THE E-MERGING MIND

Franco Orsucci
Division of Psychology and Language Sciences, University College London

1. E-MERGENCE

We are going to explore a dynamical space delimited by two basic conceptual poles in system dynamics:
e-mergence and *mergence* or, if you prefer, *fusion*. While the first concept is more frequently cited and discussed, the second one is often neglected. It is unclear why, as it might be difficult to define and understand the first without the second and vice versa. We might say that they form a dynamic couple. If we have a look at their semantic fields in natural language, we could easily see why (Merriam-Webster, 1998).

MERGE – etymology: Latin *mergere*; akin to Sanskrit *majjati* ('he dives').
transitive senses:

- Archaic, to plunge or engulf in something, immerse;
- to cause to combine, unite, or coalesce;
- to blend gradually by stages that blur distinctions;

intransitive senses:

- to become combined into one;
- to blend or come together without abrupt change;

mergence \ noun
Synonyms: mix, amalgamate, blend, compound, fuse, interblend, interfuse, intermingle, meld and mingle.

EMERGE – etymology: Latin *emergere*, from *ex* + *mergere* to plunge.
Senses (intransitive):

- to become manifest
- to rise from or as if from an enveloping fluid out into view
- to rise from an obscure or inferior position or condition
- to come into being through evolution

Synonyms: appear, loom, and show.
Related Words: derive, originate, spring, stem; arise, materialize, rise; come (forth), come out, emanate, flow, issue (forth); proceed.
Idioms: appear on the horizon, come on the scene, come out in the open, come to light, and make its appearance.
Contrasted Words: disappear, fade, fade (out); evaporate; dissolve.

From a first comparison we find interesting that *emerge* is a semantic evolution from *merge* (see Sanskrit and Latin roots).
We could say that the dialectics

$$M \Leftrightarrow E$$

represents a dynamic relation between a system's whole and its part(s).

For example, following the Sanskrit etymology, if we dive into the sea for an external observer we become part of its system. If we then start swimming we produce a sequence of fusions and emergences. While we do so, we are certainly not *caused* by the sea, but we have a dynamic relation with it. The simplicity or complexity of an object depend from the perspective and resolution in place when the object is considered.

Ernest Nagel (Nagel, 1961) cites Mill's *System of Logic* (Mill, 1843) as the *locus classicus* on the notion of emergence. For Mill, the key to a distinction between emergent and non-emergent properties is grounded on the distinction between different ways in which conjoint causes might produce an effect. Non-emergent properties are effects that are mere summations of the components in a causal process, whereas emergent properties are effects that are somehow multipliers of them.

The term *emergence* (Lalande, 1962) has been used mainly to designate the fact that one thing comes from another *without a simple relation of cause and effect: in these terms it would imply self-organization and/or a different perspective for the observer*.

Lloyd Morgan (1922) wrote: "The emergence of a new quality from any level of existence means that, at that level, there comes into being a certain *constellation* or collocation of the motions belonging to that level, and possessing the quality appropriate to it; and this collocation possesses *a new quality distinctive of the higher complex*. The quality and the constellation to which it belongs are at once new, and expressible without residue in terms of *the process proper to the level from which they emerge*; *just as mind is a new quality distinct from life, with its own peculiar methods of behaviour."* (Italics are mine) (Morgan, 1923).

2. THE EMERGING MIND

A system exhibits emergent properties when those properties are more than the sum of its parts' properties. We could posit that mental properties emerge from certain complex sets of physical properties, for instance, physical properties of human brains. Thus mental events are not identical to any brain events but instead emerge from them. After advanced studies on neural plasticity we might also say the reverse: brain emerges from mind, because it is moulded by mental events. As in a *Moebius band*, container and content in the mind-brain relationship can be reversed in their reciprocal function depending from the perspective of an observer. We might need to consider both the whole (as decomposable), its parts (as fusible) and an observer function.

In the study of complex systems, the idea of emergence is referring to the arising of patterns, structures, or properties that do not seem adequately explained by a system's pre-existing components and their interactions. Emergence becomes of increasing importance as an explanatory construct when the system is characterized by the following features:

- when the organization of the system, i.e., its global order, appears to be more salient and of a different kind than the components alone;
- when components can be replaced without decommissioning the whole system;
- when global patterns or properties are radically novel;
- when emergent patterns seem to be unpredictable, irreducible and non-deducible from the components.

3. EMERGENCE VS FUSION

Emergence is a universal phenomenon that can be defined in a very general mathematical way. This might be useful for the study of scientific legitimate explanations of complex systems, here also defined as hyperstructures. Living as cognitive beings in a world of instability and change, we permanently face known and unknown situations, old and new. We usually cope with the complexity of ordinary life in a sort of easy way and supposed to be simple patterns of behaviour. It can be astonishing to realize the underlying complexity of any problem solving behaviour if seen from a scientific point of view. In this case we would try to correlate descriptions of the body as a complex system and its coupled environment (as given by physics, biology and cognitive science) to the life and actions (as experienced) of our "normal" daily world.

In the so-called sciences of complexity (e.g., non-linear dynamics, complex adaptive systems, artificial life, artificial intelligence, cognitive science etc.), complex phenomena, such as the appearance of life on Earth, the evolution of new species, or the structures of thinking, are often considered as instances of some emergent higher-order that may be explained by lower-level dynamics generating a collective behaviour or emergent property of the system in question. The sciences of complexity offer important new insights, theories, and methodologies for dealing with complex, higher-order phenomena. Can the emergence of new properties a complex system really be explained?

The very idea of scientific explanation as a strictly deductive argument should be re-interpreted and we should perhaps see explanations in a more dynamic and context-dependent setting. As they could *eventually be emergent structures, emergent explanations*.

4. HYPERSTRUCTURES

Here, we are proposing a new general framework for the description of higher-order structures, or *hyperstructures*, which includes a mechanisms of self-observation and, eventually, of self-generation. During this process, new observers may also emerge from within the system itself (N.A Baas, 1994).

When it comes to such questions as the very generation of explanations, the discovery of new structures or principles, the appearance of new insights to the inquiring mind, i.e. the emergence of structures that can be said to explain a phenomenon, very little has been said. Of course, one can argue that it is the very law of nature that has the explanatory power in physical science, so any research programme should attempt to discover such laws. However, in understanding complex systems, the challenge is often to understand the consequences of laws on other levels of organizations, i.e., to understand the history and complexity of the boundary conditions.

Understanding a system means creating some kind of generalized resonance: a link between understanding and change for both parties, system and subject.

Traditional deductive notions of scientific explanation have frequently been criticized for being too reductive to account for complex mental phenomena. Hence, in a somewhat romantic vein G. Spencer Brown declared:

"To explain is literally to lay out in a plane where particulars can be readily seen. Thus to place or plan in flat land, sacrificing other dimensions for the sake of appearance. Thus to expound or put out at the cost of ignoring the reality or richness of what is so put out. Thus to take a view away from its prime reality or royalty, or to gain knowledge and lose the kingdom" (Spencer-Brown, 1957).

The pure dilemma of reductionism vs. holism could become an illusion if we can expand our knowledge while preserving the richness of a world of emergent structures.

5. EMERGENCE IN HYPERSTRUCTURES

In recent years, the notion of emergence has been extensively studied, not always defining first what emergence might mean. We will consider *emergence* as the way complex systems and patterns arise out of a multiplicity of relatively simple interactions. In the general sense proposed by Baas (1994) the crucial point in his definition is the notion of *an observer defining the emergent perspective*. In the study of complex systems one often sees that a collection of interacting systems shows *collective (nonlinear) behaviours*. In order to study the phenomenon further it may be useful to introduce a more formal framework as follows:

$$\left\{S\right\} i \in I$$

let it be a family of *systems* or agents. Let Obs^1 be *observation* mechanisms and Int^1 be *interactions* between agents. The observation mechanisms measure properties of agents in interactions. Interactions then generate new structures

$$S^2 = R\,(S^1_i\,,\,Obs^1\,,\,Int^1)$$

The new structure could be a stable pattern or a dynamically interacting system. We call S^2 an *emergent structure* which may be subject to new observational mechanisms Obs^2. This leads to:

$$\text{P is an emergent property}$$
$$\Updownarrow$$
$$\text{P} \in Obs^2(S^2) \text{ and P} \notin Obs^2(S^1_i)$$

The observational mechanism may be internal or external.

Examples:

- Coupling of dynamical systems. (control and/or synchronization);
- Large collections of objects get new behaviour (like in phase transitions);
- Functionality of bio-molecules in cells.
- Consciousness is not a property of individual neurones.

With the interactive help provided by coupling each agent may perform tasks which none of them could do separately. Hence we get a *second order agent* (CS) which again may serve as a master in a new context. This is related to *control and synchronization theory.* Consciousness is not a property of individual neurones, it is a natural emergent property of interacting neurons in nervous system in a given environment. Consciousness generates a structure that is related to lower level interactions as well as higher level thoughts, and it represents a new observational mechanism for the entire system (Baas 1994; Maturana & Varela, 1980).

General causes of emergence would be: non-linear interactions, large collections of limits, open-ended evolution in heterogeneous environments, context-dependence of properties in complex systems.

Depending on the case, the $Obs^2(S^1_i)$ may have elements, or it may be an empty set if for instance *Obs* does not or cannot observe anything.

6. INTERACTIONS AS MORPHISMS

We propose that the present framework might be useful for analysing the nature of emergence, particularly its dependence from observational mechanisms. In order to set this perspective into a more formal framework, category theory could be very useful.

We will let systems be represented as objects in a category and their ***interactions as morphisms***. A complex system with its interactions is then represented by a diagram. Since morphisms are represented by arrows, this may be viewed as a process oriented scheme.

The observational mechanism may here be thought of as a functor. In categories we may form direct limits ($\varinjlim$) of diagrams, and in this case the $\varinjlim$ may be thought as both an observation functor (*Obs*) and a complexification process (*R*).

It is always impossible to deduce the properties of the whole from its constituents and its observational mechanisms. Thus, within the general framework proposed here, one must distinguish between two different kinds of emergence:

A. ***Deducible emergence***. There exists a deductional or computational process or theory *D* such that P $\in$ $Obs^2(S^2)$ can be determined by D from (S^1_i, Obs^1, Int^1). This is **structural** or ontic emergence.

B. ***Observational emergence***. If P is an emergent property, but <u>cannot</u> be deduced as in (A). This is a **phenomenic** emergence.

Examples of deducible emergence include: some compositional structures in nonlinear dynamical systems, phase transitions, non-triviality of complexity manifolds in topology. In these cases, the various properties can be decided by well-defined procedures, so *Obs* can be seen as instantiating an algorithm leading to a set of properties. Examples of *observational emergence* include Gödel sentences' in a formal system (the *Obs* is the truth function; cf. Gödel's theorem), and the property of membership in the Mandelbrot set and in most Julia sets (Mandelbrot, 1983).

Furthermore, it was indicated that the eventual semantic non-compositionality of a language would imply that the meaning of sentences in such a language was observationally emergent. In formal string systems, compositionality can be defined as the condition that there exists a computable function *F* such that

$$M(s) = F(M(s1), ..., M(sk)),$$

where the *s*'s are the syntactical relations and *M* is a semantic *meaning function*. If we take *Obs* as our *M*, then *compositionality* amounts to deducible emergent meaning, whereas *non-compositionality* would imply the existence of observationally emergent meaning. As opposed to formal systems, the meaning of sentences in natural language are often context-dependent, i.e., the meaning of a sentence is not simply deducible from the meaning of its components, but dependent of the larger discourse in which it is placed. Thus, *observationally emergent meaning* constitutes a problem for semantic analysis (at least in the Tarski tradition, which is set theoretical, truth functional and compositional), as well as for classical AI that follows `the formalist motto' of deducing semantics from syntax .

In spite of the existence in mathematics of a large set of yet undecided statements or conjectures about mathematical properties that may exemplify either deductible or observational emergence, it is a general observation that the most transparent and clear-cut cases of the two kinds of emergence are found within the logical and mathematical domain. Nevertheless, the distinction may also have considerable potential value in empirical sciences, for instance in the ongoing discussion about reductionism and explanatory relations. For example, the *autonomy* of biology in relation to physical science is, so to speak, grounded in the observational emergence of specific properties of biosystems, such as the self-reproduction of living cells. For theoretical biology it is of interest to determine in what sense observational emergent properties, as studied by Artificial Life models, can or cannot be considered as real instantiations of living entities.

8. AUTOPOIESIS

One may even go further by conceiving a living system as *autopoietic* (Maturana & Varela, 1980). This definition would describe a system as a bounded network of production, transformation and destruction of components which can regenerate. This would realize a living network and its boundaries, thereby constituting a unity in a new (autopoietic) space of relations. This property can, we suggest, be understood as the observational emergence in the physical space of systems that realize their own self-production, boundaries and self-observation, thus being *cognitive* in a primitive sense. If this is true, an autopoietic system is autonomous because it realizes the observational emergence of itself as an observer. These processes would create *hyperstructures,* as multi-level emergent structures.

A hyperstructure of order *N* is given by

$$S^N = R(S^{N-1}_{i_{N-1}}, Obs^{N-1}, Int^{N-1}, S^{N-2}_{i_{N-2}}, ...)$$

extending the construction in the definition of emergence. This is a cumulative structure, not necessarily purely recursive.

The client/(ob)server situation may easily be extended to a hyperstructure of the *N*-th order clients or (ob)servers. Within the living realm, one can observe hyperstructures as realized by multicellular organisms and the community structure of ecosystems. Consciousness may be seen as a hyperstructure of mental events embodied in a central nervous system and capable of self-observation and self-interaction.

Hyperstructures may be thought of as an organizational scheme or design principle. The role of *Obs*- which may also be an interacting environment - may also allow for evolution to be incorporated.

The point is to combine the notion of *emergence and hierarchy* into the notion of *hyperstructure* which implies also *fusion*.

Wherever a problem, a situation, or a structure can be organized into a hyperstructure, this has an explanatory power. We think that the proposed framework implies an interpretation of autopoiesis theory can integrate evolution and emergence of autonomy.

9. THE OB-SERVER

As already emphasized, the notions of *emergence* and *hyperstructure* depend critically on an ob-server. This is natural in so far as phenomena have to be explained through observational facts (even in the abstract sense of facts).

When phenomena are modelled in thermodynamics by means of statistical mechanics we may view temperature and pressure as emergent properties and phase transitions as emergent phenomena. These are components of collective behaviours which in many cases are well understood, in a reductionistic sense, in physics. However, temperature has been introduced as a formal parameter ad hoc. A deeper level of explanation could be to see the *laws* of thermodynamics as derived from the laws of Hamiltonian mechanics, i.e., such that temperature would *emerge*.

The emergent properties of hyperstructures of biological and social systems are deeply dependent of the existence of observers which are intrinsic to the system. For example, a single cell with its membrane bound proteins could constitute an observer for some aspects of its immediate environment (i.e. molecules that can be recognized as signals or nutrition), as multicellular organisms depend critically on inter-cell signalling. On a more complex level, most if not all institutions in human societies have self-observing mechanisms (e.g., evaluation and assessment in research and production), as well as mechanisms for observing other institutions.

New topological and geometrical properties occur, but may often require *sophisticated "observational" functors like cohomology theories* to be detected and described. Complicated surfaces, like manifolds, are being glued together from elementary pieces. Furthermore, in a knot where is the knottedness? It is a global property, having no meaning locally. Or in a Moebius band - where is the *twist*? (Penrose, 1994).

Category theory is the mathematical language suited for discussing structures in general. A category consists of

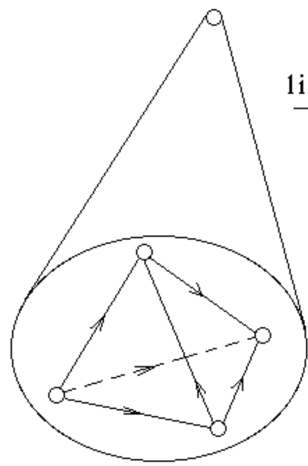
- Objects: X, Y, ...(like spaces, groups, algebras, ...)
- Morphisms: X→Y represented by arrows (functions, interactions)

To each pair of objects we have a set of morphisms (X, Y). A category is closed under morphism composition

$$x \xrightarrow{f} y \xrightarrow{g} z, \qquad x \xrightarrow{g \circ f} z$$

meaning that if *f* and *g* are morphisms, so is also $g \circ f$.

We can form networks of morphisms as commutative diagrams and construct their categorical limits.



$\lim_{\rightarrow}$ D is an object which is a kind of synthesis of D and which is called the direct (or co) limit of D. Limits often play the role of emergent structures.

The *limit construction* may be viewed as a *complex process leading to new emergent properties*, according to observational mechanisms. Specifically, if

$$D = \xrightarrow{\lim} D_i \text{ in } C$$

F a functor:

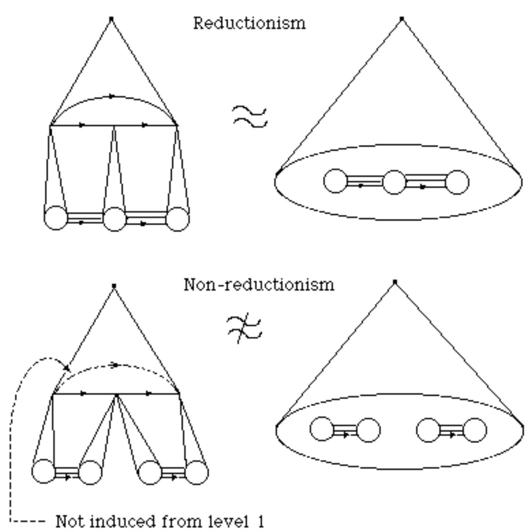
$$F: C \rightarrow \mathcal{E}$$

$$F: \quad C \rightarrow \mathcal{E}$$

say F(Di) = 0 trivial object in $\mathcal{E}$, but if F(D) is a non-trivial object in $\mathcal{E}$, we may view F(D) as an emergent structure or property of the diagram.

10. REDUCTIONISM AND NON-REDUCTIONISM

Within the framework of category theory we can beautifully present some differences between reductionism and non-reductionism. We refer here to the figure:



Circles represent diagrams in a category, while horizontal arrows are morphisms, and cones are limits (Nils Andreas Baas & Emmeche, 1997; Ehresmann & Vanbremeersch, 1987).

Usually, in an explanation there is a deductional procedure, an algorithm, leading from something basic and well-known to the new thing. In essence this is a reductionistic explanation procedure as formally illustrated in the figure. An observer just singles out in a situation what is to be explained. Therefore a *deductive emergence is basically a kind of traditional reductionistic explanation, but with an observer as an additional enrichment*. Non-deducible or observational emergence is more subtle. In this case there is no algorithmic explanation. As we see in the figure in the case of limits a two level structure is needed in order to explain. It cannot be explained or understood only from the primitive level. At level 2 new phenomena emerge (in this case caused by the compositional properties in categories), which are needed at the next level. Even if there is no algorithm from the bottom up, still we would claim that this construction or figure is a perfectly good explanation - a second order emergent explanation ($\underrightarrow{\lim}$ may be thought of both as a construction and as an observation). The iterated limit construction is just a special case of a hyperstructure, which is a multilevel emergent structure. Therefore we will say that we have higher order or *N*-th order explanations of a phenomenon wherever it occurs as a result of a suitable *N*-th order structure.

In our discussion of hyperstructure we have suppressed time, which should be added in a dynamical picture. But the basic ideas would remain the same. We may think of the scheme

$$\frac{S_1,...S_n}{S} \text{ rel } (Int, Obs)$$

meaning that *S* is an emergent structure, as an inference rule. A property observed in *S*, but not in the *S*'s could then be said to have an emergent explanation. This extends to more levels and hyperstructures in general, and could lead to a *dynamical process logic*, an *emergent deduction*, which would be useful in order to explain and discuss about emergent phenomena.

The important, and new, point is that an emergent deduction is not only a *syntactic* process, but it combines *syntax* and *semantics* in reasoning and explanation. After all, this is how much of human reasoning occurs, for example in mathematical thinking.

11. EXPLANATION AND INSIGHT

On the subjective level, it is a common experience to have sudden insights, eureka and aha experiences. They are due to the emerging consciousness of a possible solution to a problem that for long time has occupied the working mind (in its conscious as well as subconscious components). The sudden intuition is experienced as the appearance of a solution and as a new cognitive structure. This kind of experience has been vividly described (Poincare & Halsted, 1929) as the detection of a new pattern (Chaitin, 1987; Hofstadter & Fluid Analogies Research Group, 1995). Of course, such experiences are quite common consciousness in general and seem to be a property of an *overflow* (Searle, 1992) in which whole and complex situations are suddenly seen in a new light. It is as if a higher order observational mechanism has accessed properties of new structures, as generated through the interactions of previous experiences. We propose that the characteristic phenomenon that conscious states refer *beyond* their immediate content (as seen in the overflow phenomenon, in the so-called "Aha! experience", and in the well-known Gestalt shifts between figure and ground) is deeply related to hyper-structured constitutions of consciousness.

12. THE EMERGENT MIND

The traditional conflict between objective explanations of consciousness and subjective understanding of consciousness (i.e., of its intrinsic qualities, phenomenal aspects, "what it is like", *qualia* etc.) may be transcended within the general framework of hyperstructures.

If laws of nature are a kind of algorithms giving us highly compressed descriptions of phenomena we can observe in nature (Chaitin, 1987), the existence of observationally emergent properties which cannot be computed from lower level algorithms shows the necessity of reformulating the notion of our explanations so as to encompass the historical generation of hyperstructures.

Any scientific explanation has objective as well as subjective aspects. As objective, the explanation can be publicly, explicitly and precisely stated (eventually in a formal mode); it can be critically discussed (and eventually tested); and it can generate adequate representations with explanatory power. As subjective, the explanation must be understood and make sense to a competent observer; it must be fully or partly accepted as a genuine explanation (i.e., as one which comprehends the phenomenon); and it must thus mentally reflect the emergent structure. Hyperstructures can be found existing in objective as well as in subjective reality.

The methodology of a science of consciousness must concern itself not only with objectively observable behaviours (from a third-person perspective), but also with what has been termed as a first-person point of view (Searle 1992). The observer is observing the emergence of new structures from *within the system*, as exemplified in mathematical discovery or in other kinds of sudden flashes of insight. In living systems high level new phenomena such as consciousness emerge as a construction processes, in which *Int* and *Obs* occur at several levels, and in which (at least some) observation mechanisms are intrinsic to the system itself. Even though there is probably no algorithm from the bottom up, self-construction is a perfectly good explanation, a high order emergent explanation, open for further analysis.

The approach we presented here does not consider mind as self-transparent, nor does it invoke self-introspection as a privileged observation mechanism; rather, it relaxes inflated expectations and quixotic hopes for a different kind of explanation of conscious phenomena.

A crucial epistemological consequence of current advancements in neural plasticity is that, we can also say, brain emerges from mind, because it is moulded by mental events. As in the Moebius band, container and content in the brain/mind relationship can be reversed in their reciprocal function depending from the perspective of the observer.

We consider at the same time a decomposable whole, its merging parts, and an observer function. We find, in the end, that the observer might be observed by the whole, in this way becoming a mirrored whole object, just to vanish in a dissolving merger.

13. REFERENCES

[1]. Baas, N.A. (1994). Emergence, hierarchies, and hyper structures. Addison-Wesley.

[2]. Baas, N. A. & Enmeshed, C. (1997). On emergence and explanation. Retrieved from http://www.nbi.dk/~Emmeche/coPubl/97d.NABCE/ExplEmer.html

[3]. Chitin, G. J. (1987). *Algorithmic information theory*. Cambridge Cambridgeshire: Cambridge University Press.

[4]. Hermann, A. C., & Vanbremeersch, J.-P. (1987). Hierarchical evaluative systems: a mathematical model for complex systems. *Bulletin of Mathematical Biology*, *49*(1), 13–50.

[5]. Hofstadter, D. R., & Fluid Analogies Research Group. (1995). *Fluid concepts & creative analogies computer models of the fundamental mechanisms of thought*. New York: Basic Books.

[6]. Laplander, A. (1962). *Vocabularies technique et critique de la philosophies* (Vol. 9. ,d). Paris: Presses Universities de France.

[7]. Mandelbrot, B. B. (1983). *The fractal geometry of nature* (Vol. Updated and augmented). New York: W.H. Freeman.

[8]. Maturana, H. R., & Varela, F. J. (1980). *Auto poises and cognition the realization of the living*. Dordrecht, Holland: D. Riesel Pub. Co.

[9]. Merriam-Webster, I. (1998). *Merriam-Webster's collegiate dictionary* (Vol. 10th ed). Springfield, Mass: Merriam-Webster.

[10]. Mill, J. S. (1843). *A system of logic, ratiocinative and inductive was being a connected view of the principles of evidence, and methods of scientific investigation*. London: J. W. Parker.

[11]. Morgan, C. L. (1923). *Emergent evolution the Gifford lectures, delivered in the University of St. Andrews in the year 1922*. London: Williams and Negate.

[12]. Nagel, E. (1961). *The structure of science problems in the logic of scientific explanation*. New York: Harcourt, Brace & World.

[13]. Penrose, R. (1994). *Shadows of the mind a search for the missing science of consciousness*. Oxford: Oxford University Press.

[14]. Poincare, H., & Halsted, G. B. (1929). *The foundations of science and hypothesis, The value of science, Science and method*. New York: The Science press.

[15]. Searle, J. R. (1992). *The rediscovery of the mind*. Cambridge, Mass: MIT Press.

[16]. Spencer-Brown, G. (1957). *Probability and scientific inference*. London: Longmans, Green.