How can INBIOSA approach its goal? Can MES / MENS help?

by

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WHY A DYNAMIC CATEGORY THEORY?

MENTAL OPERATIONS	CATEGORICAL NOTIONS
Distinguishing objects and their relations	(Multi-)Graph
Combination of relations Communication, Change	Category Evolutive System
Binding process Hierarchy	Colimit Hierarchical Evolutive Systems
Emerging Properties	Multiplicity Principle Complexification

Category Theory analyses how the mathematician thinks, hence reflects prototypical mental operations: comparisons, synthesis, analysis, classification, optimization.

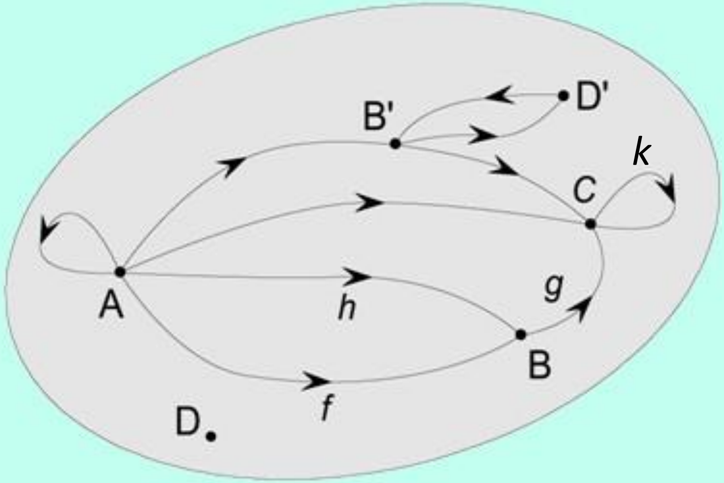
It provides a frame for 'modeling' complex systems, e.g. studying:

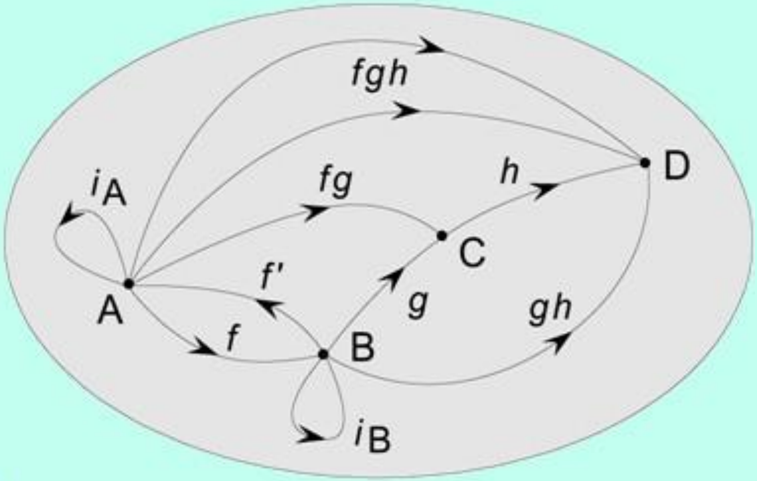
Binding problem: how do simple objects bind together to form "a whole that is greater than the sum of its parts " What are the simple and complex interactions arising between them?

Emergence problem: how to measure the 'real' complexity of an object and to explain the formation of increasingly complex objects?

Complexification and dynamics via multi-scale self-organization, by incorporating Time under the form of multiple temporalities and propagation delays

GRAPHS AND CATEGORIES



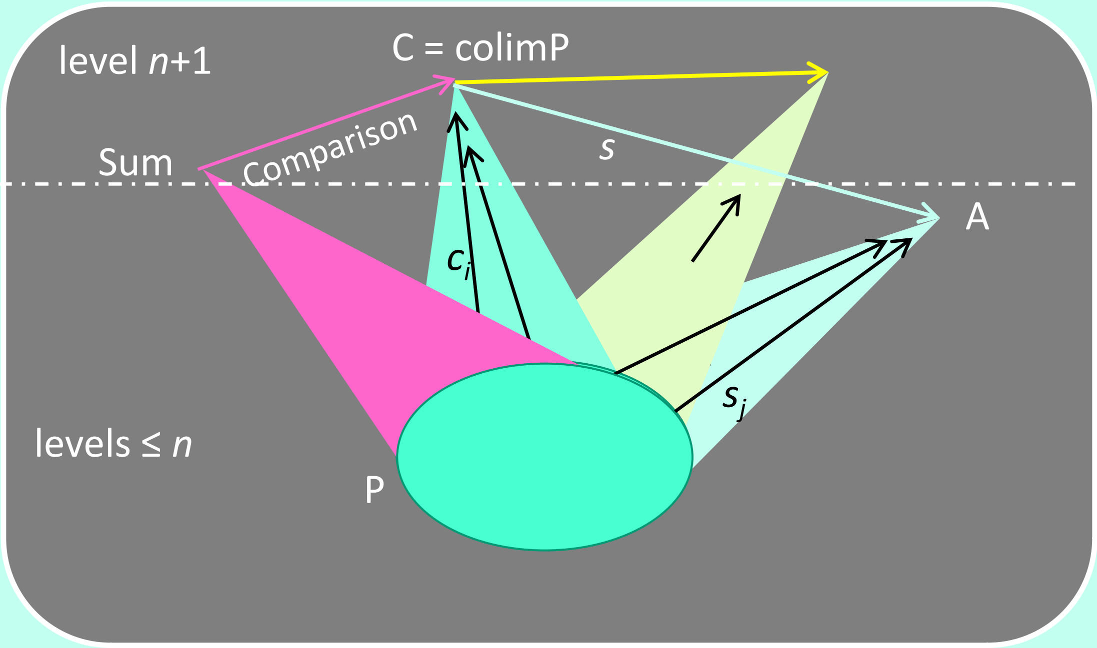


(Multi-)graph = a set of vertices and a set of oriented edges (or *links*) between them.
P*ath* of the graph = sequence of consecutive links (*f, g, k*).
Example. The graph of neurons with neurons as vertices and synapses as arrows.

Category = graph with an internal composition associating to a 2-path (*f, g*) a composite *fg*,; it is associative and each object has an identity.
Two paths with the same composite are *functionally equivalent.*

The paths of a graph form a category with composition by convolution) . Example: the category of neurons = the category of paths of the graph of neurons.
Each category is a quotient of the category of its own paths by the equivalence: "same composite".

BINDING OF A PATTERN. HIERARCHY



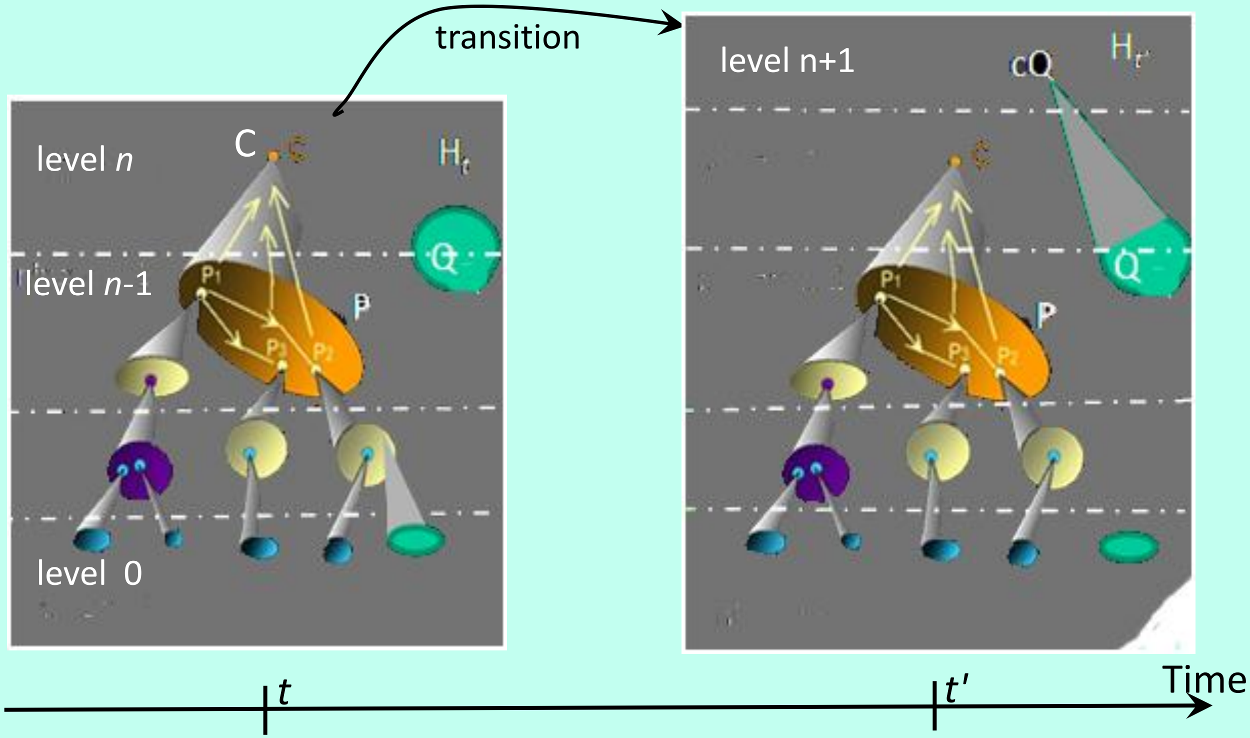
Pattern P = family of objects P_i with distinguished links between them.
Collective link from P to A = family of links s_i: $P_i \rightarrow$ A correlated by the distinguished links of P.

P admits C as its *binding* if C has the same functional role as P; it is modeled by the *colimit* of P, defined by the 'universal property': there is a collective link (c_i) from P vers C through which any other collective link (s_l) from P to an A factors uniquely.

Sum of the family (P*i*) = colimit of the pattern without distinguished links; the constraints imposed by the distinguished links of P are measured by the link: *comparison*: Sum → C = colimit C .

A category is *hierarchical* if its objects are divided into levels of 'complexity' so that an object C of level *n* +1 is the colimit of at least one pattern P with values in levels < *n* +1.

HIERARCHICAL EVOLUTIVE SYSTEM. COMPLEXIFICATION



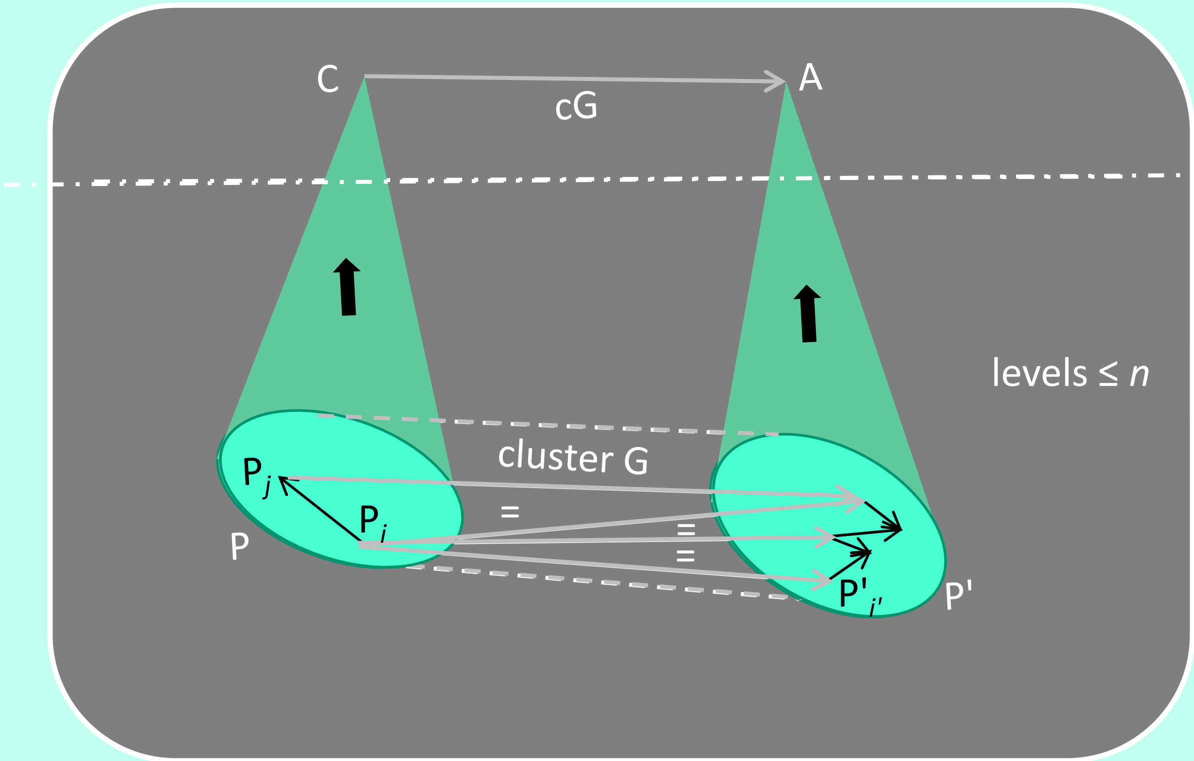
A *Hierarchical Evolutive System* **H** consists of:

(i) a family of hierarchical categories H_t (*configuration* at *t*) indexed by the timescale Time;

(ii) for $t < t'$, *transition* functor from a sub-category of H_t to $H_{t'}$; (iii) the transitions satisfy a transitivity condition so that a *component* of **H** is a maximal set of objects linked by transitions.

The transition results from a *complexification of* H_t *w*ith respect to a *procedure* S on H_t with objectives of the types: 'adding' external elements; 'binding' (or preserving the binding of) some patterns; 'syuppressing' or 'decomposing' some components. Thus $H_{t'}$ is the category where these objectives are optimally satisfied. We have explicitly constructed it.

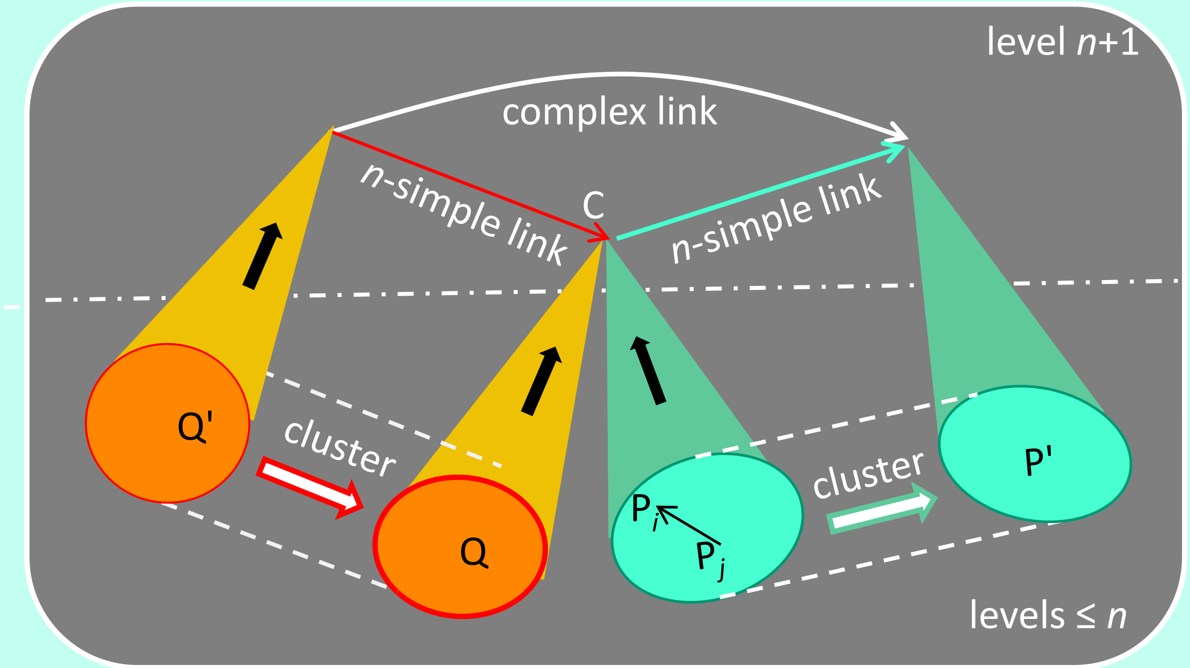
THE BINDING PROBLEM. SIMPLE LINKS



Among the links between complex objects, there are first 'simple' links binding la cluster of ower level links between their components. A *cluster* from P to P' is a family of links from each P_i to at least one P'_k, well correlated by the distinguished links of P and P'.

If P and et P' bind into A and C respectively, the cluster G binds into a unique link cG from A to C, called a (P, P')-*simple link,* or an *n-simple link* if P and P' are contained in the levels ≤ *n.*
A composite of *n*-simple links binding adjacent clusters is *n*-simple. The *n*-simple links are entirely determined by links between the components of P and P'.

MULTIPLICITY PRINCIPLE. COMPLEX LINKS



The following principle generalizes the "degeneracy" property of Edelman (1989). Roughly it means that there are functionally equivalent patterns which are not inter connected (by a cluster,) so that C has multiple realizabilities by non-connected patterns of lower levels.

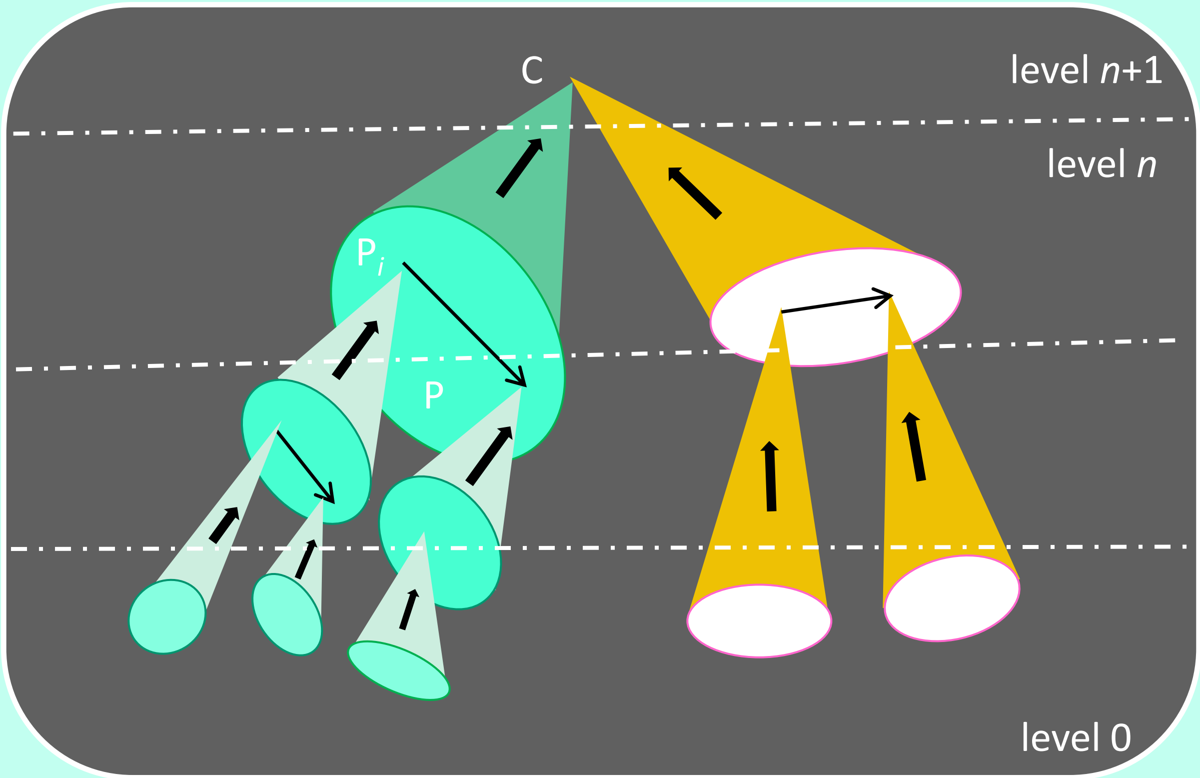
Multiplicity Principle (MP): There are objects C, called *n-multiform*, which bind 2 patterns Q and P of levels ≤ *n* which are not connected by a cluster. The passage from P to Q is a *complex switch.*

This MP extends to a complexification, and it mplies the existence of

n-complex links = composites of *n*-simple links binding non-adjacent clusters.

Such links are *emerging* ar the level *n*+1 and depend on the *global* structure of the levels ≤ *n* ; they cannot be recognized 'locally' through links between the extreme patterns Q' and P'.

COMPLEXITY ORDER



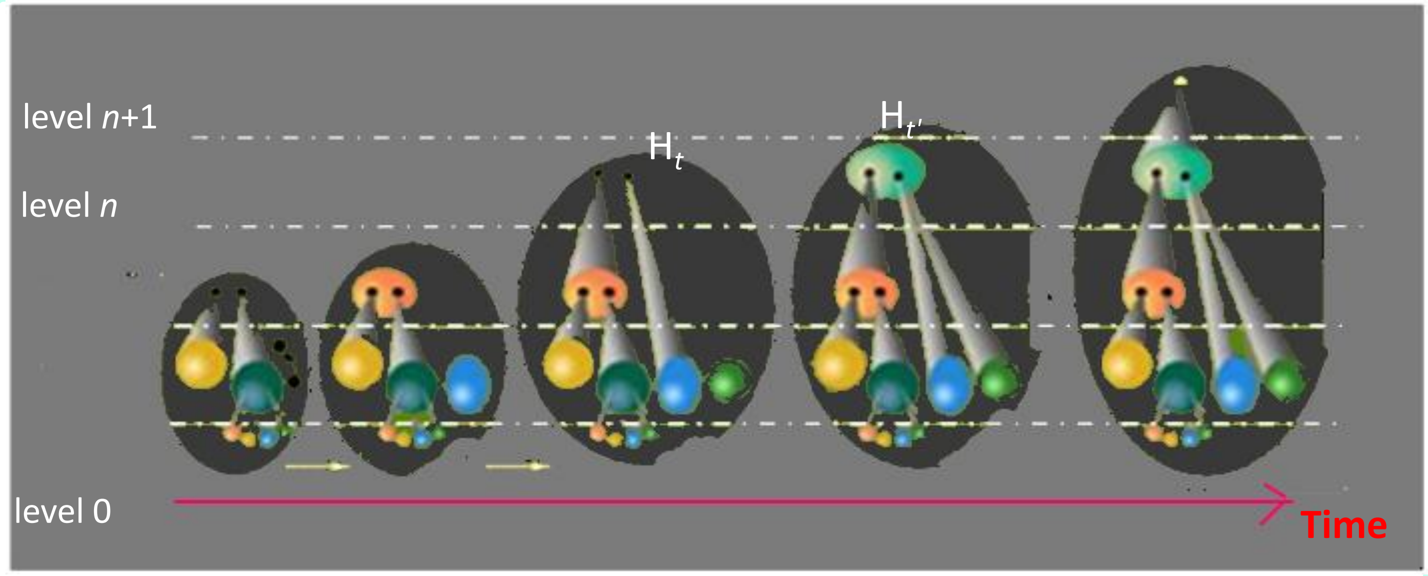
A component C of level n+1 binds at least one pattern P of strictly lower levels; each P_i also bind a pattern of lower levels, and so on. Whence a *ramification* of C down to the level 0.

C may have several ramifications of different lengths, hence several freedom degrees for unfolding a ramification , leading to *multiple realizabilities* of C by patterns of level 0. We define:

Complexity order of C = smallest length of a ramification of C.

It measures the smallest number of steps necessary for constructing C from level 0 up, by successive bindings of patterns; or conversely for the realization of C by patterns of level 0 .

EMERGENCE OF HIGHER COMPLEXITY

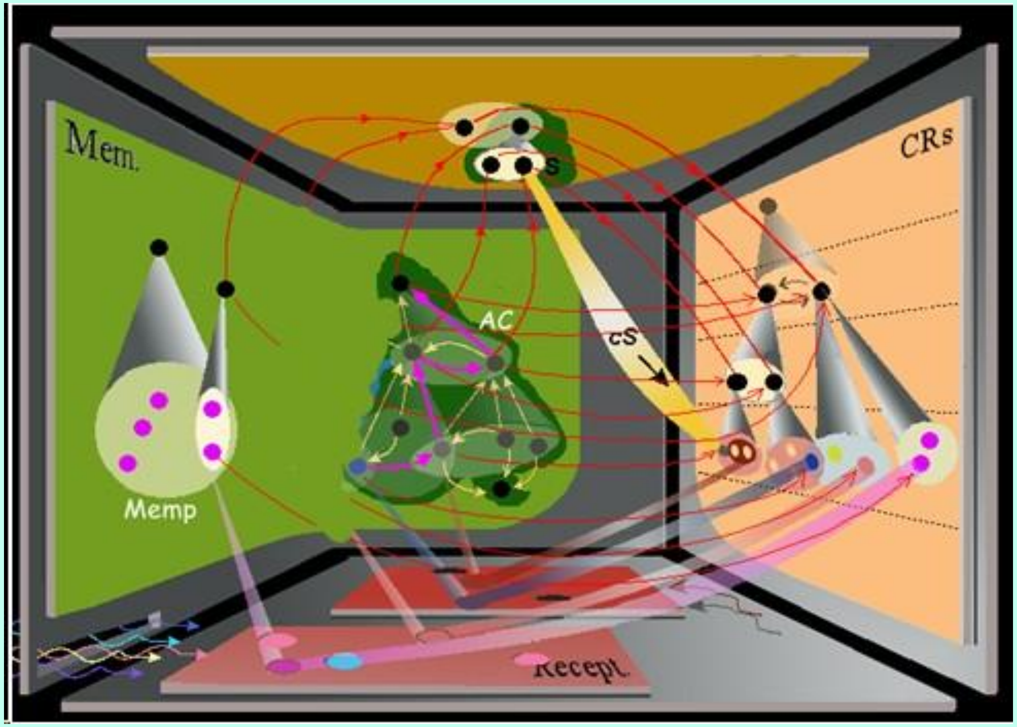


EMERGENCE THEOREM. In a Hierarchical Evolutive System, the MP is the condition characterizing the existence of components of complexity order > 1, and the possibility of emergence over time of components of strictly increasing complexity order. If MP.
Corollary. MP distinguishes organisms from mechanisms (in Rosen's sense).

If the MP is not satisfied, any component is reduced to the simple binding of a pattern contained in the level 0. This would characterize a 'pure' reductionism.

Example. The HES **MENS** modeling a neuro-cognitive system is obtained by successive complexifications of the ES of neurons **Neur** whose configuration at *t* is the category of neurons around *t.* Its components, called *cat(egory)-neurons* model more and more complex mental objets seen as binding (classes of functionally equivalent) patterns of (cat-)neurons. A cat-neuron has multiple 'physical' realizabilities through the unfolding of a ramification down to the neuronal level 0.l

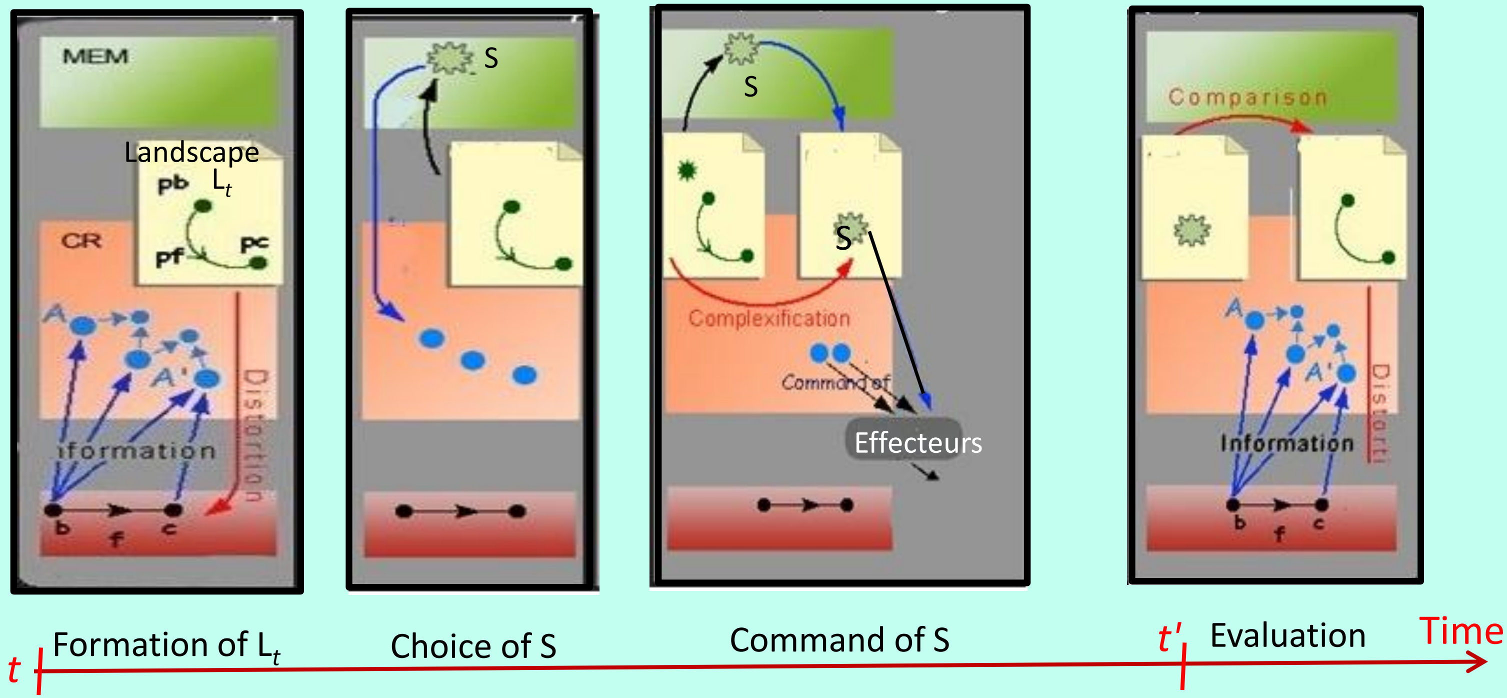
MEMORY EVOLUTIVE SYSTEM (MES)



A MES is a Hierarchical Evolutive System satisfying MP and with a self-organization directed by the cooperative and/or competitive interactions between a net of specialized functional subsystems, the *coregulators*. with the help of a central flexible memory **Mem** developing over time**.** We suppose that the links are labelled in **R** by a propagation delay and a strength.
Each CR has its complexity level, its own discrete timescale extracted from the continuous Time, and a differential access to **Mem**, in particular to retrieve procedures depending on its function for participating to the formation of the transitions.

Example. MENS 'is' a MES in which the CRs are based on (meaning have ramificatios down to) specialized modules of the brain and **Mem** models the flexible memory of the animal.

ONE STEP OF A CR



A CR acts stepwise at its own rhythm as a hybrid system. Phases of the step from *t* to *t'*:

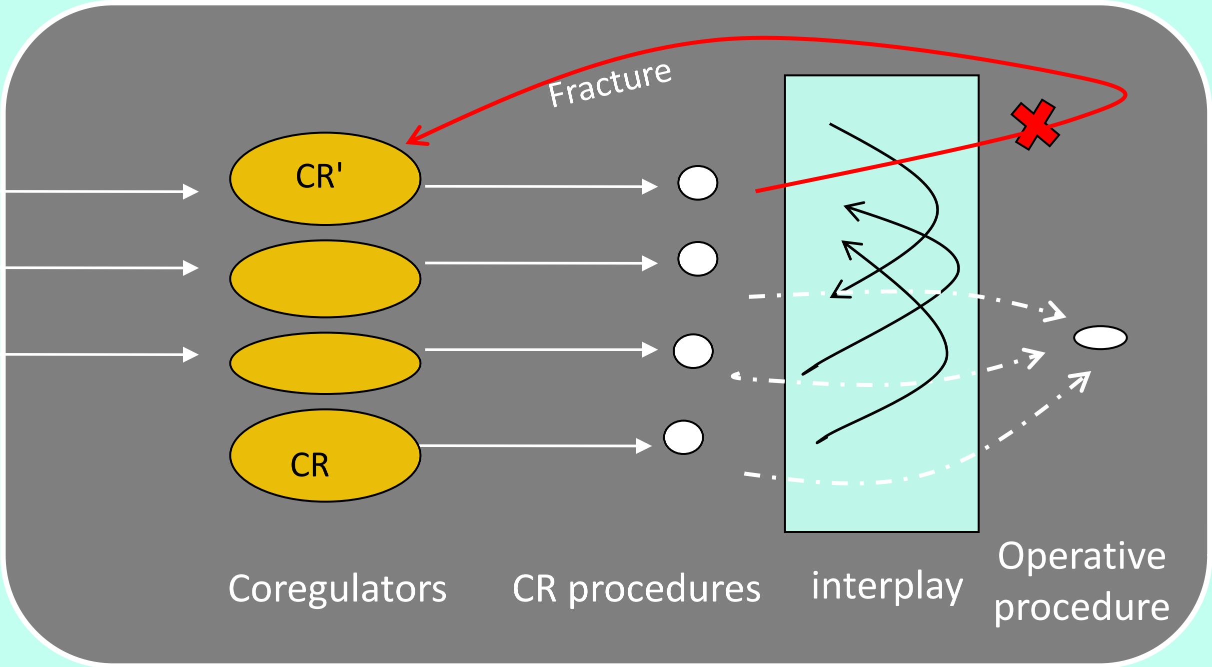
(i) Formation of its *landscape* L$_t$ *at t* with the partial information it can access.

(ii) Choice on L$_t$, with the help of Mem, of a procedure S to respond (it should lead to the complexification AL of L$_t$ by S).

(iii) Sending commands to effectors to realize S starts a dynamic process which unfolds during the continuous time of the step. It is directed by differential equations, implicating the propagation delays and strengths of the links, and it should move the landscape to an attractor.

(iv) The result is evaluated at the beginning *t'* of the next step by comparing AL to the new landscape. In the event the objectives are not attained, we speak of a *fracture* for the CR.

INTERPLAY BETWEEN CRs



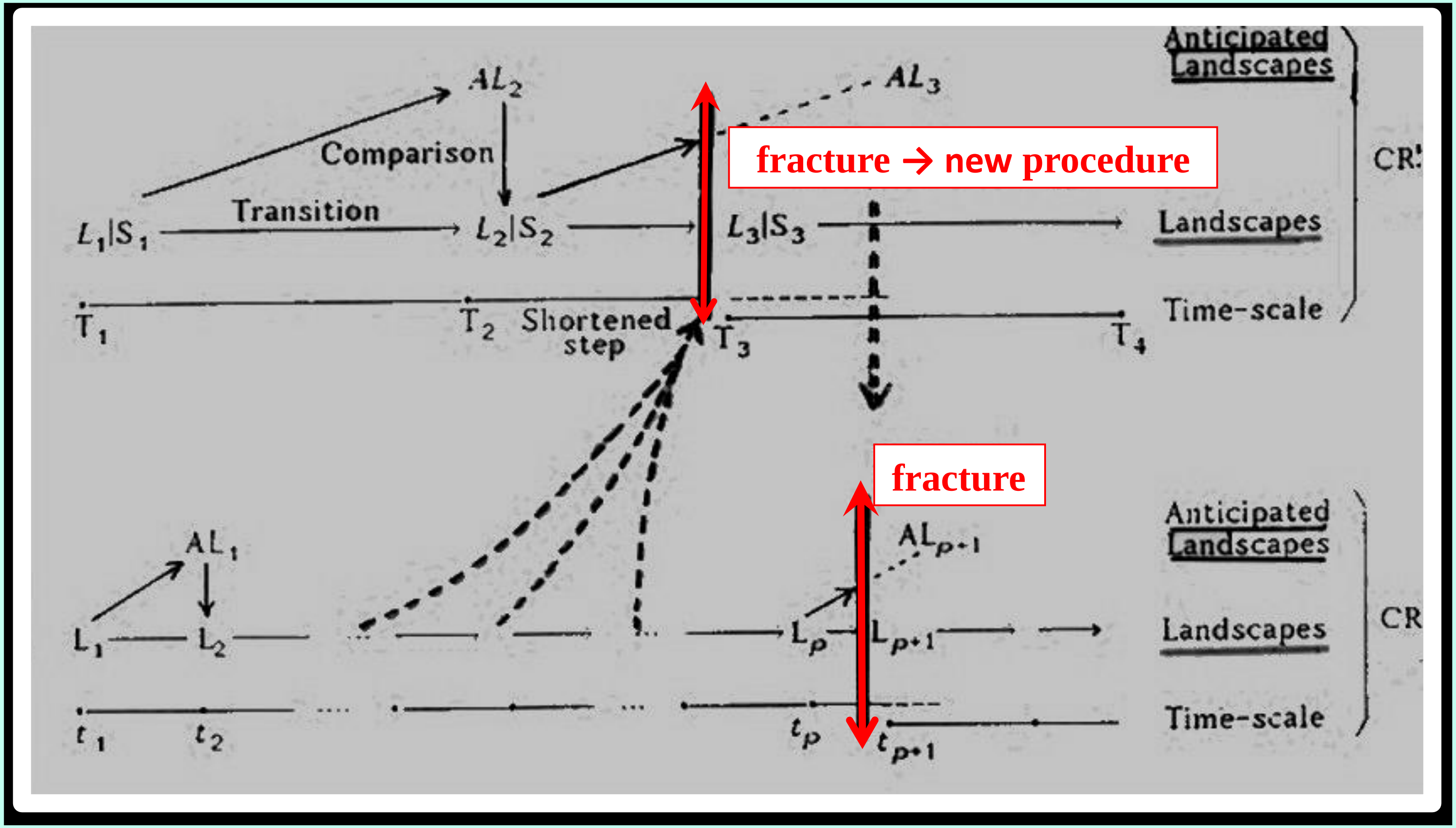
The *operative procedure* actually carried out on the system at a given time comes from an equilibration process between the procedures of the various CRs. This *interplay among the CRs*, takes advantage of complex switches between ramifications, and of the structural temporaly constraints of the CRs.

It may by-pass the procedures of some CRs, thus causing fracture or dyschrony) to them.

In particular there is a 'dialectics' between the dynamics of CRs heterogeneous with respect to their complexity and temporality.

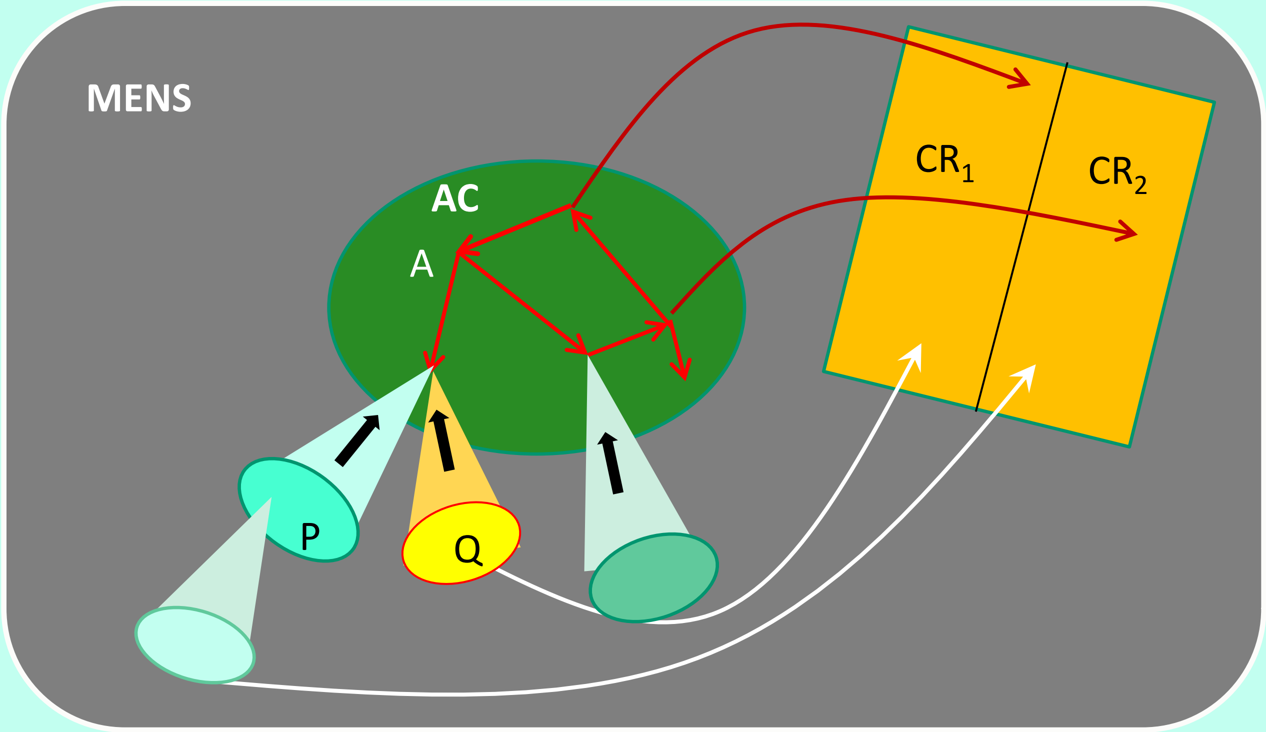
The repair of a dyschrony backfiring between CRs of different levels may lead to a change of the rhythm of some of them. Example: we have proposed a *theory of aging* for an organism through such a cascade of *resynchronizations* of CRs of higher and higher levels (1993).

DIALECTICS BETWEEN HETEROGENEOUS CRs



CR is a lower coregulator, with small steps, and CR' is a much higher one with much longer steps. A sequence of events at CR during successive steps, and the corresponding changes at the lower level are not transmitted in real time to CR' (propagation delays,...). However their accumulation may cause a noticeable event for CR' up to causing a fracture. The response of CR' and its change of procedure may backfire to CR by causing a fracture at its level, and the process can repeat.

ARCHETYPAL CORE. CONSCIOUSNESS



In **MENS** we have described (2001) how a *semantic memory* develops and allows the evolution of a subsystem of **Mem,** the *Archetypal Core.* **AC** intertwines higher order recurrent memories (based on the neural core, Hagman & al. 2008), with strong and fast links forming *archetypal loops.* It acts as a flexible internal model of the self, at the root of higher cognitive processes.

An increase of activation of cat-neurons in **AC** extends through archetypal loops and leads to a self-maintained recollection of a large part of **AC**, which resonates to lower levels via the unfolding of ramifications and complex switches between them.

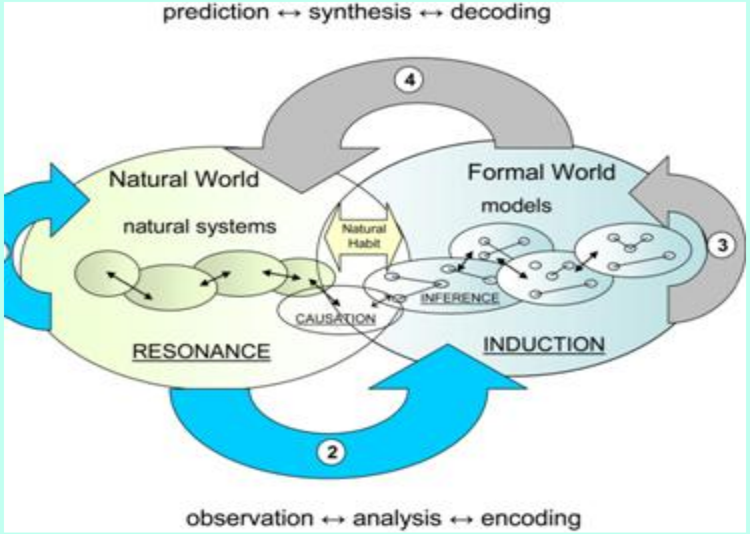
It leads to the formation of a *global landscape* **GL** uniting the landscapes of higher CRs. Conscious processes develop in **GL**, characterized by integration of time retrospection (making sense of the past) and prospection (allowing for long term anticipation)).

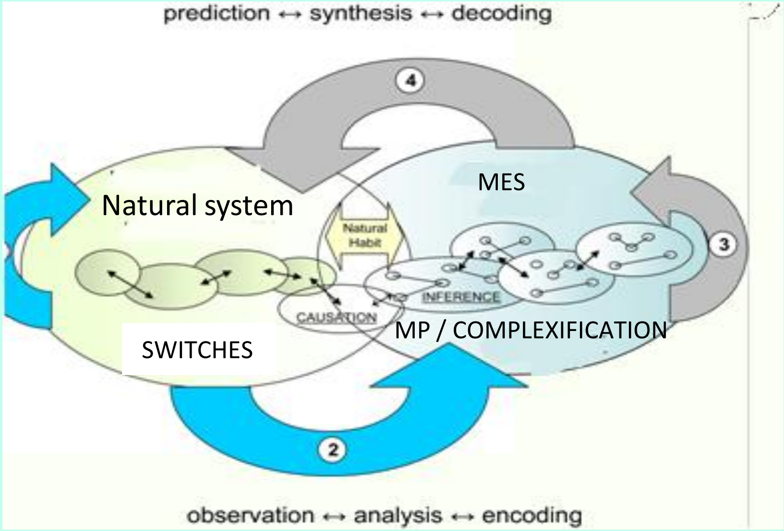
CONCLUSION. PROBLEMS

MES (and MENS) give models for autonomous evolutionary complex systems such as living or social systems. Here are some problems:

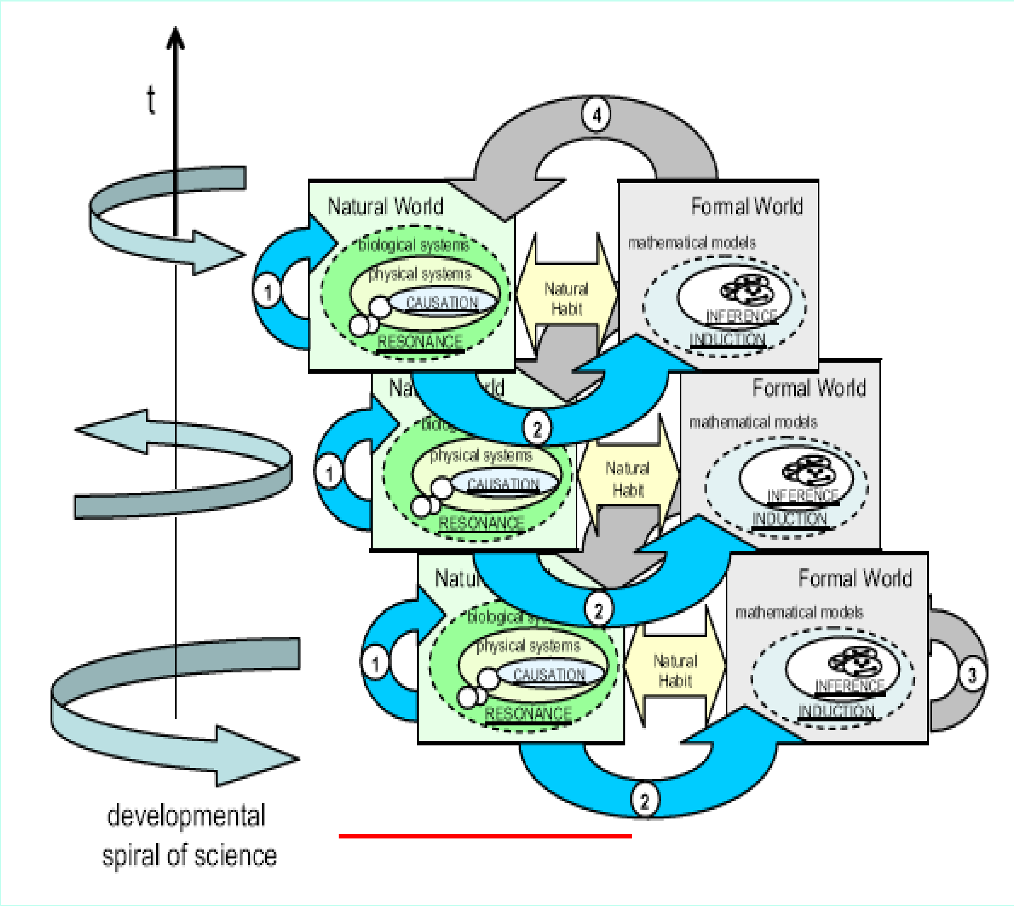
1. *Enrichment* of MES with supplementary structures, e.g., topologies, higher order categories, probabilities. It is possible but how would it be interesting?

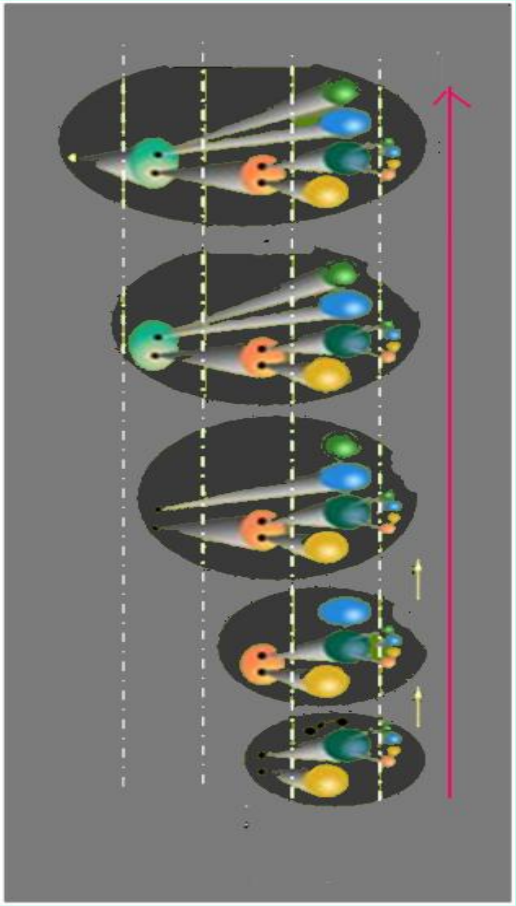
2. *Computations and simulations.* In what sense are MES computational? simulable by algorithms? One step of a CR is simulable, but probably not the MP, at the root of impredicability.





3. *MES as 'models'.* Rosen intends to model the invariant 'objective' structure of the system. MES (and **MENS**) are not models in this sense since they try to internally model the stepwise dynamics. However they can enter in Plamen Simeonov's notion of a model, if we replace 'resonance' and 'induction' by "complex switches" and "MP/ complexification". or better in his 'temporal'' frame (with arrows 4 going to the upper level instead of the same one).





References. *Memory Evolutive systems* (Elsevier, 2007). Papers downloadable from the sites:

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THANKS