, and the fact that evolution is not enough to explain the acquisition of intelligent properties, requiring instead combinations with the intelligence of matter. We point out how our intelligence can recognize itself (as the intelligence of matter and in living beings) and study itself. In parallel, we have only one conception of life (it should be difficult to recognize other forms of life and intelligence). Our intelligent life seems to be self-referential.

In section 4, we introduce some miscellanea related to consciousness as an acquired intelligent property by living matter, when metacognition is intended as self-cognition, cognition of cognition, assuming the approach of reflexivity, and selfness. Then the generative property of consciousness of living matter to be considered, is the self-reflexivity based on recurrent memory and self-memory.

The perspective is to logically open, make incomplete and quasi the models of intelligence. *as if* *we had multiplicities of them to deal with*. We conclude by figuring out an ideal game on how to break the reductionistic, logically closed, prevalent attitude of self-referential (life recognizes only itself, intelligence recognizes only itself, evolution occurs without the discontinuities of emergence) simulated environments. Are internal interventions sufficient or is there a need for external interventions?

2 Outlines and definitions

In this section, we outline some concepts and phenomena mentioned and used in the following elaboration. Particularly, in section 2.1, we consider systemic concepts important when dealing with systems complexity: logical openness, theoretical incompleteness, quasi-ness, self-organization and emergence, and models of dynamical coherences. Furthermore, in sections 2.2 and 2.3, we outline the concepts of intelligence and life, widely elaborated in the literature, focusing here on aspects and levels suitable for the subsequent introduction of related issues, in particular, related to the intelligence of matter and logical openness.

2.1 References to some essential systemic concepts

We outline the concepts, models, and phenomena considered in the science of complex systems considered relevant here when dealing with acquired properties of matter, such as intelligence and life.
Such concepts are combined with the fact that the issues of life and intelligence are inevitably systemic in nature, as are their constituent and evolutionary processes.

2.1.1 Logical openness

As is well known, closed systems are intended to be isolated, with no exchange of either matter or energy with the environment. Their final state is reached uniquely as determined by the initial conditions. This is the case for all ideally thermally insulated machines.
We may then consider the concept of a *logically closed model* to describe the evolution of such *thermodynamically closed systems*.
In this regard, a model is defined as logically closed when

a) a formal, *complete*, and explicit (i.e., analytically describable) description of the relations between the state variables of the model is available;
b) a formal, *complete*, and explicit (i.e., analytically describable) description of the interaction between the system and its environment is available;

and

c) all possible states that the system can take and its structural characteristics are *completely* deducible from the knowledge of the previous two points, allowing deduction of all possible states that the system can take together with its structural characteristics.

Conversely, we may consider then the concept of a *logically open model* to describe the evolution of a system intended as *logically open* when there is violation of at least one of the three points above [1, 2, p. 111–112; 3, p. 447–51]. *Logical openness* is related to the infinite number of degrees of freedom when the system includes the environment in principle independent, thus making the system incomplete as regards the environmental influence.
Logically open systems are systems, for instance, autonomous learning systems, particularly living systems.
In order to introduce a formalized understanding of logical openness, let us consider [1]:

- the observer, with his/her knowledge, language, and purposes;
- the model carried out by the observer on the basis of his/her knowledge and goals;
- experimental data, intended as *answers to questions about nature as experiments are* (no answers without questions) obtained from the context by using the model and the observer's language.

Logical openness may be formalized in the following way [1].
Let us apply a suitable operator R_1 to the observer at moment *n* (for instance, perform an experiment). This produces a corresponding model. This process may be indicated by the expression

$$model\ (n) = R_1\ (observer\ (n)).$$

In turn, an operator R_2 may show a correspondence between *experimental data (n)* obtained from a process of application of the *model (n)* as by the expression

$$experimental\ data\ (n) = R_2\ (model\ (n)).$$

The observer's knowledge and goals are influenced by experimental data.
An operator R_3 can show that the subsequent state of the observer depends on the experimental data obtained, as in the expression

$$observer\ (n+1) = R_3\ (experimental\ data\ (n)).$$

If we combine the three circumstances, we obtain

$$model\ (n+1) = R_1\ (observer\ (n+1)) = R_1(R_3(R_2\ (model\ (n))).$$

If we consider the abbreviation $R = R_1\ R_2\ R_3$ we obtain:

model (n)= R_n (model (0)).

where R_n indicates n interactions of the operator R.

In the recursive formula *model (n)= R_n (model (0))*, it is possible to consider as (eigen-) models:

$$Model^{(\infty)} = \lim_{n\to\infty} R^n (model^{(0)}).$$

We may consider that ∞ has no practical meaning and notice how the process may converge to two different possible ends:

- logically closed models, having finite degrees of openness;
- it is impossible to identify a definite (eigen-) model.

Finally, we may mention as another example of formalized logical openness the case of the *Oracle* introduced by Turing [3, p. 52–53].

2.1.2 Theoretical incompleteness

The concept of completability relates, in general, to the possibility of making complete what is not. Logically closed models are complete, whereas logically open models are not.

Theoretical incompleteness is assumed as non-completability in principle or as invariant property.

Examples of non-completability in principle include

- In mathematical logic, completeness refers to the fact that a set of axioms is sufficient to prove the truths of a theory. However, Gödel introduced the incompleteness theorems in 1962 [4];
- Partial or non-decidability due to non-computability of non-analytical models formulated as learning (for instance, based in ANN) [5];
- Non-complete, non-explicit, non-univocal, and non-equivalent modeling as in quantum physics.

Examples of non-completability as invariant property include

- The Uncertainty Principle in quantum mechanics;
- Complementarity in theoretical physics, such as between wave and particle natures;
- Dynamics of equivalences in processes of emergence where partial acquisitions, losses, and recovery of properties occur, keeping, however, predominant coherences [6].

The concept of theoretical incompleteness [7–10] specifies the one of quasi-ness introduced below.

Theoretical incompleteness is a property of phenomena that is incomplete enough to permit emergence, introduced below.

An example of a strong form of interdependence *theoretically complete* between a population of, for example, 10 variables, occurs when they are analytically interrelated such as in systems of *ordinary differential equations*:

$$\begin{cases} dx_1/dt = f_1(x_1, x_2, \dots x_{10}) \\ dx_2/dt = f_2(x_1, x_2, \dots x_{10}) \\ dx_3/dt = f_3(x_1, x_2, \dots x_{10}) \\ dx_4/dt = f_4(x_1, x_2, \dots x_{10}) \\ dx_5/dt = f_5(x_1, x_2, \dots x_{10}) \\ dx_6/dt = f_6(x_1, x_2, \dots x_{10}) \\ dx_7/dt = f_7(x_1, x_2, \dots x_{10}) \\ dx_8/dt = f_8(x_1, x_2, \dots x_{10}) \\ dx_9/dt = f_9(x_1, x_2, \dots x_{10}) \\ dx_{10}/dt = f_{10}(x_1, x_2, \dots x_{10}) \end{cases} \qquad (1)$$

Change of any value x_i, therefore, is a function of all other x's. The change of any x entails a change of all other x's, as a whole. *These systems of differential equations can be understood as the prototype of complete and stable coherence, when there is total interdependence between the* variables (see section 2.1.5).

A conceptual formalization of *theoretical incomplete* interdependence may be represented by situations occurring over time where, just to give an idea to be then generalized, there is partial validity of different systems:

At time t_n, variables x_3, x_6, and x_8 vary independently:

$$\begin{cases} dx_1/dt = f_1(x_1, x_2, \dots x_{10}) \\ dx_2/dt = f_2(x_1, x_2, \dots x_{10}) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ dx_4/dt = f_4(x_1, x_2, \dots x_{10}) \\ dx_5/dt = f_5(x_1, x_2, \dots x_{10}) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ dx_7/dt = f_7(x_1, x_2, \dots x_{10}) \\ \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \\ dx_9/dt = f_9(x_1, x_2, \dots x_{10}) \\ dx_{10}/dt = f_{10}(x_1, x_2, \dots x_{10}) \end{cases} \qquad (2)$$

At time t_{n+1}, variables x_1 and x_5 vary independently, variables x_2–x_4 are mutually interdependent, and variables x_6–x_{10} are mutually interdependent:

$$\begin{cases} dx_2/dt = f_2(x_1, x_2, \dots x_{10}) \\ dx_3/dt = f_3(x_1, x_2, \dots x_{10}) \\ dx_4/dt = f_4(x_1, x_2, \dots x_{10}) \end{cases} \qquad (3)$$

and

$$\begin{cases} dx_6/dt = f_6\,(x_1, x_2, \ldots x_{10}) \\ dx_7/dt = f_7\,(x_1, x_2, \ldots x_{10}) \\ dx_8/dt = f_8\,(x_1, x_2, \ldots x_{10}) \\ dx_9/dt = f_9\,(x_1, x_2, \ldots x_{10}) \\ dx_{10}/dt = f_{10}\,(x_1, x_2, \ldots x_{10}). \end{cases} \quad (4)$$

Different combinations and variations of these situations may then take place at different times.

However, cases of theoretical incompleteness should have limited and not absolute predominance in order to keep *significant* the interdependence stated in (1), such as the variable, lost, and recovered coherence of a flock.

In order to generalize, it is possible to consider indexed equations, where the indexes indicate the interdependence grouping of belonging. Sequences of such indexes may be considered as characterizing the interdependence of the population, such as its collective forms and levels of collective behaving.

We mention here the conceptual correspondence of considering the interdependence of groups of belonging in instantaneous clustering in collective behaviors. In the case of instantaneous clustering, as in the meta-structural project [3, p.105–108], we consider the properties of clusters, having possible common elements, such as their numbers of components, regularities in their composing same cluster(s), recurrences, and partial or local regularities.

2.1.3 Quasi-ness

In quasicrystals, atoms are arranged in deterministic structures, but they are not periodic or repetitive as in normal crystals. Conversely, there are patterns where the local arrangement is regular and stable but, however, not periodic. The characterizing deterministic structural property is incompletely respected in multiple possible ways [11].

In theoretical physics, quasiparticles are considered to possess traditional particle properties with the exception of localization [12].

In mathematics, quasi-periodicity relates to recurrences whose periodicity has components that are irregular or unpredictable.

Quasi-ness is considered an attribute to the generic dynamics of the occurrence of incompleteness in collective phenomena, such as self-organization and emergence, when multiple levels of coherences are partially kept, lost, resumed, or recovered.

In collective phenomena, countless equivalences occur, among which the selections (for instance, cognitive-like in flocks or energetic and due to fluctuations in liquids) constitute a subsequent new initial condition.

Accordingly, complex systems (i.e., systems where phenomena of self-organization and emergence occur or are even established entirely by them) are quasi-systems in that they are incomplete as only almost partially predominately systems and the same system [3].

2.1.4 Self-organization and emergence

Theoretical incompleteness is a property of phenomena that are incomplete enough to permit the establishment of coherences in multiple equivalences of collective phenomena, as in self-organization and emergence of complex systems.

Their multiple structural dynamics and dynamical coherences establish a space of equivalences constantly incomplete in that no specific structure or single order predominate. This is a necessary condition for the occurrence of multiple, quasi coherences having variable levels of predominance. The sufficiency may be given by different factors, such as contextual degrees of freedom (e.g., whirlpools induced by shapes of the tubes in which the liquid flows or convective patterns in heated liquids induced by energetic factors).

Completeness is an ‘enemy’ of emergence because it produces single specific structures without leaving a role for equivalences necessary to *replace structures with coherences* [13].

At this point, we may distinguish between

- Self-organization intended as a periodic, quasi-periodic, iterative process of acquisition of coherent new structures. Sequences of new properties are acquired in a phase transition-like manner, having regularities and repetitiveness. Examples include the Bènard rolls [14], structures formed in the Belousov–Zhabotinsky [15] reaction, swarms having repetitive behavior (e.g., mosquitos around a light), and dissipative structures [16, 17] such as whirlpools in the absence of any internal or external fluctuations. The simplest and most celebrated related model is the so-called *brusselator* (from its origin in Brussels) introduced by Prigogine and Lefever in the 70s to model tri-molecular reactions. The model is very useful for describing self-organizing chemical reaction-diffusion systems, such as the Belousov-Zhabotinsky reaction. The brusselator allows to model the reaction between two intermediates using the following equations:

$$d\phi/dt = D_1\Delta_2\phi + A - (B + 1)\,\phi + \phi^2\,\psi$$
$$d\psi/dt = D_2\Delta_2\,\psi + B\phi - \phi\,\psi \quad (5)$$

where:

- ϕ and ψ are to be interpreted as concentrations of appropriate chemical substances;
- D_1, D_2, A, B are control parameters of the model;
- Δ_2 is the *Laplace operator*, which, in the case of three spatial dimensions, has the explicit form $\Delta_2 f = d^2 f/dx^2 + d^2 f/dy^2 + d^2 f/dz^2$.

- Emergence where the sequence of new properties is not regular, not repetitive, but irregular and, however, still prevalently coherent (i.e., the reoccurrences are partial, combined, having long-range correlations [18]). Examples include the properties of collective behaviors adopted by fish schools, flocks, herds, networks such as the Internet, protein chains and their folding, queues and traffic, and swarms. Examples of acquired emergent properties include coherence, decentralization in reacting, resilience, self-adaptation, self-defense capabilities, and stigmergy [19] which studies how communication occurs through indirect communication, such as environmental modifications.

2.1.5 Models of dynamical coherences

In this section, we present some models of coherence in populations of interacting elements (modeled, for instance, as oscillators or logistic maps), specifying the concept. We first introduce the concept of

- Synchronization

  A first case may be the so-called Kuramoto model, when a better understanding of coherence maybe related to processes of *synchronization* [20].

  We consider, for example, populations of oscillators, such as clocks and timers, organized in dynamic clusters where synchronization is the *source* of their coherence [21]. Interesting situations arise when such oscillators interact. Let us consider a population of N coupled oscillators. Each is characterized by a time-variable phase. A natural frequency can be given, for example, by [22, 23]

$$\dot{\theta}_i = \omega_i + \sum_{j=1}^{N} K_{ij} \sin(\theta_j - \theta_i) \qquad (6)$$

  where:
  - $i = 1, \ldots, N$
  - $\dot{\theta}_i$ is the time derivative of the phase of the *i*-th oscillator,
  - ω_i is the natural frequency of the *i*-th oscillator,
  - K_{ij} denotes a coupling matrix.

  Among the different possibilities, we mention when $K \to \infty$ all oscillators become synchronized to their average phase, reaching global synchronization.

- Upper synchronization

  We relate to the occurrence of multiple different synchronizations *when such multiplicity becomes synchronized*, as in the human nervous system. Such *upper synchronization* can be considered as a form of *coherence* [24]. This applies, for instance, to the case of populations of chaotic systems [25–27].

- Ensembles of globally coupled chaotic maps

  These phenomena have been introduced in [28] (see also [29, p. 155]. Their dynamics, in the simplest case, are described by

$$x_i(n+1) = (1-\varepsilon) f(x_i(n)) + \frac{\varepsilon}{N} \sum_{j=1}^{N} f(x_j(n)) \qquad (7)$$

  where:
  - N is the number of chaotic maps;
  - $i = 1, \ldots, N$ is a space index;
  - $x_i(n)$ denotes the value of the *i*-th map in correspondence to discrete time $n = 0, 1, \ldots$;
  - the function $f(x)$ is given by $f(x) = a\,x(1-x)$ (logistic map);
  - a denotes the nonlinearity parameter of the logistic map;
  - ε denotes the coupling parameter.

  When considering numerical simulations of the dynamics of such systems, we have evidence that when the coupling parameter ε overcomes a critical value ε_c, the ensemble reaches a state of *full synchronization*. In such states, all maps, at any instant, behave like a single chaotic map.

  When the coupling parameter ε is allowed to grow up to the situation of full synchronization, the reached dynamics are characterized by an ordered sequence of different synchronizations, ending in a situation of global coherence [24, 29].

- Correlations

  In statistics, correlation refers to classes of statistical relationships involving dependence among random variables [30]. Furthermore, different kinds of *correlation measures* are used to detect different forms of synchronization phenomena. Linear approaches include the ones underlying the Bravais–Pearson coefficient [31]. There are classes of correlation measures: linear and nonlinear (see, for a review, [32]).

- Cross-correlation

Among linear correlation measures, generalizing the traditional Bravais–Pearson approach mentioned above, the most popular is given by the *cross-correlation* function. It applies to two-time series having the same length *N*. The values of the time series are respectively denoted by X_n and Y_n. Such values have been normalized in order to have a zero mean and a unitary variance. This function depends on the time lag τ within the interval from - *(N-1)* to *N-1*:

$$C_{XY}(\tau) = \{ \begin{array}{ll} \frac{1}{N-\tau}\sum_{n=1}^{N-\tau} x_{n+\tau} y_n & if \quad \tau \geq 0 \\ C_{XY}(-\tau) & if \quad \tau < 0 \end{array} \tag{8}$$

The cross-correlation value C_{XY} *(τ) = 1* corresponds to maximum synchronization, whereas C_{XY} *(τ) = -1* corresponds to a loss of correlation.

By considering the frequency rather than time, the cross-correlation is replaced by the so-called *cross spectrum*:

$$C_{XY}(\omega) = E\left[F_X(\omega)\ F_Y^*(\omega)\right] \tag{9}$$

where:

- ω denotes the frequency,
- *E* is the estimation function,
- F_X is the Fourier transform of *x*,
- * is the complex conjugation.

The cross-spectrum makes it possible to compute the *coherence* function $\Gamma_{XY}(\omega)$ through the relationship

$$\Gamma_{XY}(\omega) = \frac{\left|C_{XY}(\omega)\right|^2}{\left|C_{XX}(\omega)\right|\left|C_{YY}(\omega)\right|} \tag{10}$$

We mention how in long-range, scale-free correlation, the *correlation length* coincides with the total extension of the systems and coincides with the coherence of the entire population.

A further example of coherence is the occurrence of ergodicity in collective behaviors [3, p. 291–313]. The *same* system can be *both* ergodic and non-ergodic depending upon on time scale considered, as in polymers, and even only temporarily ergodic. Furthermore, it is possible to introduce degrees, indexes of ergodicity.

2.2 Intelligence of matter

The intelligence of matter should be considered a special property of matter. In this regard, we should, first of all, notice the criticality of the concept of ‘matter’, a subject of endless discussions.

2.2.1 Matter

The concept seems to be a philosophical one. It is intended as a generic platform on which everything is necessarily grounded. Matter is intended to have no or only basic properties as the general basis for significant properties. In the classic view, such properties are intended to contrast with a vacuum considered as having no properties, being the lack of matter and, as such, opposed to the quantum vacuum. Levels of such matter (such as particle physics) are considered to derive from the simplest, inferior one. Is such an inferior level a metaphysical entity if the simplest one does not exist? Is matter a conceptual entity with no actual scientific meaning, and however a level can be intended as being built upon a lower, simpler one? Do these hierarchical levels have a final end at the bottom? Does this eventual end constitute the real generic matter?

At this point, we should consider the concepts introduced by quantum field theory (QFT). For instance, QFT considers the quantum vacuum as an entity that precedes matter, so it also must precede space and time [33]. The quantum vacuum is intended to give properties to matter, such as that of being always connected, and not the vacuum being a lack of matter.

However, from Faraday and Maxwell and onwards to general relativity, a long tradition in physics is the approach based on considering material entities, particles as excited states of their underlying quantum fields, as in statistical field theory. The concept of a particle is considered to denote regions of space where a field is of particularly high intensity. Matter is considered as a condensation of emergent properties acquired by the quantum vacuum. Higher levels of emergence allow the acquisition of macroscopic properties, such as dimensionality, mass, volume, and weight [3].

2.2.2 Intelligence of matter

As mentioned above, the intelligence of matter should be considered a special property of matter. In this regard, we distinguish between classic *possessed* properties always available such as conductivity, consistency, hardness, light reflection, resistance, and weight, which are, however, context-dependent (e.g., temperature or pressure dependent), and *acquired properties*.

A first case of acquired properties is the dynamical properties, occurring during time and related to processes. Elementary examples include dilution, effervescence, evaporation, mixing of liquids, oxidation, and solidification.

More sophisticated cases relate to the acquisition of properties, such as

- fractal self-similarity as for snowflakes and lightning;
- non-periodic or repetitive structures of quasicrystals, as can be observed in normal crystals. There are patterns where the local arrangement of the material is regular and stable but not periodic throughout the material;
- the condensed phases of matter, phase transitions;
- self-organization as for structures formed in the Bènard rolls [14], the Belousov–Zhabotinsky [15] reaction, and dissipative structures such as whirlpools in the absence of any internal or external fluctuations.

A further, more sophisticated case relates to living matter. Some properties mentioned above still apply in the case of the living, for instance

- fractal self-similarity as for tree's branching, ferns and leaves in general, and allowing for the availability of large surfaces in small volumes, for example, alveoli of the lungs;
- self-organization, emergence of collective acquired properties as for flocks, herds, schools of fish, and swarms acquiring intelligent-like behaviors, for example, in defense from predators.

However, at this point, we focus on two special acquired properties, special because they include autonomy, that is, the acquired behavioral properties are not linearly deducible but rather emergent:

- acquisition, as an intelligent acquired property of matter, of cognitive properties, such as intelligence by systems of neurons;
- life itself as an intelligent [34] acquired property of matter.

Processes of acquisition of properties occur as the establishment of forms of coherence, as processes of emergence, and are incomplete and modellable as logically open.

2.2.3 Outlining human intelligence

We elaborated above about the generic intelligence of matter.

The subject is considered here for evolute single (not collective intelligence mentioned above) living beings such as animals and human beings.

As is well known, the subject is broadly elaborated [35] in cognitive science, psychology, and artificial intelligence (AI) research.

We mention, without any claim to completeness and without any priority or level of importance some characterizing topics of human intelligence intended as a network with different balances and imbalances between:

- Intelligence as recognition of a game in progress, assumption of a possible game, participating in a game, designing a game, inventing rules;

and the ability to

- Solve problems
- Create unsolvable cases
- Invent problems, stories, scenes, languages
- Translate languages
- Semantic research
- Foresee
- Design
- Repair
- Influence
- Learn
- Hypothesize, abduct
- Relate, correlate
- Attribute, detect, communicate, represent meaning
- Make metaphors
- Detect, build, measure correspondences
- Extend arguments
- Generalize
- Demonstrate
- Make scenarios and configurations
- Generate theories
- Form tactics, strategies, invent approaches
- Generate theories
- Detect errors
- Detect incoherences, inconsistencies, incompatibilities
- Create consistency
- Ability to optimize
- Invent experiments
- Create abstractions
- Represent and simulate
- Transform a problem into another equivalent or into others that are globally equivalent to the original one
- Communicate with complexity (facts and reasonings), for example, writing, codes, encryption, voice/image.
- Compose and play music
- Write stories, poems
- Paintings, sculptures
- Invent sports

- Invent technologies
- Invent uses
- Invent paradoxes
- Invent ambiguities
- Invent and apply rules
- Have existential issues.

2.2.4 Life

We consider the widely and endlessly discussed questions *What is life? What is living?*

As is well known, an explicative approach is to hypothesize, recognize, identify, and consider the generative and sustaining processes of the living:

- The generative processes of life, the origin of life, are tentatively considered today as based on autocatalysis (molecules that catalyze their own or reciprocal replication in a mutually advantageous way [36-38].
- The sustaining processes of the living are understood as metabolic, dissipative, reproductive, and evolutive [39].

Another, possibly complimentary, approach is to recognize, identify, and consider characteristic and invariant properties of living matter. As we mentioned above, some properties may, however, be shared with non-living matter, such as the ability to dissipate.

Examples of characteristic and invariant properties of living matter include the ability to self-repair (however, there are self-repairing bioinspired materials), self-generation (regenerating to heal), and self-reproduction. Do they, at least partially, define the living? Is it theoretically correct to assume the availability of absolutely separated definitions of living and non-living?

As is well known, viruses are tiny protein and nucleic acid structures and can reproduce only inside host cells. They have many of the properties of life but do not have a cellular structure and cannot reproduce without a host. They probably do not maintain homeostasis or their own metabolism. We mention some even simpler molecules, such as self-replicating proteins and self-replicating RNA enzymes, also having some, but not all, of the properties of life.

Life can be therefore considered in all respects an intelligent, emergent property with all the features of coherence and incompleteness.

3 Selected issues on

In this section, we present some almost original issues about intelligence and life. These issues are presented in a conceptual way and proposed with the aim of constituting, after appropriate refinements and redefinitions, real research approaches and options. The article aims to operate as an incubator of systemic hypotheses, theories, and research projects.

3.1 Intelligence

The distinction between intelligence as an acquired property and the possessed intelligence of matter is not always simple. In some cases, this distinction is not easy because the acquired property is understandable as an *extension* of the possessed intelligence of living matter. Such extension should be intended as an expansion, extension, and transformation of a version of the intelligence of living matter without emergence occurring from biochemical or cognitive processes.

Some behaviors appear to be due to acquired intelligence, but in reality they are not, given also their invariability over time without forms of learning and delineating themselves as characteristics of the species.

Examples include the building of spider webs, the spraying of cuttlefish ink, the broken-wing display to drive away predators from the ground nest, or the emission of a foul-smelling liquid by birds.

In this regard, in section 3.3, we consider as an issue an ideal *biological-cognitive converter* through which living matter acquires behavioral properties such as the ones mentioned above.

Furthermore, we can consider influencing processes from cognitive to biochemical such as self-destructive and suicide effects due to forms of depression.

Issue #1: Intelligence is required to recognize intelligence.
How can intelligence do not to recognize only itself?

As life recognizes itself, so our intelligence can recognize only itself in nature. The lack of a general definition of intelligence allows the identification of intelligence to be only a closed, self-referential loop. *Our intelligence can recognize and study itself.*

The closedness of the self-referential loop seems to make it unavailable to recognize, even if admissible in abstract, different forms of intelligence.

Can we consider intelligence as being separate from life? Yes, up to a certain level. This is the case for AI-non-living autonomous intelligence.

The issue arises about where the *inner* possessed intelligence of matter comes from. Surely, we may recognize it as self-referential, as the maximum that our intelligence can do. We may consider the intelligence of matter as due to processes of self-organization and subsequentially as emergent, However, it is always our intelligence that inquiries about its originator mechanisms. Furthermore, the hypothesis of *residue property* after the Big Bang [40, 41] was introduced in [42].

3.2 Life

The difficult univocal definition of life opens the way to consider the possibility of the existence of other forms of life defined, at least partially, in a different way.

Different forms of life are admissible but difficult to recognize if they are supposed to have different characteristics and invariant properties.

For instance, characteristic and invariant properties of the living matter considered above may apply to other situations, such as to fields [43]:

- self-adapting, self-maintenance, self-sustaining properties of a field;
- self-restoring, reoccurring of a field;
- diffusion (possibly not continuous) of a field and combinations of fields.

We may consider such properties present in collective behaviors as self-generating, repairing, and reproducing coherent collective behaviors. Excluding cases of collective behaviors established by living entities such as flocks and swarms, we mention cases of collective behaviors established by *non-living systems* that include lasers, nematic fluids, networks, rods on vibrating surfaces, and shaken metallic rods.

It seems that a more general definition of life should be considered based, for instance, on the ability to generate and keep *different levels of coherence rather than homeostasis*.

Issue #2: Self-referential definition of life. How can life not recognize only itself?

3.3 Evolution

The issue considered here is that the evolution, the ability of living matter to evolve, of a species is an intelligent property of matter in its living phase. However, the mechanism of evolution must be considered as being *combined* with the possessed intelligence, and the intelligence acquired as properties of matter [44, 45].

The 19th-century English naturalist Charles Darwin introduced the idea that organisms come about by evolution based on natural selection mechanisms.

His theory of natural selection as the explication of evolution provided a scientific, essentially correct but incomplete explanation of how evolution occurs and organisms have features (e.g., eyes, kidneys, legs, and wings) to perform certain functions. Natural selection is intended to occur when individuals have a competitive advantaging resource, such as more effective vision, hearing, and smell, allowing them to survive better and produce more progeny than individuals with less-favorable resources. However, genetics and then molecular biology led to the development of the modern theory of evolution.

However, evolution seems insufficient to explain the acquisition of intelligent properties by living matter (see section 3.1), such as the building of spider webs to hunt, the geometricity in the construction of beehives, and the defensive spraying of cuttlefish ink. Therefore, evolution should be almost combined with processes of acquisition of properties through processes of emergence, in quasi-like ways, and allowing phenomenological logical openness. Incompleteness and quasi-ness leave room for subsequent adjustments and the establishment of multiple levels of equivalence.

Evolution should be intended as intelligent property of living matter, consisting of multiple sequences of incomplete acquisition-loss of coherences, having local and temporal predominance. Models of evolution are intrinsically logically open.

Issue #3: Evolution is not enough to explain the acquisition of intelligent properties: it must combine with processes of emergence.

It is possible to hypothesize an ideal process, the *biological-cognitive converter*, through which living matter acquires cognitive properties, such as the ability to recognize and desire shapes, colors, and smells; have behaviors, sensations, and actions [46, 47] and the opposite as the placebo effect when medicines have significant and persistent effects if patients are informed of their administration [48].

Issue #4: The ideal biological-cognitive converter

Other examples include the *natural* being of a newborn as beautiful because needing protection, and feminine or masculine attributes as attractive when in reproductive age. We do not fully understand how this conversion occurs, but it makes sense to consider that the properties of the matter possessed, in particular the possessed intelligence, are also involved.

4 Miscellanea

Any property, phenomenon, or process must happen in some way (possibly among other equivalent and possible ways), even if the way by which it happens is different from what happens, such as the emergent acquisition of properties.

The first sentence states the phenomenology of the becoming, the possibility of its observability, and its explicability or its well-defined inexplicability.

The second statement in parentheses states the possible equivalent or non-equivalent multiplicity of a phenomenon and its possible superimpositions.

The third sentence states possible *irreducibilities* when the way how a phenomenon happens is different from the phenomenon itself (i.e., the phenomenon cannot be reduced to or even be recognized from the ways that it happens). In processes of self-organization and emergence, what emerges is structurally different from the generative mechanism [49].

In the cases considered above, we may distinguish between what is supposed to be necessary but not sufficient, sufficient but not necessary, and, possibly, necessary and sufficient.

After these premises, we introduce some issues related to consciousness as an acquired intelligent property by living matter, when metacognition is intended as self-cognition, cognition of cognition [50, 51], assuming the approach of reflexivity in a *logical open* way, and selfness *through levels of self-modeling, self-representation*, for instance when the mirror-neuron system [52, 53] applies to itself. The conscious is considered a representation of cognition, such as the represented, the remembered present. Processes of representation of the present may be considered to occur from their simultaneous, contextual "coding" as memory [54].

The intelligent, then generative property of living matter to be considered is the self-reflexivity as autocatalysis and logical openness.

Issue #5: Consciousness from self-reflexivity and self-memory.
Application effects for AI?

Generated acquired, emergent intelligent properties allow recurrent memory and self-memory that is compatible and converging to consciousness. This reminds of the technology of recurrent neural networks (RNN) [55].

Recurrence may be considered for processes of emergence when it is possible to consider different levels [3, p. 266–273] and re-emergence.

5 Conclusions

The distinction and decoupling of our intelligence and the intelligence of matter generates incoherent, degenerated forms and with conflicting applicative consequences. Theoretical continuity is ignored. A catastrophic cognitive discontinuity is created. This is the reductionistic attitude in dealing with complex systems such as the climate, environment, social and economic imbalances, and exploitation. They are considered external, *decidable* problems.

Life recognizes life (i.e., itself). Intelligence recognizes intelligence (i.e., itself). It seems to be a closed, self-referential loop. We may admit the existence of different abstract forms of life and intelligence, but they would be, concretely, unrecognizable. However, what interests us in finding and recognizing different forms of life and intelligence in nature [56]? Would it be possible and interesting to learn, create interfaces, and interact? Should different forms of life and intelligence be assumed incommensurable in principle? Maybe just asking the question, without much hope of arriving at effective discoveries, could lead to introducing logical openness within the self-referential loop above *as though* other intelligences and lives were really effective. It could theoretically allow us to elaborate and model recurrent incompleteness, quasi-ness, multiplicity, superimpositions, and pending of models themselves, for instance, of complexity. This allows us to consider systems of approaches and overall orientation purposes rather than single objectives such as regulating and deciding.

It is possible to figure out a simulated environment of "intelligent" agents

- Recognizing only their intelligence
- Recognizing only their artificial life
- Having simulated, well-defined rules (i.e., completed evolution), without emergence and quasi-ness
- Acquisition of properties may only be collective
- Possible reflexivity is reduced to replication and iteration with no change of representation.

Is it possible to figure out a related game on the future evolutive end of such environments and break this reductionistic prevalent attitude: through internal interventions based on logical openness or necessarily *external* interventions? We may call it the game of acquired intelligent life. Can it be Turing complete as in Conway's Game of Life?

References:

[1] Minati, G., Penna, M.P., Pessa, E. *Thermodynamic and Logical Openness in General Systems*. Syst. Res. Behav. Sci. 1998, *15*, 131–145.

[2] Minati, G., Pessa, E. Collective Beings, Springer: New York, NY, USA, 2006.

[3] Minati, G., Pessa, E. From Collective Beings to Quasi-Systems. Springer: New York, NY, USA, 2018

[4] Gödel, K. On Formally Undecidable Propositions of Principia Mathematica and Related Systems, Dover Publications Inc.: Mineola, NY, USA, 1962.

[5] Licata, I., Minati, G. *Emergence, Computation and the Freedom Degree Loss Information Principle in Complex Systems*. Found. Sci. 2016, *21*, 863–881.

[6] Minati, G. *Non-classical Systemics of quasicoherence: From formal properties to representations of generative mechanisms. A conceptual introduction to a paradigm-shift*. Systems 2019, 7(51), doi:10.3390/systems7040051

[7] Minati, G. *Knowledge to Manage the Knowledge Society: The Concept of Theoretical Incompleteness*. Systems 2016, 4(3), doi:10.3390/systems4030026

[8] Minati, G., Abram, M., Pessa, G. (Eds.), *Systemics of Incompleteness and Quasi-Systems,* Springer: New York, NY, USA, 2019.

[9] Longo, G. Interfaces of Incompleteness. In *Systemics of Incompleteness and QuasiSystems*, Minati, G., Abram, M.R., Pessa, E., Eds., Springer: New York, NY, USA, 2019, pp. 3–55.

[10] Longo, G. *Reflections on concrete incompleteness*. Philos. Math. 2011, 19, 255–280

[11] Janot, C. Quasicrystals: A Primer, Oxford University Press: Oxford, UK, 2012.

[12] Pessa, E. The concept of particle in quantum field theory. In *Vision of Oneness*, Licata, I., Sakaji, A., Eds., Aracne: Rome, Italy, 2011, pp. 13–40.

[13] Minati, G. *On Modelling the Structural Quasiness of Complex Systems*. WSEAS Transactions on Systems and Control 2021, 16, 715-734, doi:10.37394/23203.2021.16.65

[14] Getling, A.V. Rayleigh-Bénard Convection: Structures and Dynamics, World Scientific: Singapore, 1998.

[15] Kinoshita, S. (Ed.), *Pattern Formations and Oscillatory Phenomena & Belousov-Zhabotinsky Reaction*; Elsevier: Amsterdam, The Netherlands, 2013.

[16] Nicolis, G., Prigogine, I. Self-Organization in Nonequilibrium Systems: From Dissipative Structures to Order through Fluctuations, Wiley: New York, NY, USA, 1977.

[17] Prigogine, I. From Being to Becoming: Time and Complexity in the Physical Sciences, W.H. Freeman & Co.: New York, NY, USA, 1981.

[18] Minati, G. Phenomenological structural dynamics of emergence: An overview of how emergence emerges. In The Systemic Turn in Human and Natural Sciences. A Rock in the Pond, Urbani, U.L., Ed., Springer: New York, NY, USA, 2019, pp. 1–39

[19] Mittal, S. Emergence in stigmergic and complex adaptive systems: A formal discrete event systems perspective. *Cogn. Syst. Res.* 2013, *21*, 22–39.

[20] Nagaev, R.F. Dynamics of Synchronising Systems, Springer: Berlin, 2002.

[21] Mikhailov, A.S., Calenbuhr, V. From cells to societies. Models of complex coherent actions, Springer: Berlin, 2002.

[22] Acebrón, J.A., Bonilla, L.L., Vicente, C.J.P., Ritort, F., Spigler, R. *The Kuramoto model: A simple paradigm for synchronization phenomena*. Reviews of Modern Physics, 2005, *77(19)*, 137-185.

[23] Kuramoto, Y., 2003, *Chemical Oscillations, Waves, and Turbulence*. Dover Publications Inc., Mineola, New York.

[24] Boccaletti, S. The Synchronized Dynamics of Complex Systems. Elsevier: Oxford, UK, 2008.

[25] Ciszak, M., Euzzor, S., Geltrude, A., Arecchi, F. T., Meucci, R. *Noise and coupling induced synchronization in a network of chaotic neurons*. Communications in Nonlinear Science and Numerical Simulation, 2013, *18*, 938–945.

[26] Boccaletti, S., Kurths, J., Osipov, G., Valladares, D.L., Zhouc, C.S. *The synchronization of chaotic systems*. Physics Reports 2002, *366 (1–2)*, 1–98.

[27] Manrubia, S.C., Mikhailov, A.S. Emergence of Dynamical Order: Synchronization Phenomena in Complex Systems, World Scientific: Singapore, 2004.

[28] Kaneko, K. *Clustering, coding, switching, hierarchical ordering, and control in a network of chaotic elements*. Physica D 1990, *41*, 137–172.

[29] Popovych, O., Maistrenko, Yu., Mosekilde, E. *Loss of coherence in a system of globally coupled maps*. Physical Review E 2001, *64*, 026205-11.

[30] Drouetm D., Kotz, S. Correlation and Dependence, Imperial College Press: London, UK, 2001.

[31] Rupp, A.A., Walk, M.J. Pearson Product-Moment Correlation Coefficient. In *Encyclopaedia of Measurement and Statistics*, Salkind, N. J., Ed., Sage: London, UK, 2010, pp. 1023–1027.

[32] Kreuz, T. *Measures of neuronal signal synchrony*. *Scholarpedia* 2011, *6(12)*, 11922-11.

[33] Preparata, G. Introduction to a Realistic Quantum Physics, World Scientific: Singapore, 2002.

[34] Minati, G. *Systems, complex systems, and intelligence: An educational overview*. WSEAS Transactions on Advances in Engineering Education 2022, *19*, 87-108, doi:10.37394/232010.2022.19.10
[35] Flynn, J.R. What Is Intelligence?: Beyond the Flynn Effect, Cambridge University Press: Cambridge, UK, 2009.
[36] Kauffman, S.A. Approaches to the origin of life on earth. Life 2011, *1*, 34–48.
[37] Serra, R., Villani, M. Modelling Protocells. The Emergent Synchronization of Reproduction and Molecular Replication. Springer: New York, NY, USA, 2017.
[38] Goldenfeld, N., Woese, C. *Life is physics: Evolution as a collective phenomenon far from equilibrium*. Annu. Rev. Condens. Matter. Phys. 2011, *2*, 375–399.
[39] Steuer, R., Junker, B.H. *Computational models of metabolism: Stability and regulation in metabolic networks*. Adv. Chem. Phys. 2009, *142*, 105–251.
[40] Licata, I., Chiatti, L. *The Archaic Universe: Big Bang, Cosmological Term and the Quantum Origin of Time*. Int. J. Theor. Phys. 2009, *48*, 1003–1018.
[41] Licata, I., Chiatti, L. *Archaic Universe and Cosmological Model: "Big-Bang" as Nucleation by Vacuum*. Int. J. Theor. Phys. 2010, *49*, 2379–2402.
[42] Minati, G. *A controversial issue: the intelligence of matter as* residue*? A possible understanding*. Biomedical Journal of Scientific & Technical Research (BJSTR) 2019, *23(1)*, 17139-17140 doi: 10.26717/BJSTR.2019.23.003848
[43] Hobson, A. *There are no particles. There are only fields*. Am. J. Phys. 2013, *81*, 211.
[44] Morgan, C.L. Emergent Evolution, Williams & Norgate: London, UK, 1923.
[45] Bazaluk, O. The Theory of Evolution, Cambridge Scholars Publishing: Newcastle, UK, 2016.
[46] Edelman, G., Tononi, G. A Universe of Consciousness. How Matter Becomes Imagination, Basic Books: New York, NY, USA, 2000.
[47] Zeki, S., Chén, O.Y., Romaya, J.P. *The Biological Basis of Mathematical Beauty*. Front. Hum. Neurosci. 2018, *12*, 467.
[48] Colloca, L., & Benedetti, F. (2005). Placebos and painkillers: Is mind as real as matter? Nature Reviews Neuroscience, 6, 545–552...
[49] Minati, G. *Interactions and Interaction Mechanisms as Generators of Complex Systems*. WSEAS Transactions on Proof 2022, *2*, 96-107, doi:10.37394/232020.2022.2.12
[50] Wilson, M. *Six views of embodied cognition*. Psychon. Bull. Rev. 2002, *9*, 625–636.
[51] Wilson, R.A. Foglia, L. Embodied Cognition. In *The Stanford Encyclopedia of Philosophy*. Edward, N.Z., Ed.; 2017; Available online: https://plato.stanford.edu/archives/spr2017/entries/embodied-cognition (accessed on 20 March 2023).
[52] Rizzolatti, G. Craighero, L. *The mirror-neuron system*. Annu Rev Neurosci. 2004, *27*, 169-92 doi:10.1146/annurev.neuro.27.070203.144230
[53] Caramazza, A., Anzellotti, S., Strnad, L., Lingnau, A. *Embodied cognition and mirror neurons: A critical assessment*. Annu. Rev. Neurosci. 2014, *37*, 1–15.
[54] Edelman, G. The Remembered Present: A Biological Theory of Consciousness, Basic Books: New York, NY, USA, 1990.
[55] Bianchi, F.M., Maiorino, E., Kampffmeyer, M.C., Rizzi, A., Jenssen, R. Recurrent Neural Networks for Short-Term Load Forecasting: An Overview and Comparative Analysis, Springer: New York, NY, USA, 2017.
[56] Urbani Ulivi, L. (Ed.), L'intelligenza della natura, EUPRESS FTL- Cantagalli: Lugano-Siena, Italy, 2022.