MENS, an info-computational model for (neuro-)cognitive systems up to creativity

by

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(Work in collaboration with Jean-Paul Vanbremeersch)

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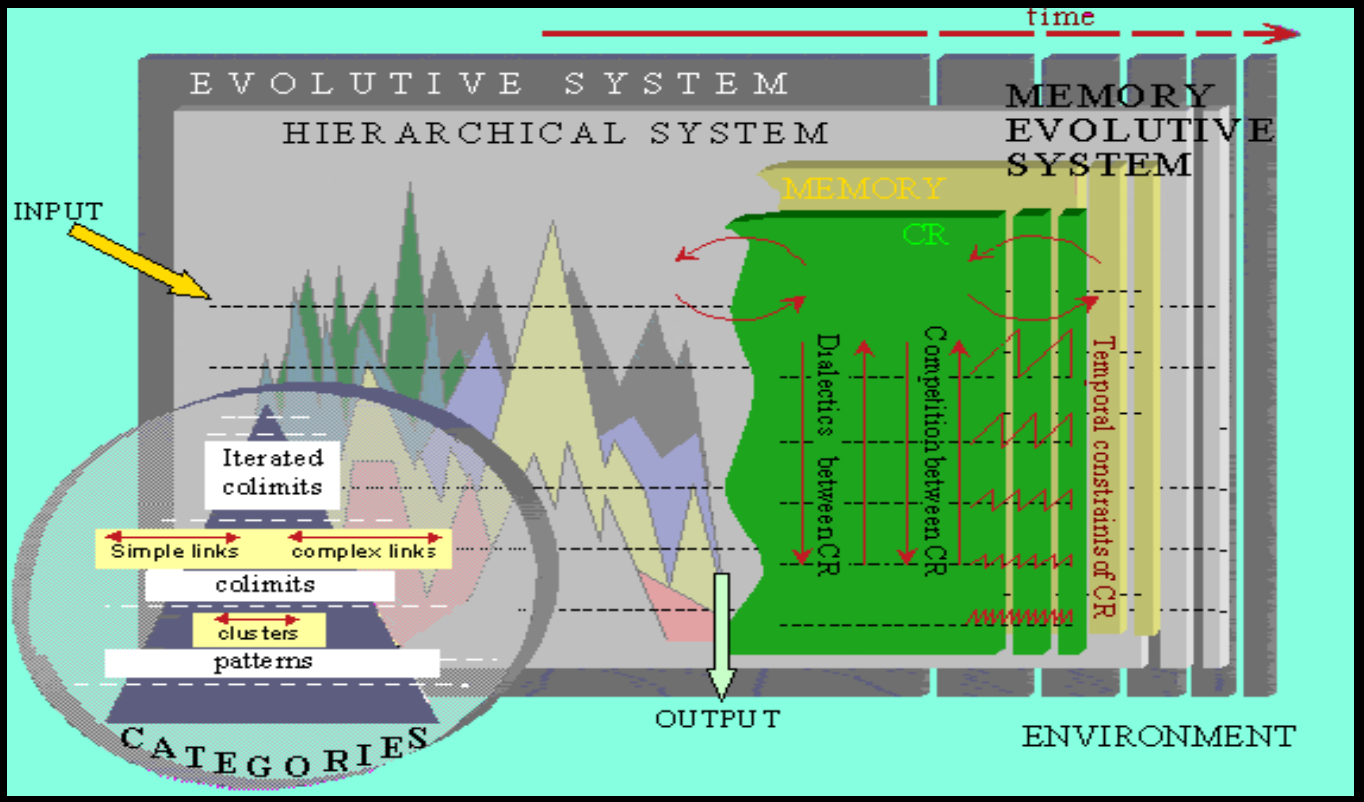
Natural/unconventional computing and its philosophical significance. AISB/IACAP, Birmingham, july 2012

MEMORY EVOLUTIVE SYSTEM (MES)



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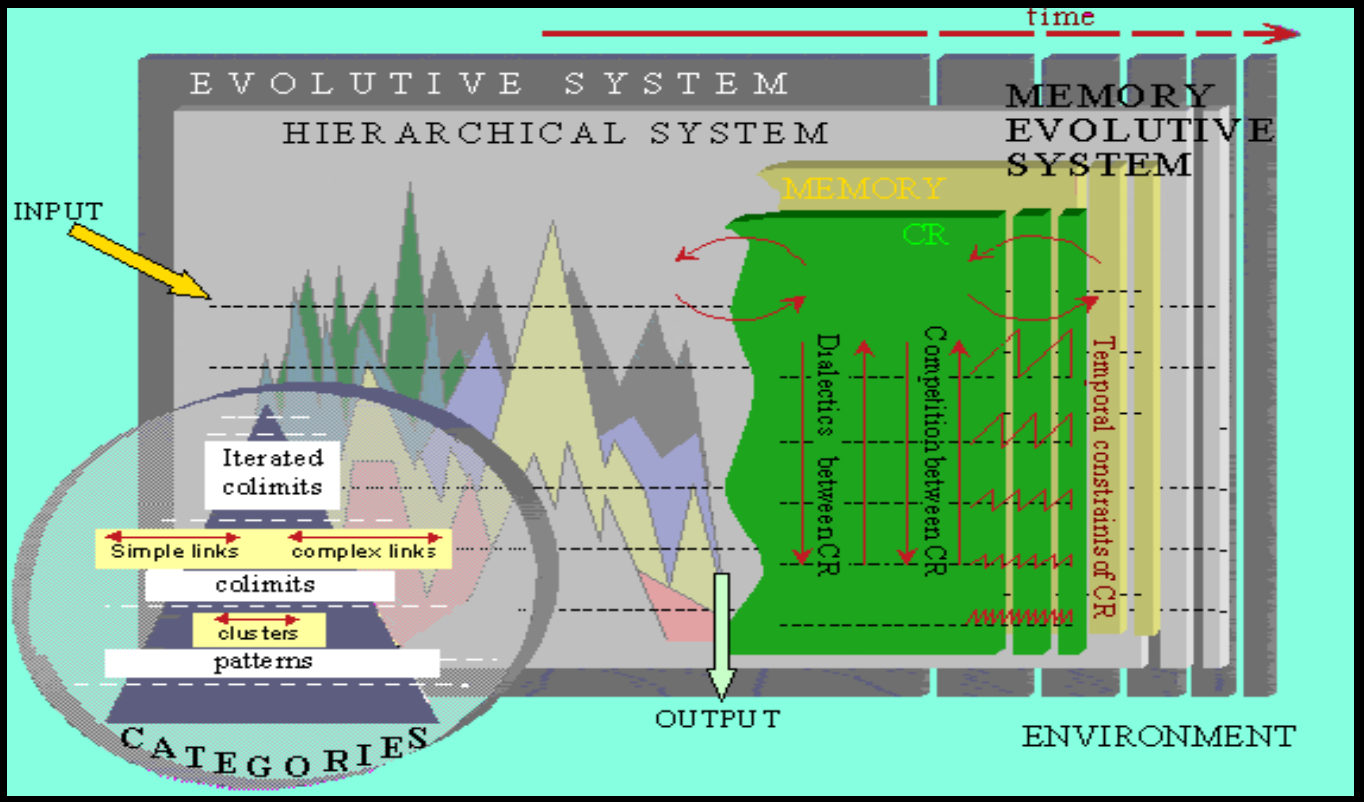


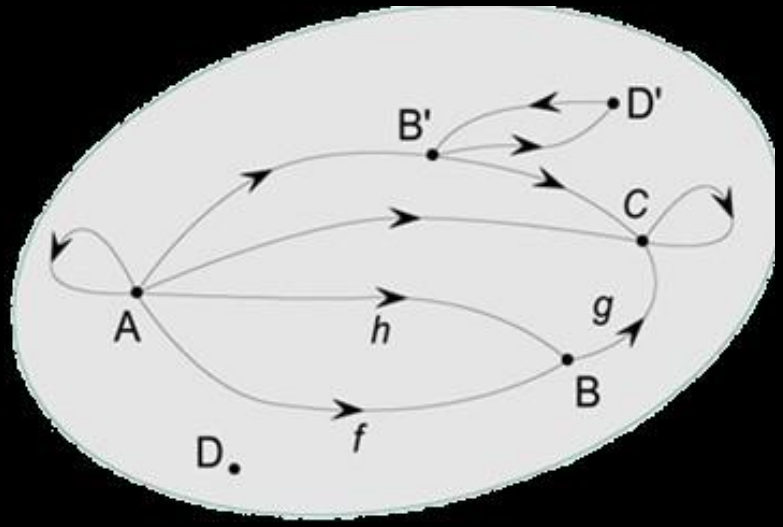
Model for bio-socio or cognitive systems based on Category Theory, with:

(i) a tangled hierarchy of components varying over time, each one "binding" a pattern of interacting components of lower levels;

(ii) a multi-scale self-organization by cooperation/competition of a net of local Co-Regulators with different rhythms and logics;

(iii) development of a flexible "Memory", including an internal model.

GRAPHS AND CATEGORIES



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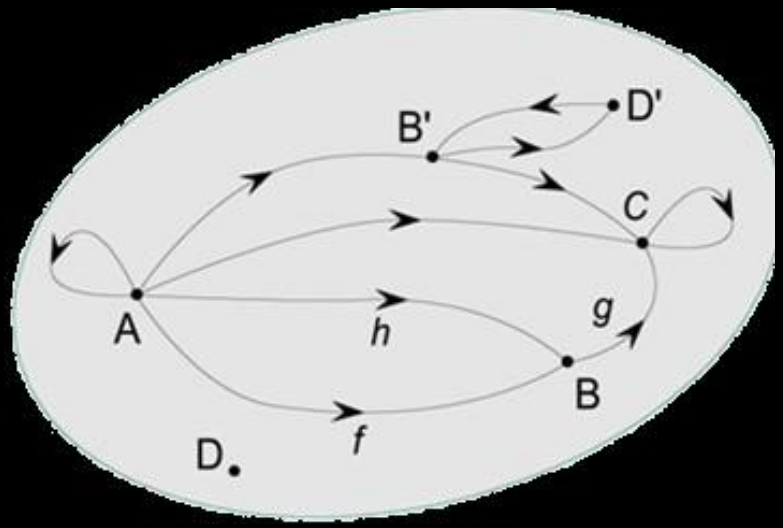

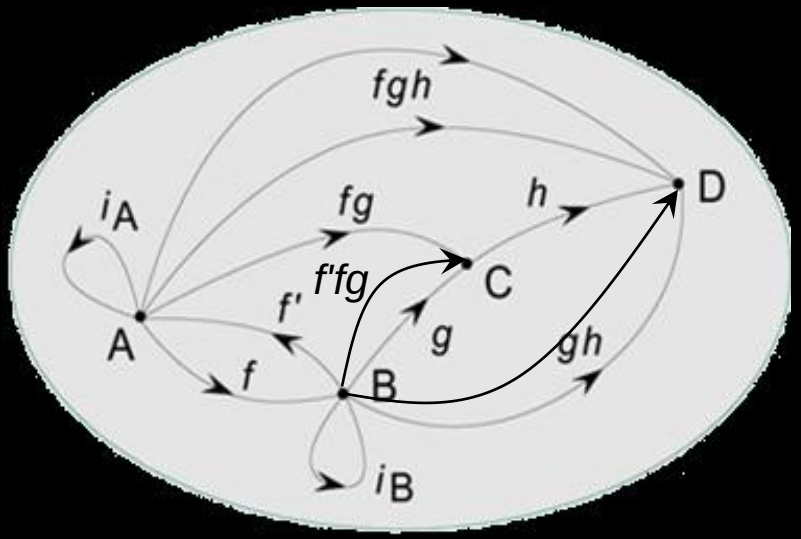

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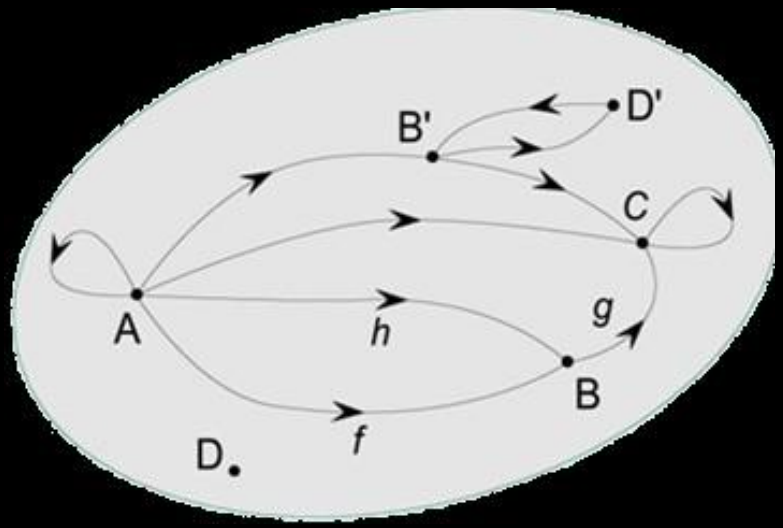

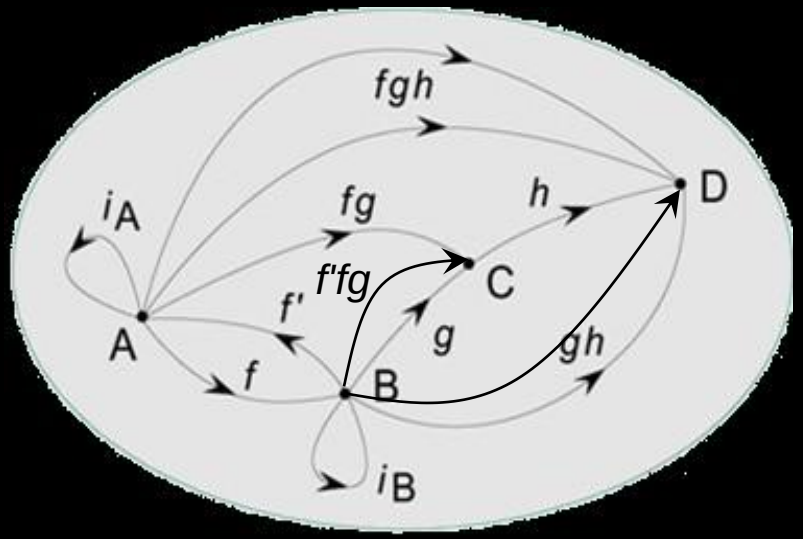

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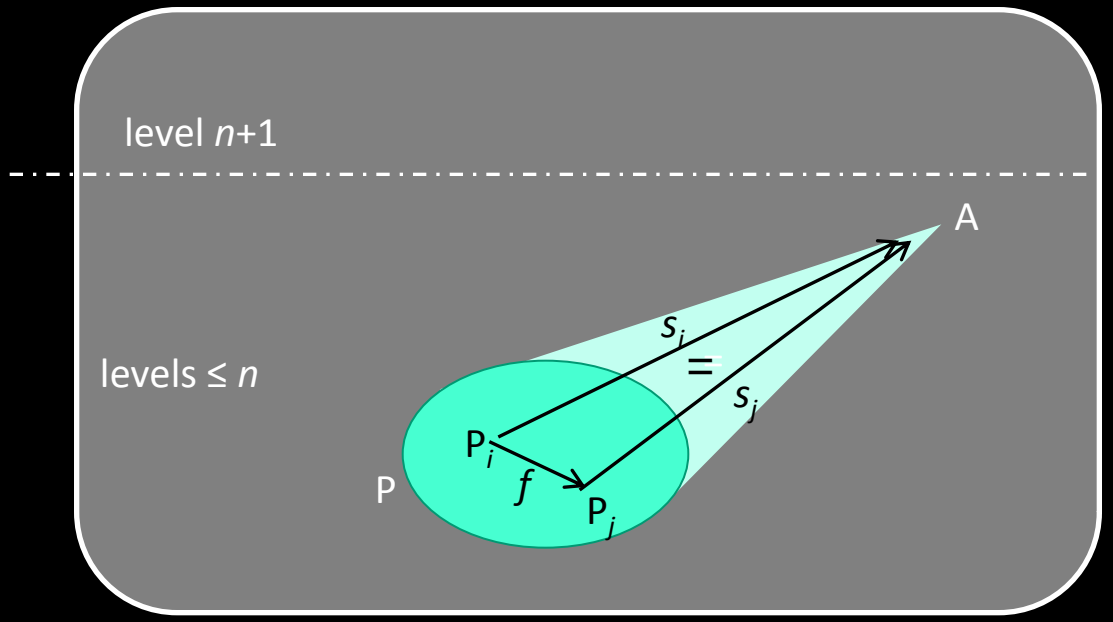
The paths of a graph form a category (composition = convolution) .
Each category is a quotient of the category of its own paths by the equivalence: "same composite".

Aristotle

BINDING = COLIMIT

"The **whole** is more than the sum of its **parts**."



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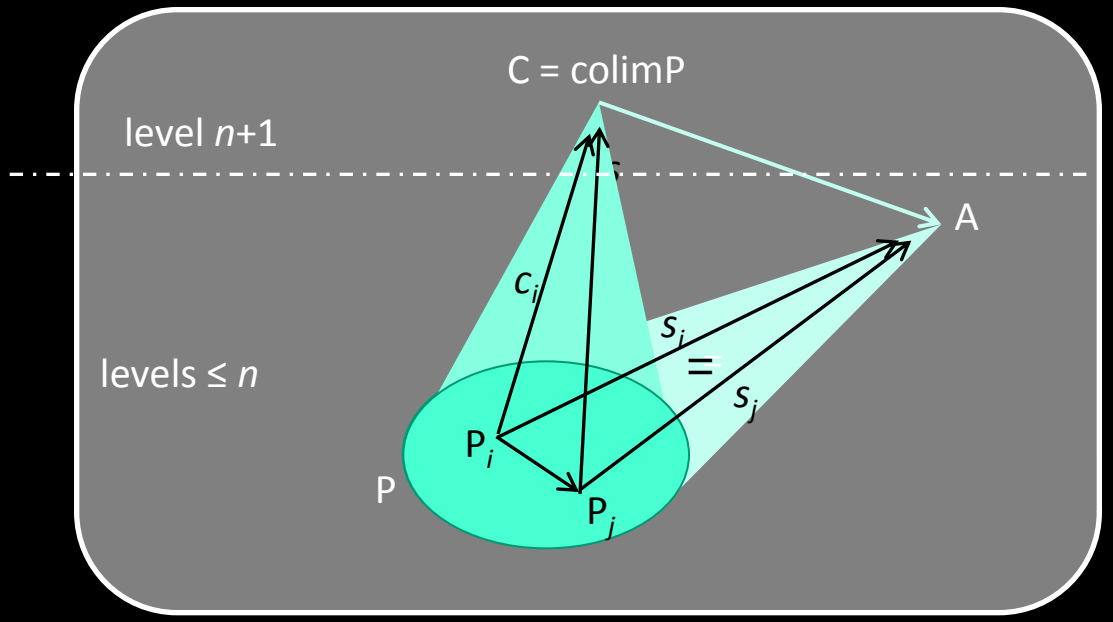

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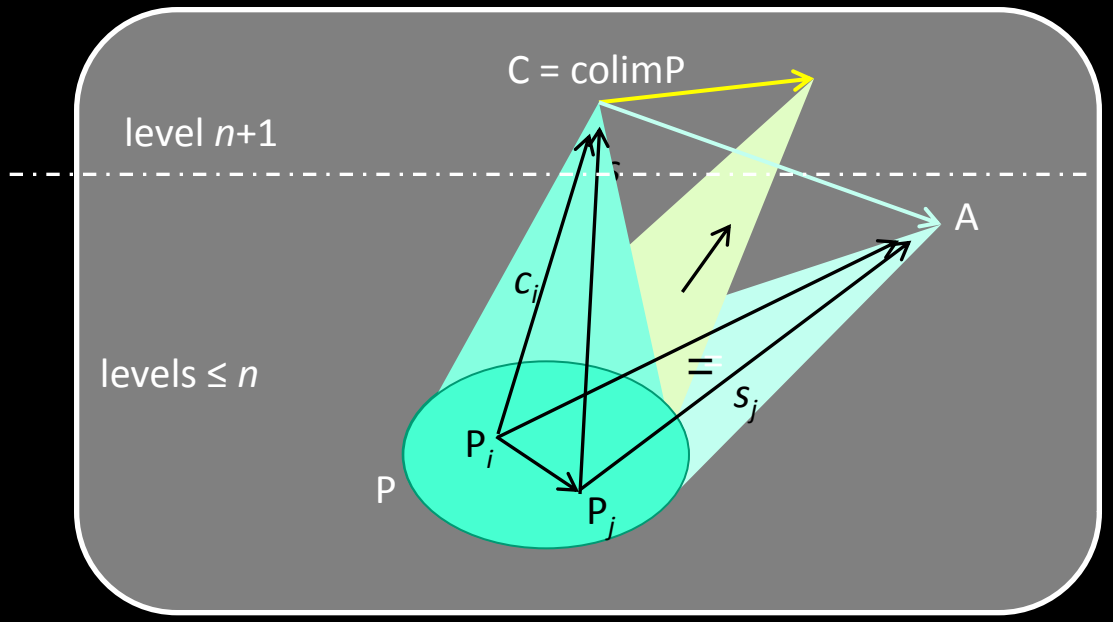

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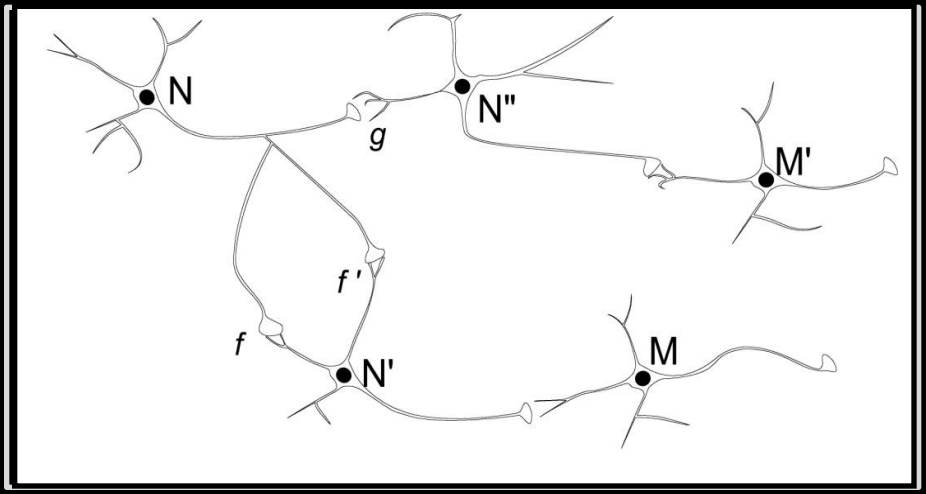

Graph of neurons at *t*:
Objects = neurons N, with their activity around *t*. Link *f* = synapse weighted by its *propagation delay d(f)* and its *strength.* A link can be active or passive at *t.*

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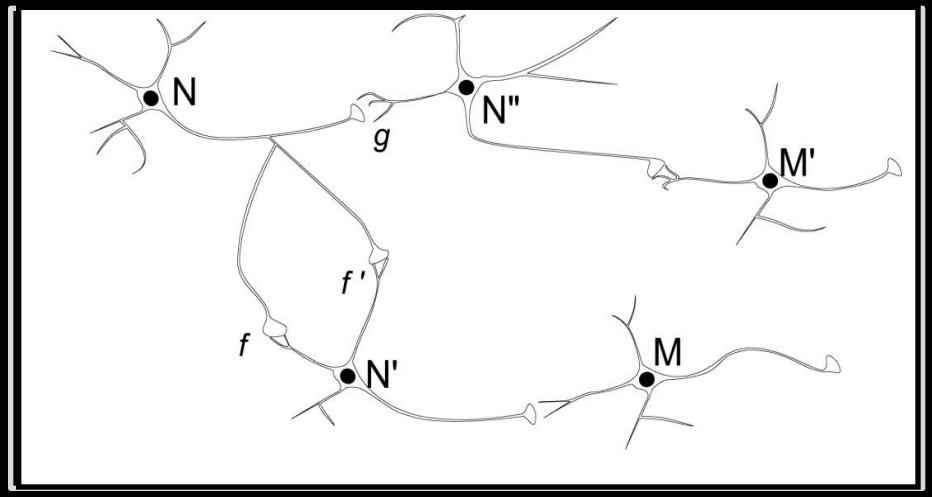

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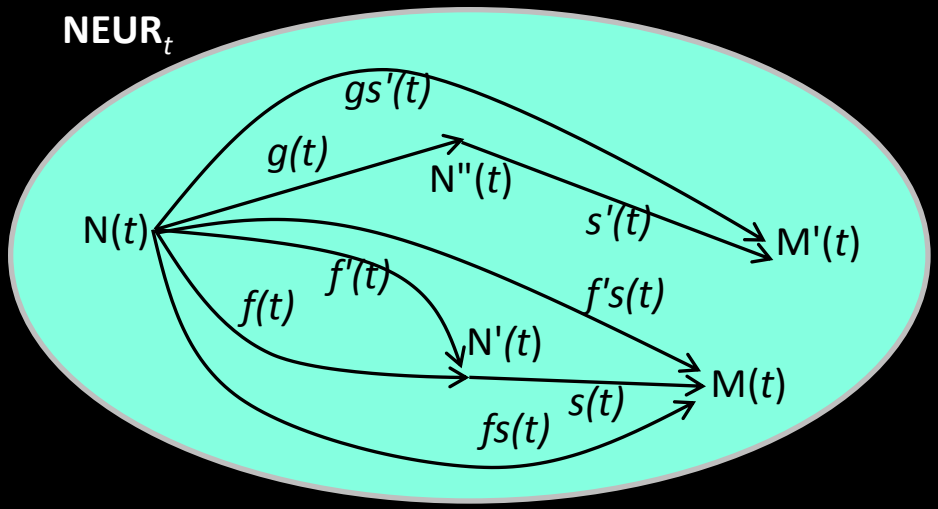
The *category of neurons at t*:
NEUR$_t$ = category of paths of this graph.
It is labelled by the propagation delays .



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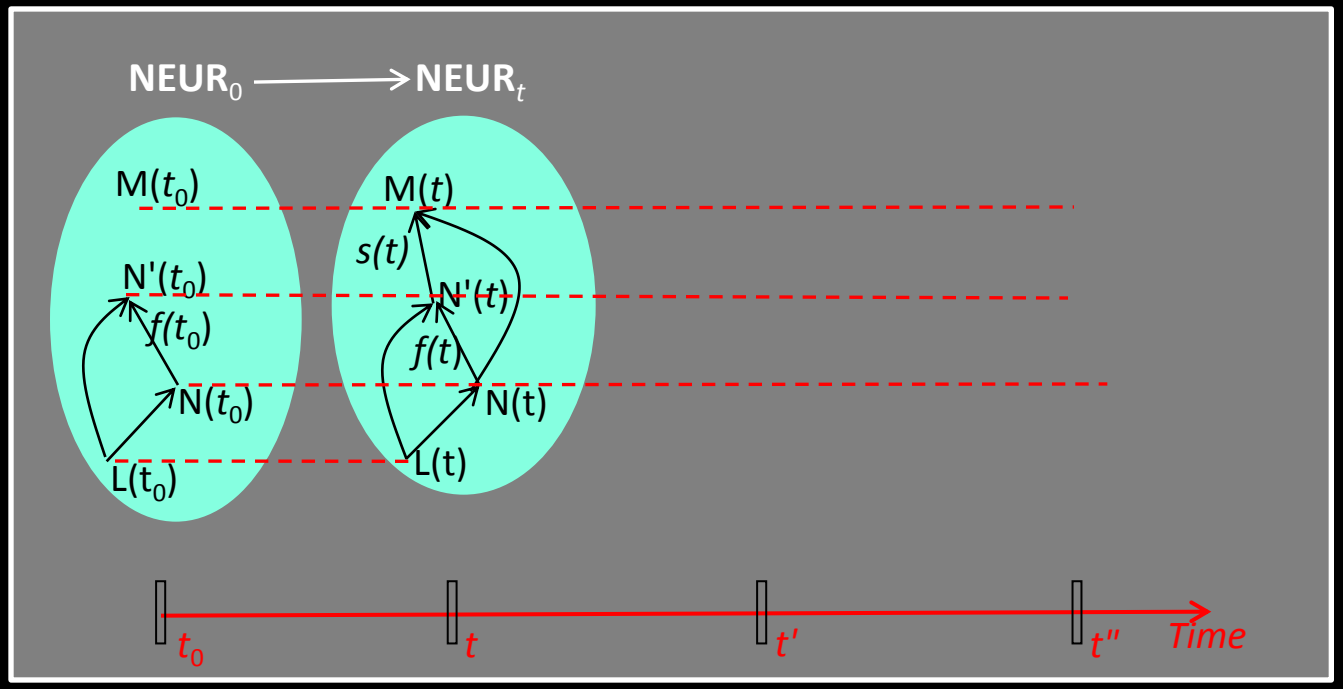

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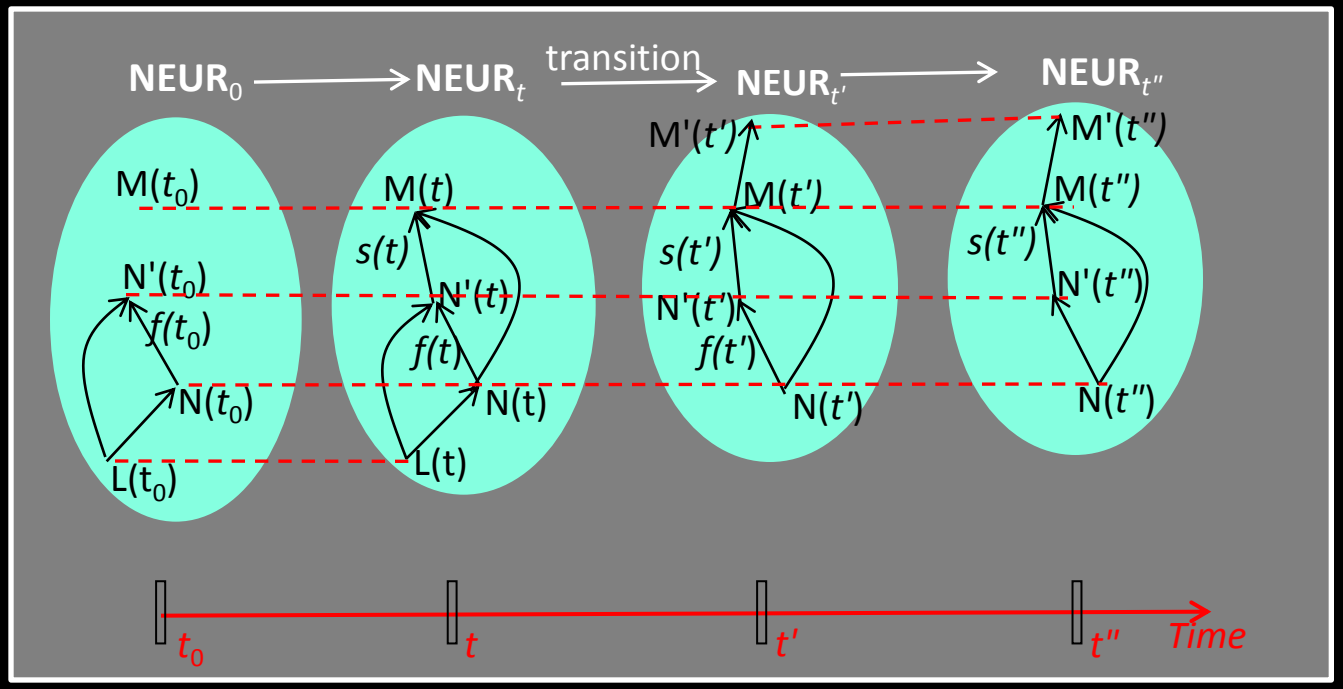

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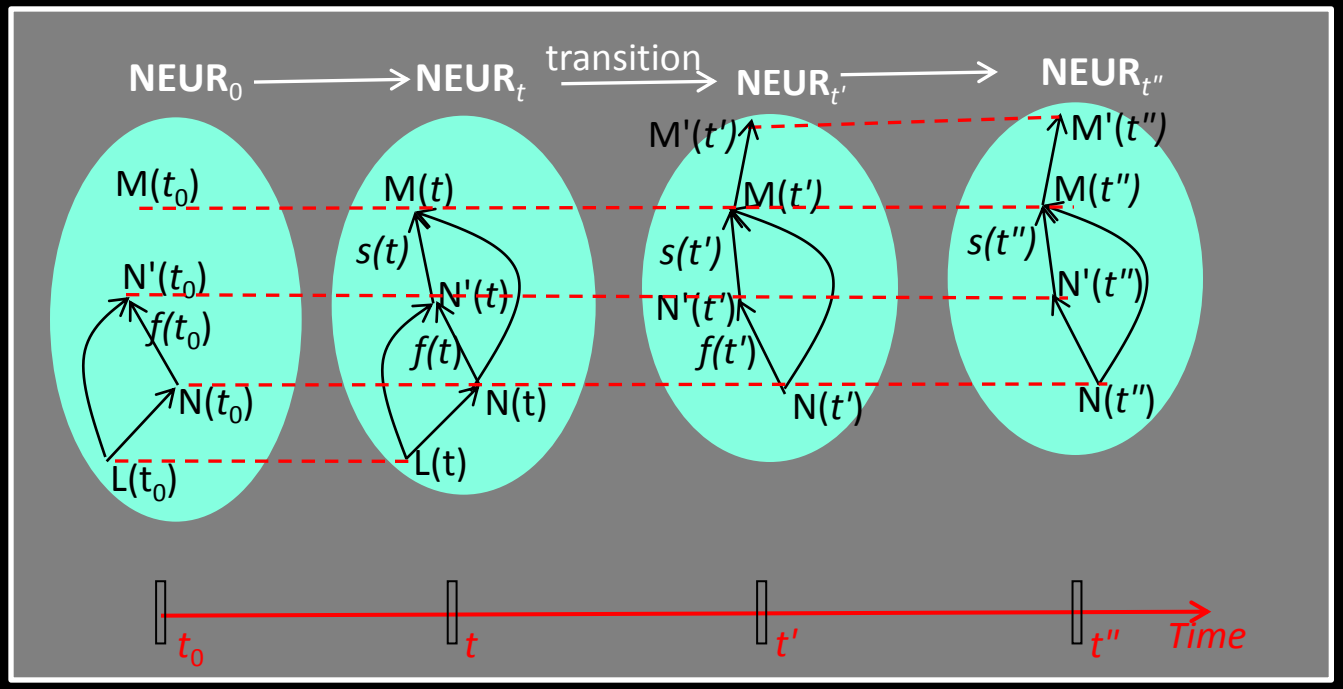

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NEUR has a modular organization, with modules of different sizes.

NEURONAL ASSEMBLIEES. DEGENERACY

In 1949, Hebb (1904-1985) defines a *synchronous assembly of neurons*:

"*Any frequently repeated, particular stimulation will lead to the slow development of a "cell-assembly" […] capable of acting briefly as a close system*"

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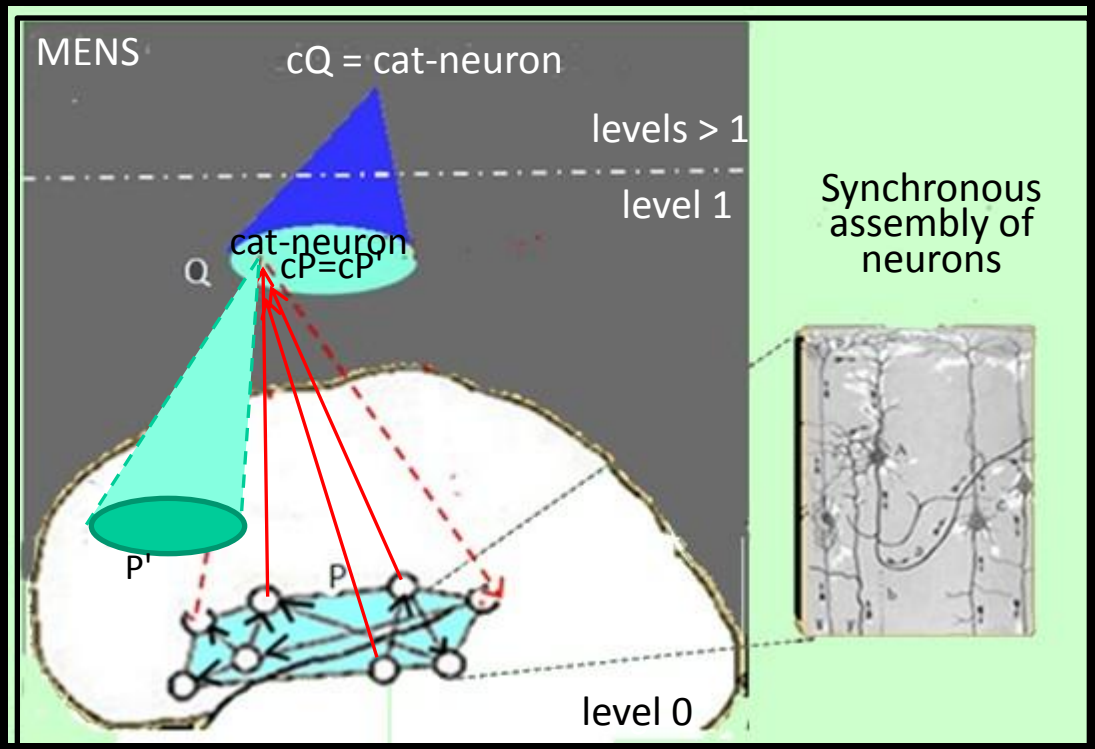
Edelman introduces the *degeneracy of the neural cod**e***:

"*More than one combination of neuronal groups can yield a particular output, and a given single group can participate in more than one kind of signaling function. "*

(The remembered present, 1989, p. 50)

GENERAL STRUCTURE OF MENS



Taken from : "The Brain from top to bottom", McGill

The 'hybrid' model **MENS** is a MES:
Level 0 represents the 'physical' neuronal system (neurons and synapses)

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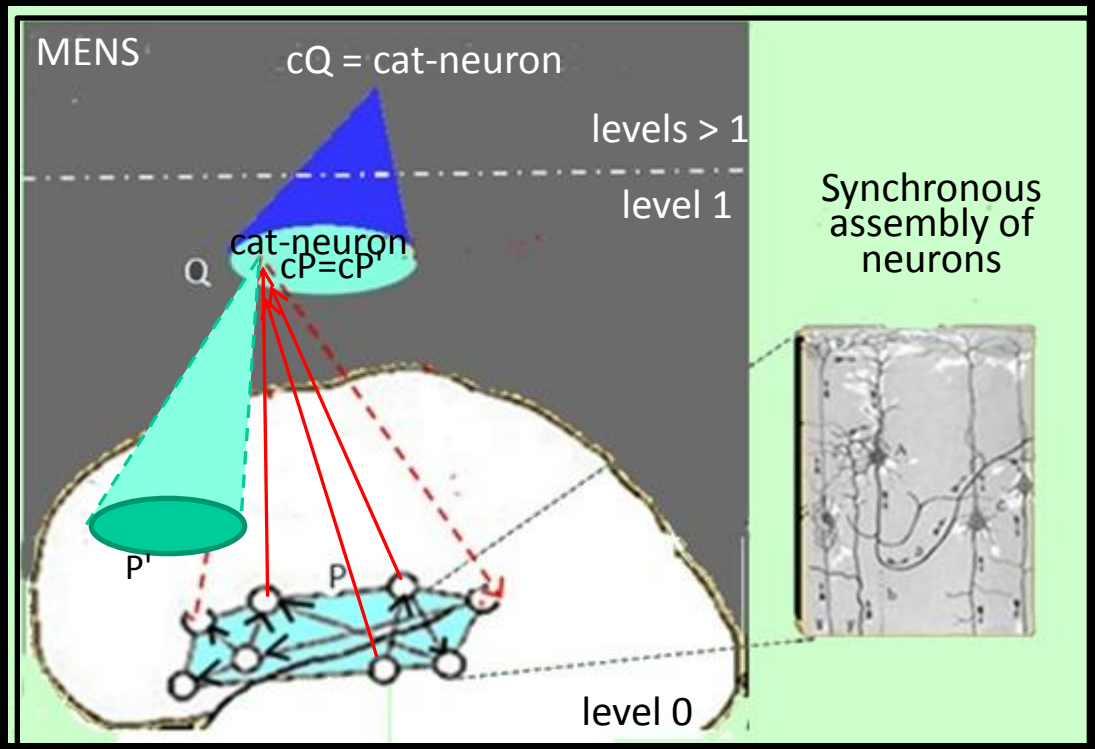

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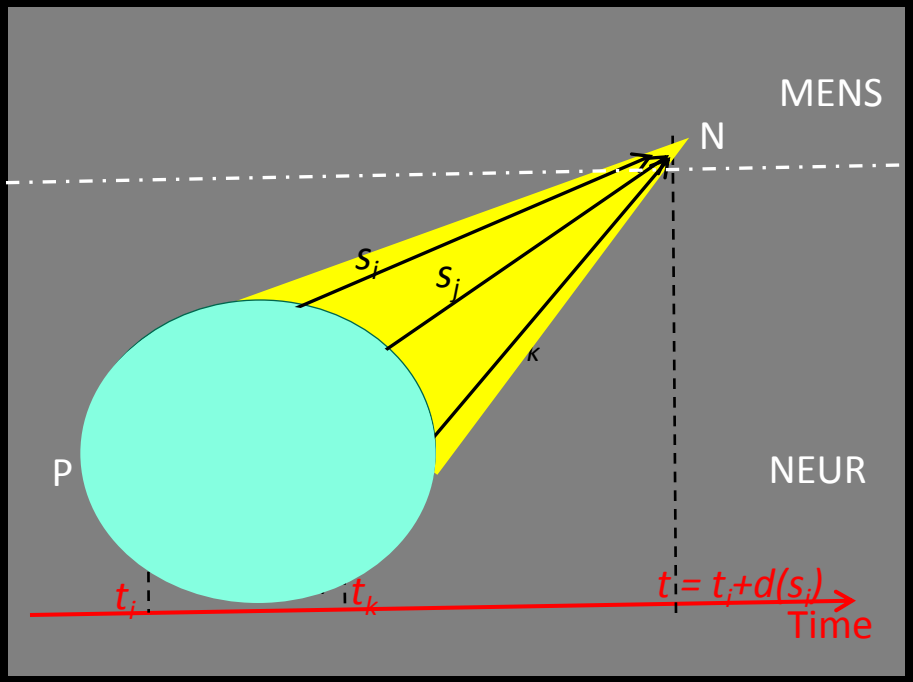
The 'hybrid' model **MENS** is a MES:

Level 0 represents the 'physical' neuronal system (neurons and synapses)

At higher levels: 'conceptual' objects, called *cat(egory)-neurons*, modeling a mental object as the colimit cP = cP' of the synchronous assemblies of (cat-)neurons P , P' which activate them.

FORMATION OF A CAT(EGORY)-NEURON



An assembly of (cat-)neurons is modeled by a *pattern* P in **NEUR** (and **MENS**). P "synchronously" activates a (cat-)neuron N if there is a c*ollective link* (s_i) from P to N ===> 2 zig-zags with the same extremities have the same delays.

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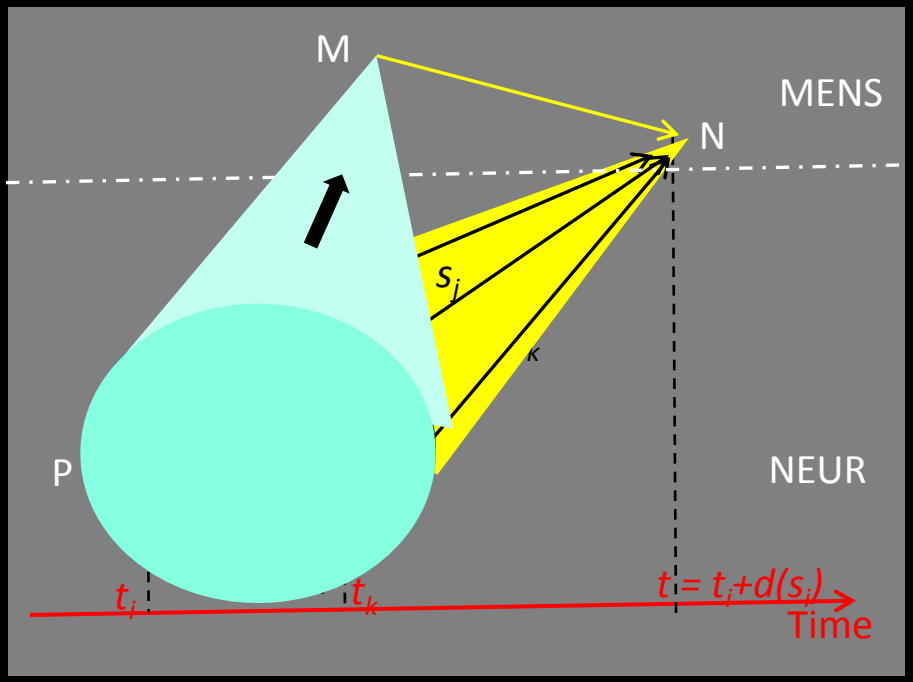

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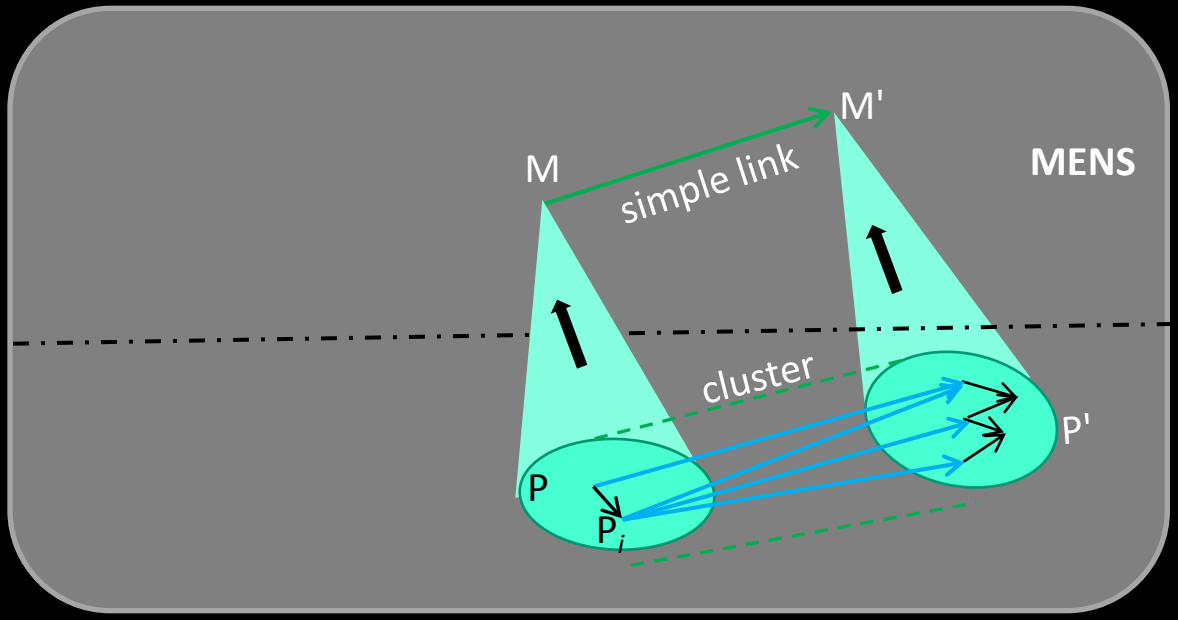
If P is repeatedly activated, its links strengthen (Hebb rule) ===> Formation of a mental object modeled by a cat-neuron M which becomes the *colimit* of P in **MENS***;* it is activated later than P.

MULTIPLICITY PRINCIPLE. COMPLEX LINKS



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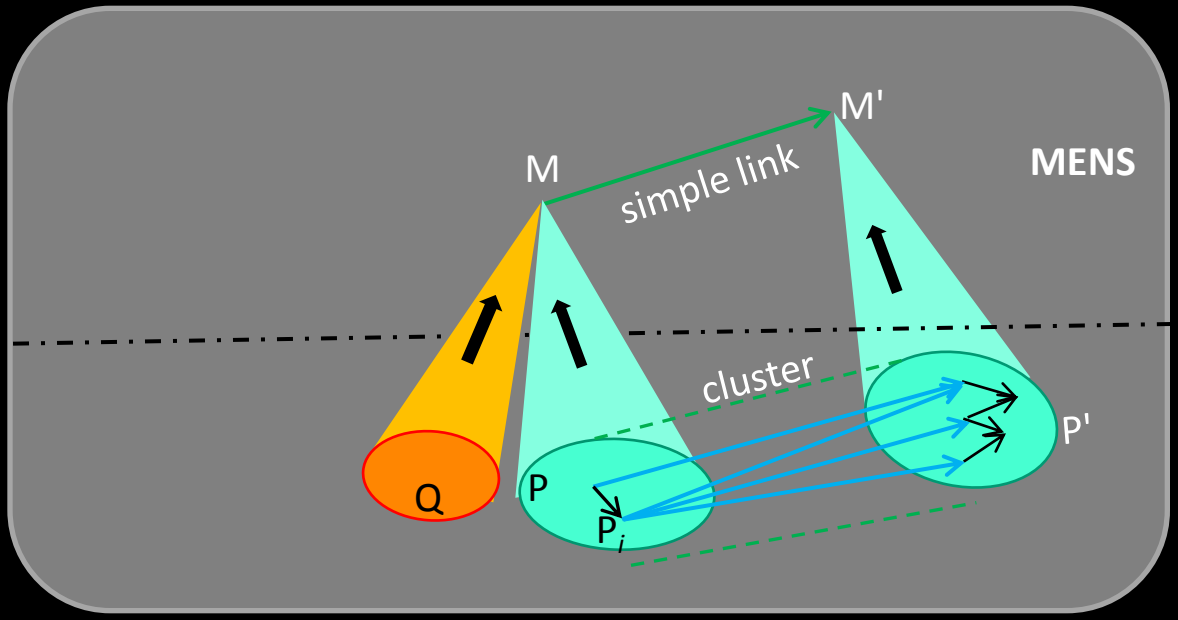

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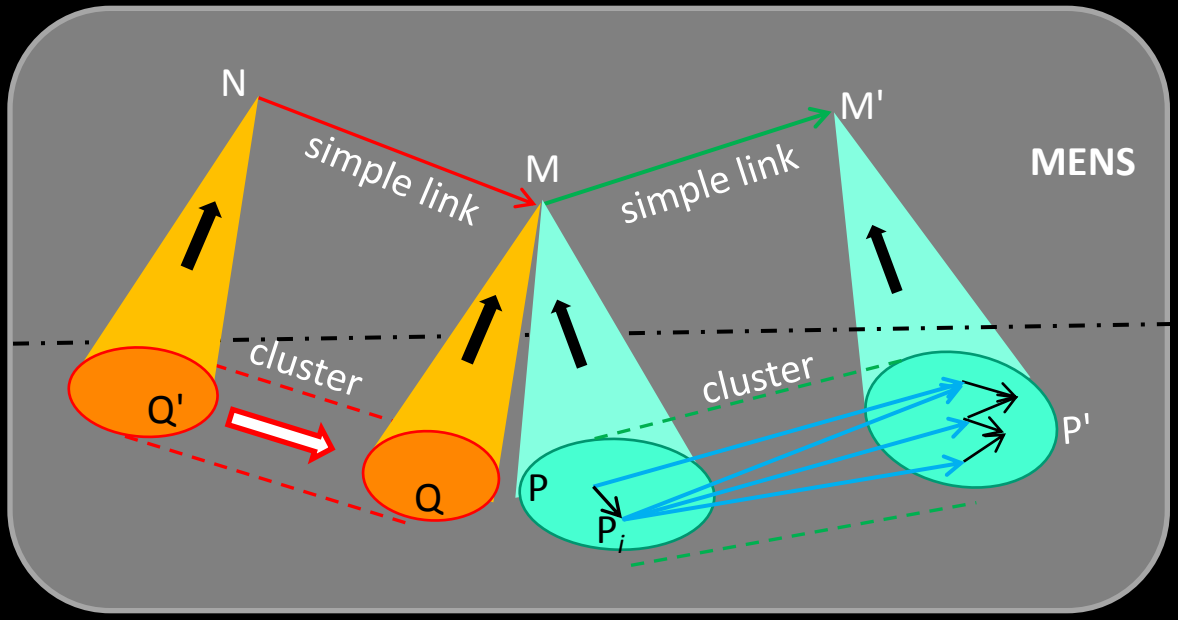

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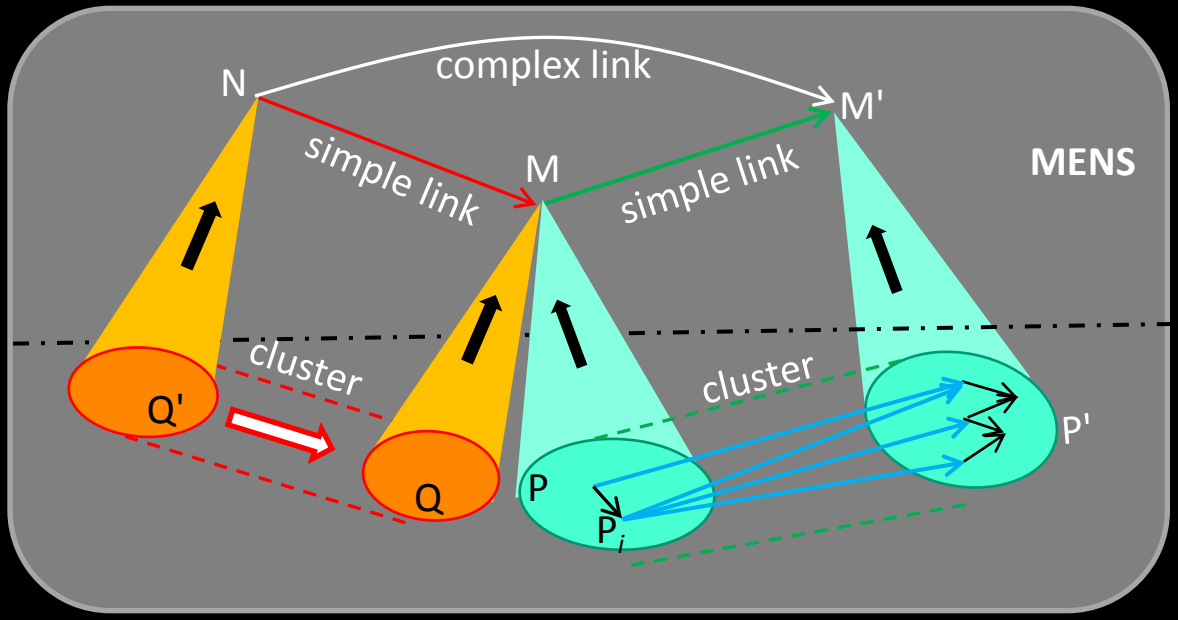

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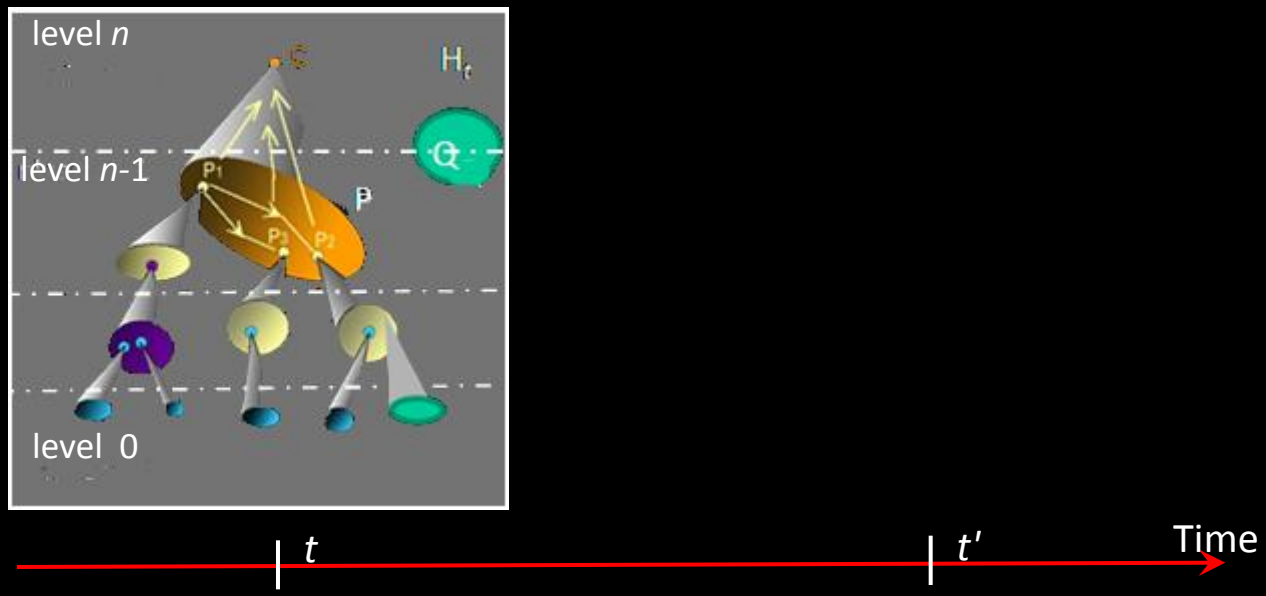

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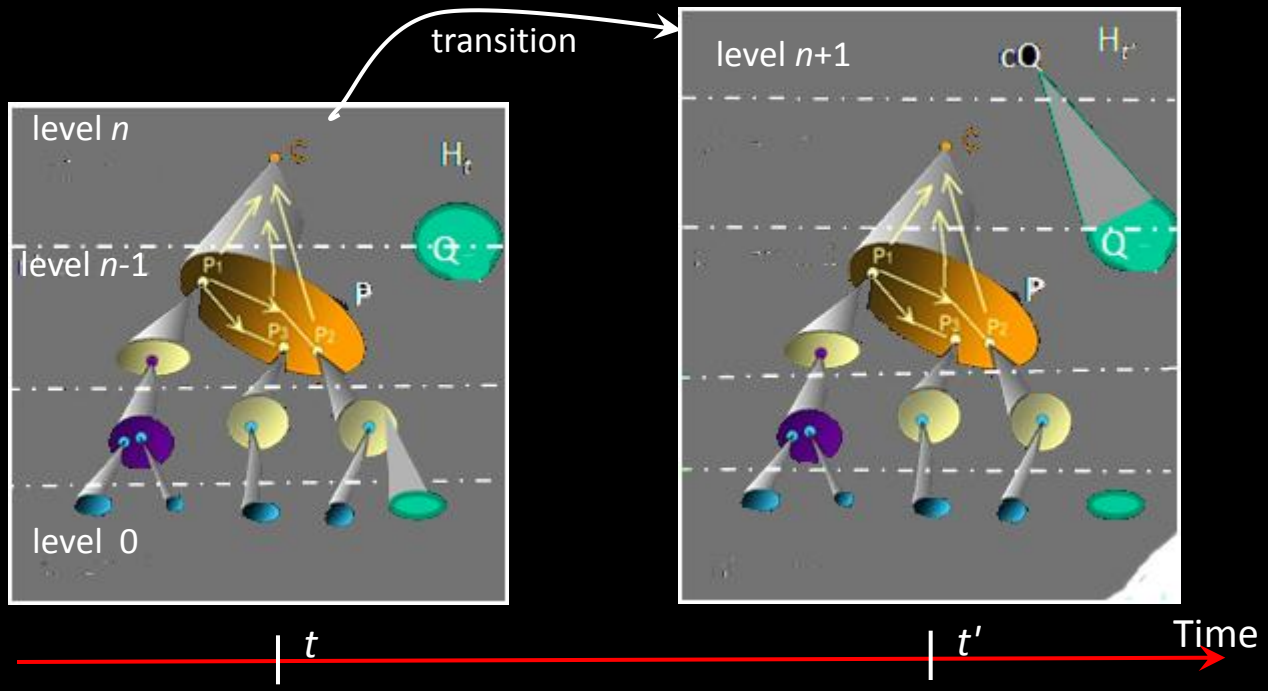

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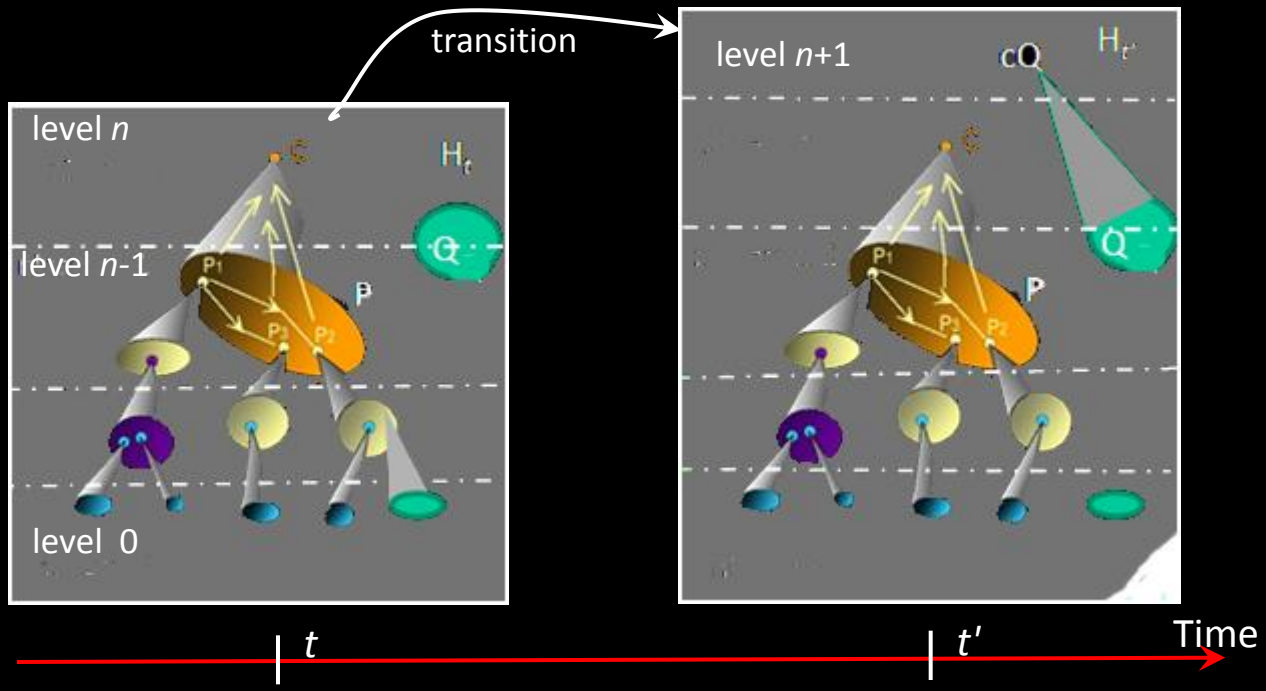

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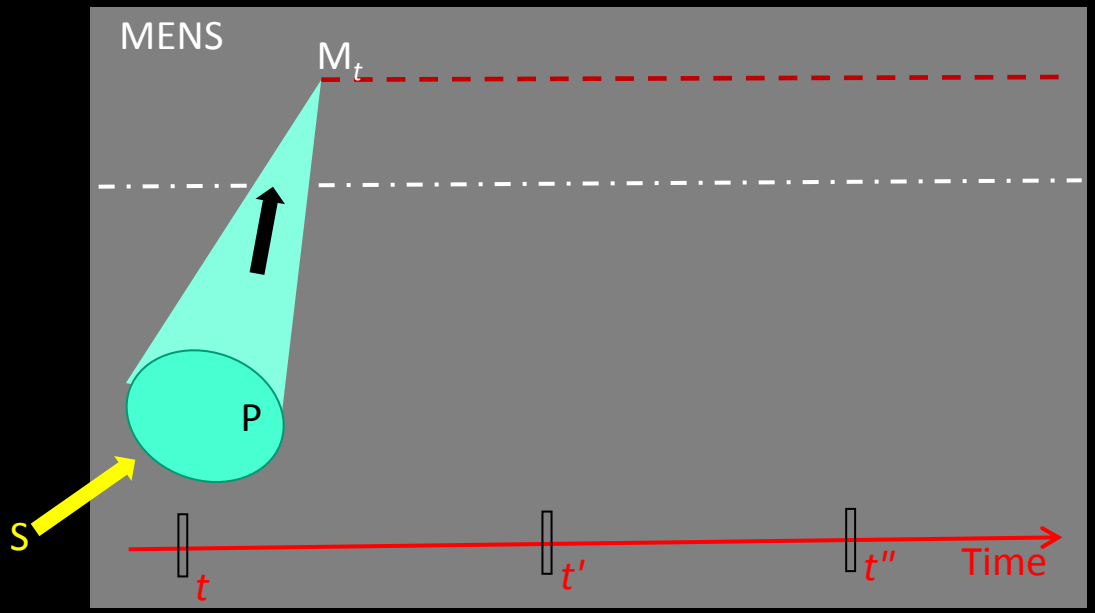
THEOREM. ***The complexification process preserves MP and extends the propagation delays and weights of the links.***

FORMATION OF A FLEXIBLE MEMORY



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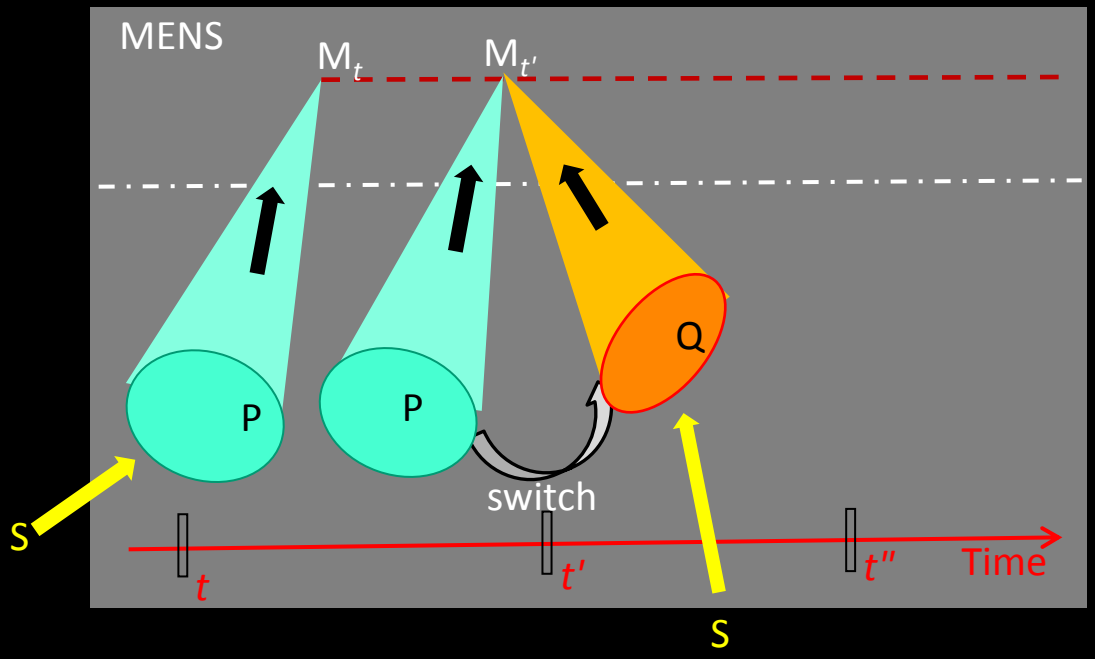

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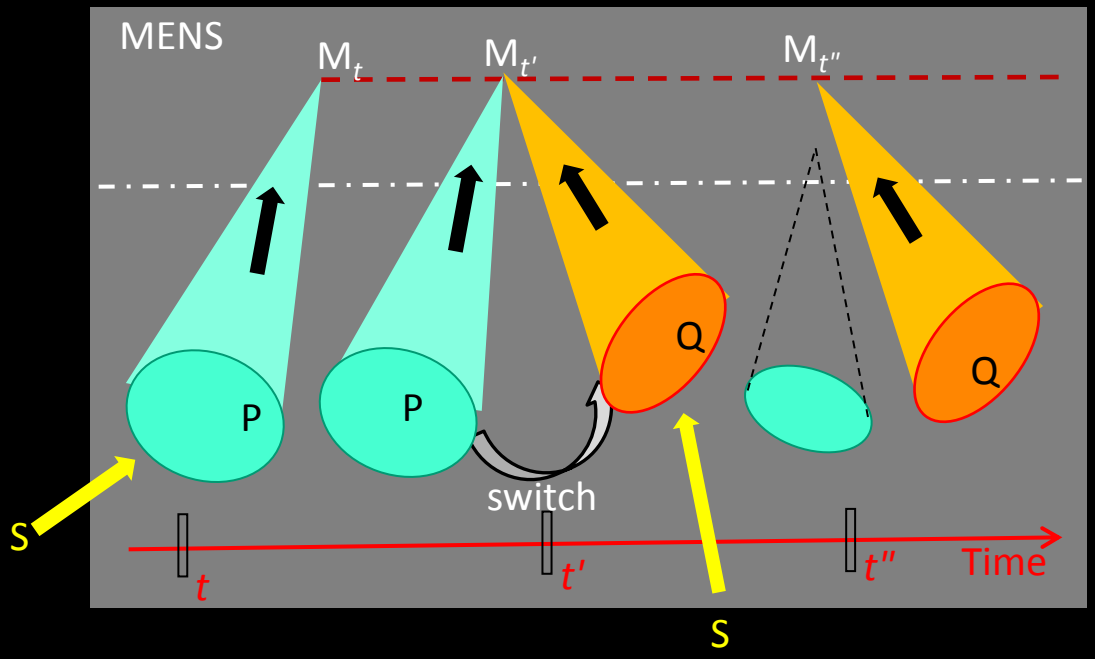

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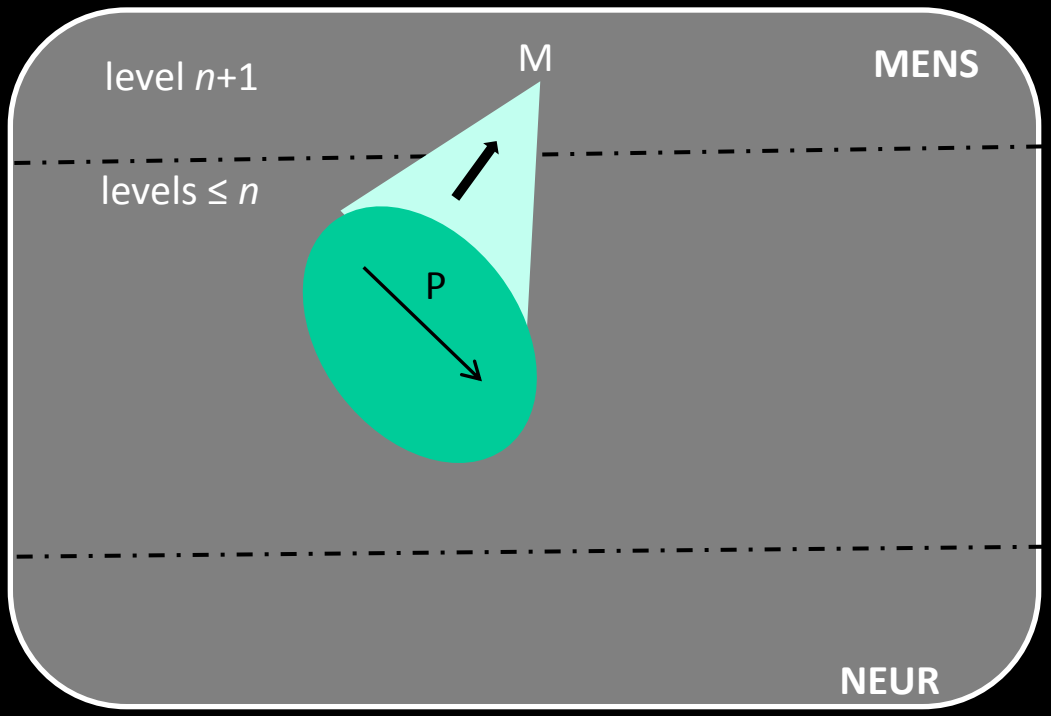
===> M takes its own identity as a *multiform cat-neuron*, and can later dissociate from P to adapt to changes in the environment.

===> *Memory is robust, flexible and plastic.*

BRAIN-MIND CORRELATION. EMERGENCE



Activation of M = unfolding of a ramification down to **NEUR**: by successive. activation of lower level decompositions, down to the *activation* of synchronous assemblies of neurons; it takes some delay.

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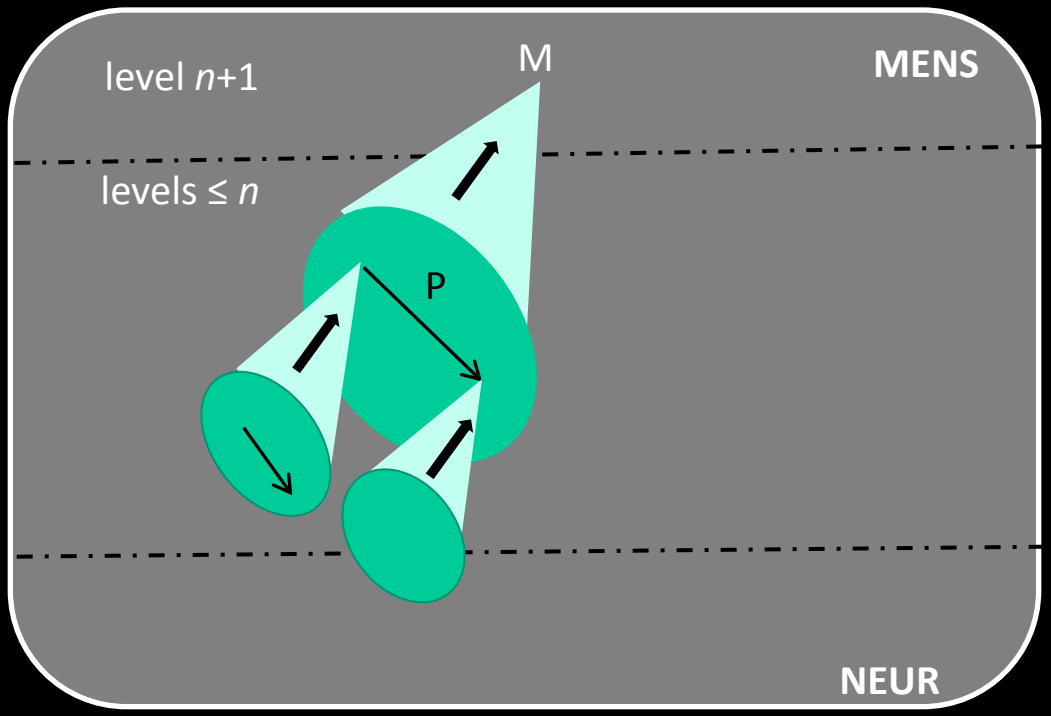

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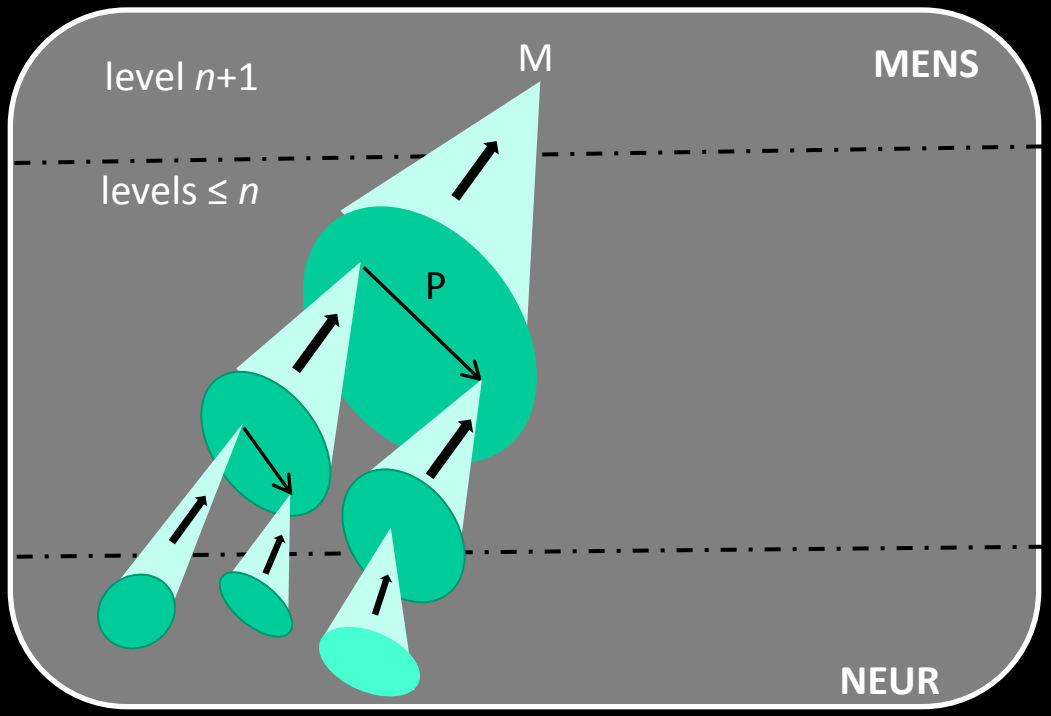

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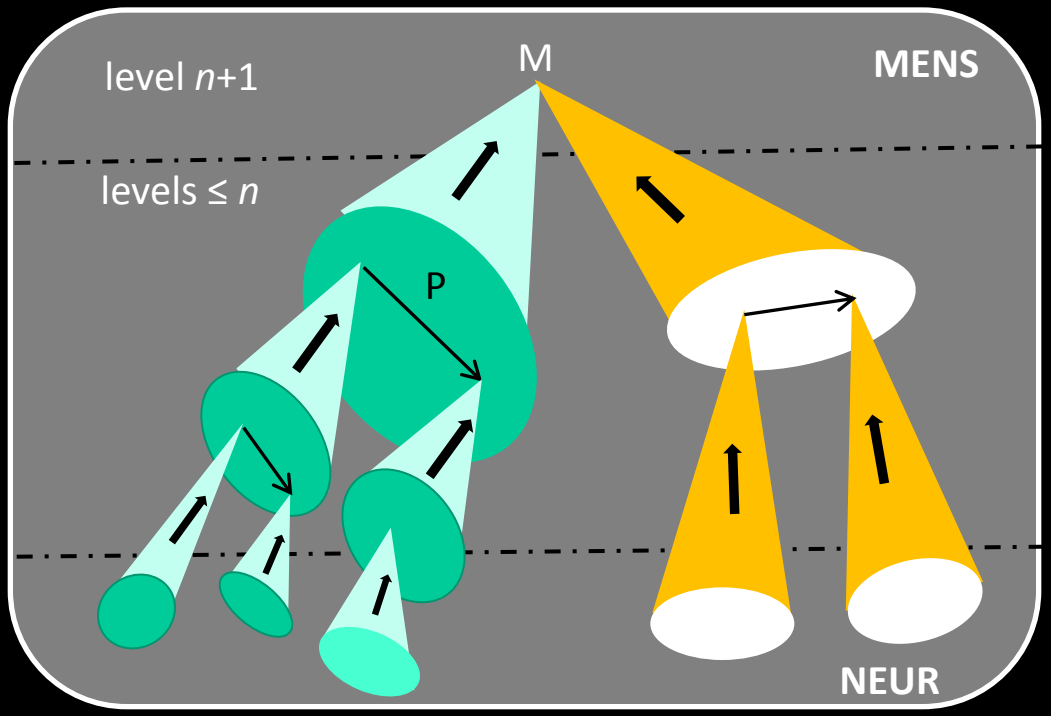

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At each step, several choices **===>** M has *multiple physical realizabilities*. *Complexity order* of M = least length of a ramification.

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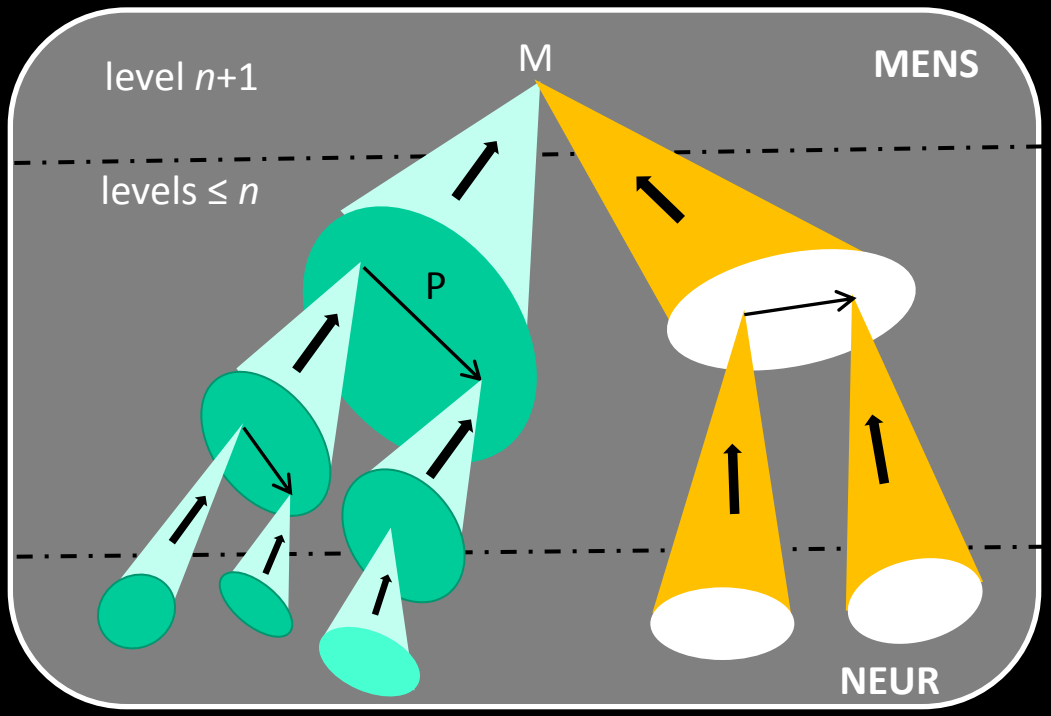

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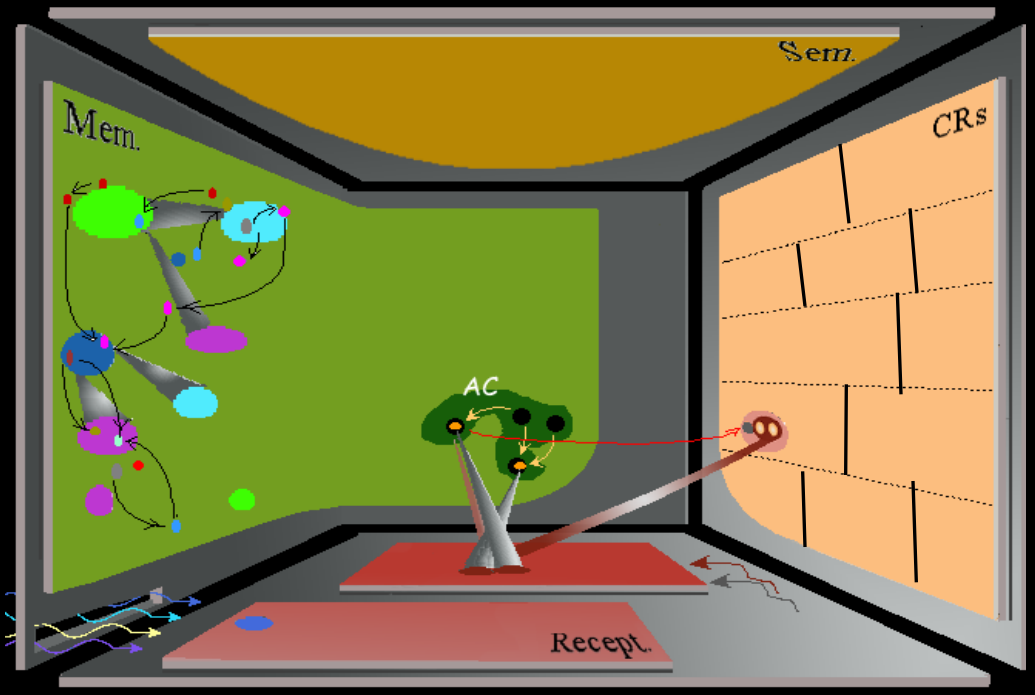
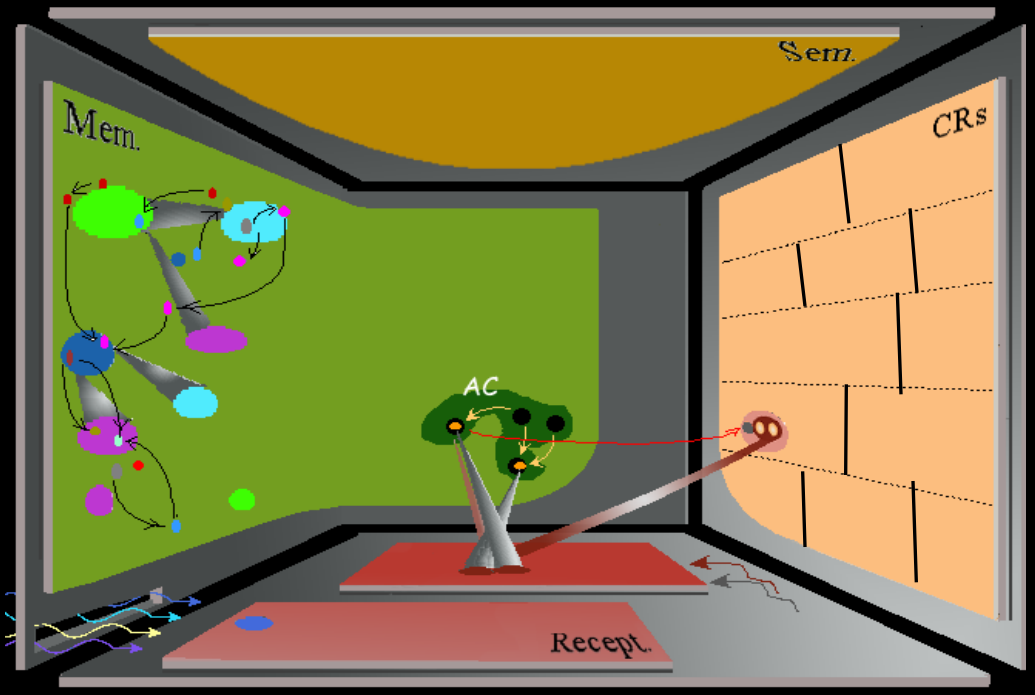
EMERGENCE THEOREM. ***MP is necessary for the existence of cat-neurons of complexity order > 1 and it allows the emergence of cat-neurons of increasing complexity orders through iterated complexifications*.**

MENS AS A MES. THE CO-REGULATORS



MENS is self-organized by a net of ***co-regulators***, based on specialized brain modules. They modulate the dynamics through their competitive interactions, and help developing the flexible central **Mem(ory)** .

MENS AS A MES. THE CO-REGULATORS



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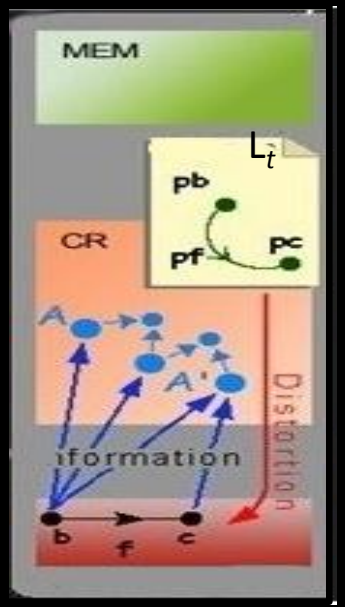
Hybrid dynamic: (i) Each co-regulator acts stepwise, at its own rhythm and with a differential access to **Mem**, e.g. to recall the *admissible procedures* corresponding to its function. (ii) Their local procedures must be harmonized.

LOCAL LOGIC OF A CO-REGULATOR CR



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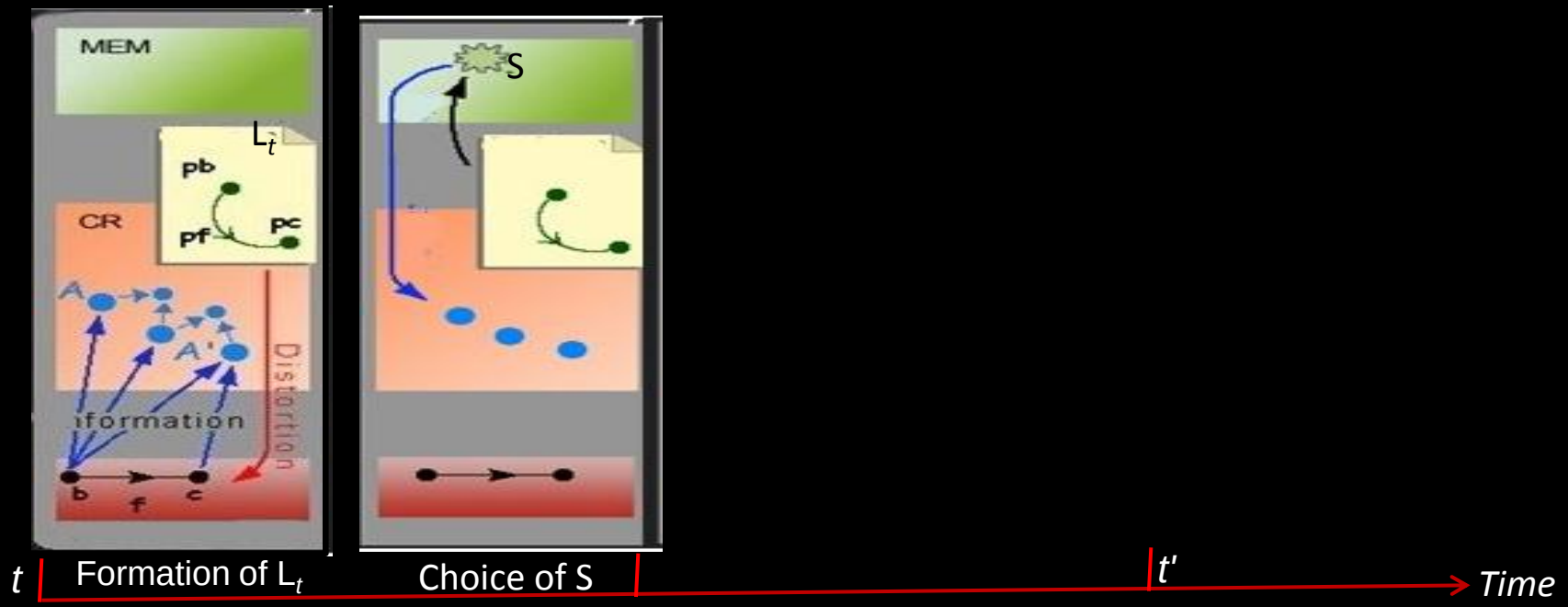

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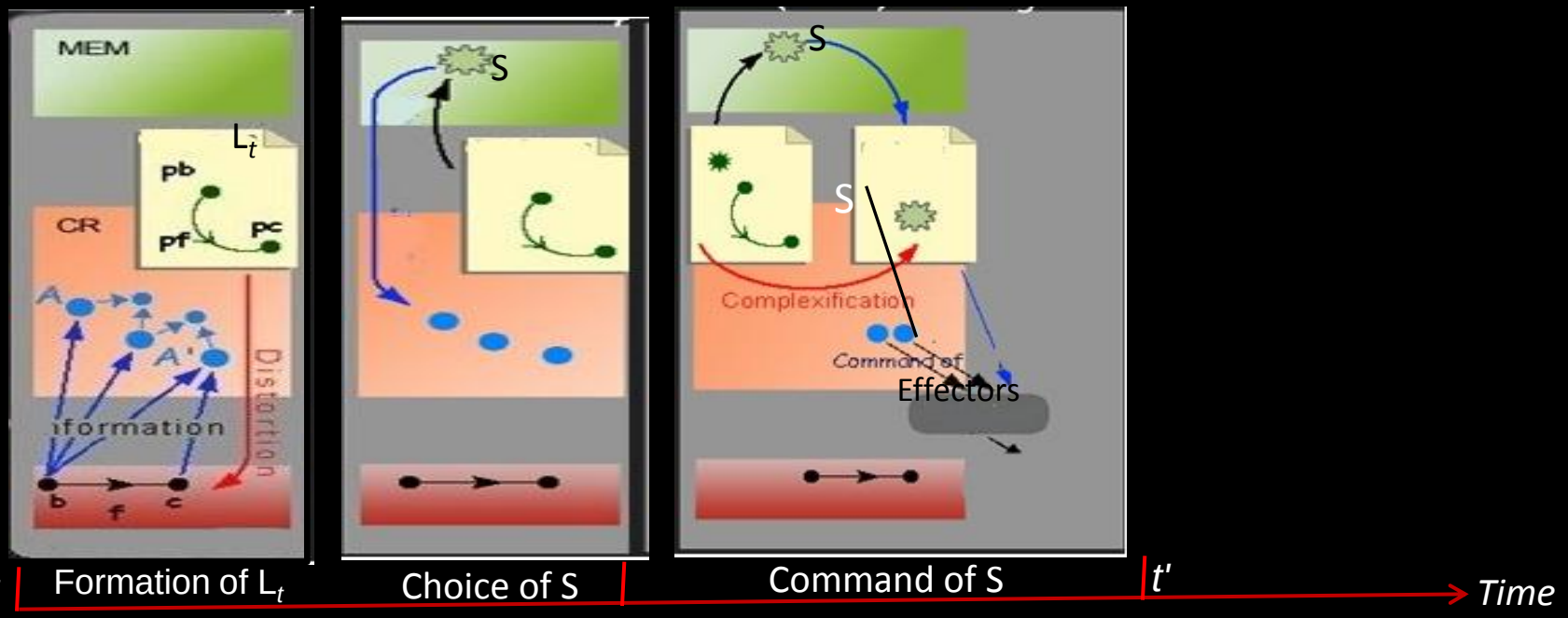

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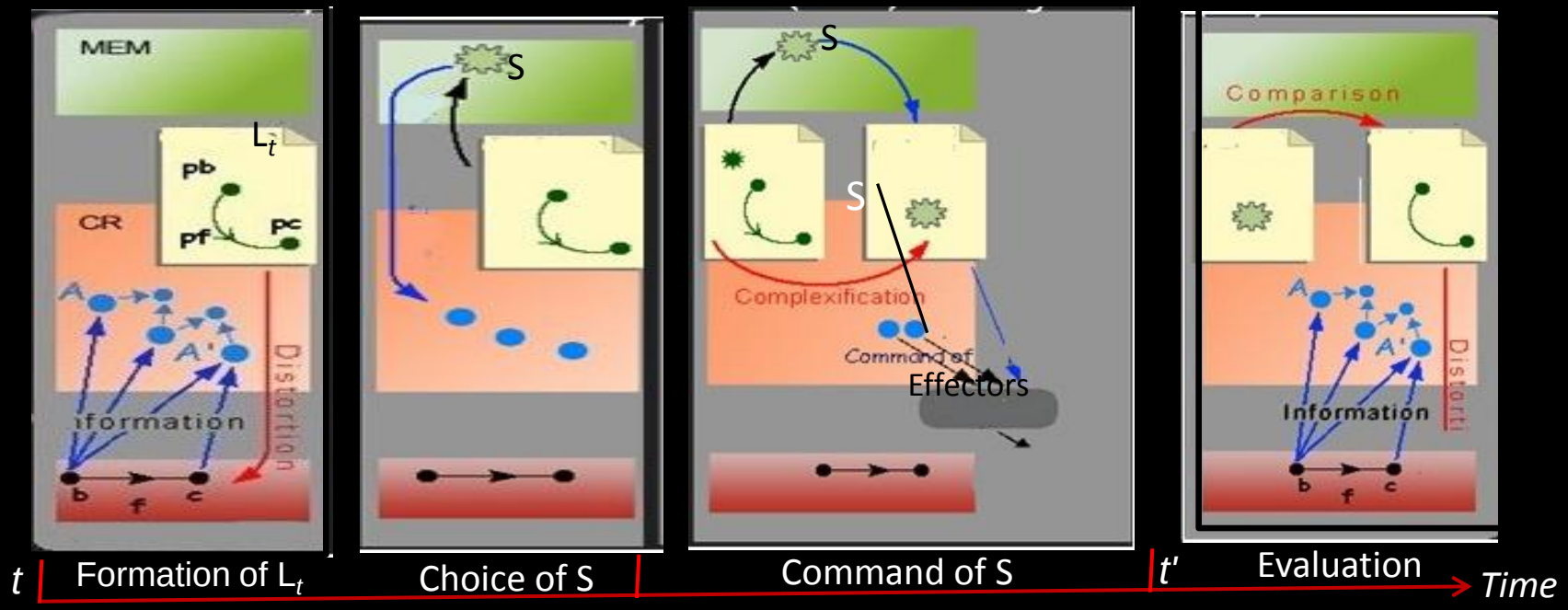

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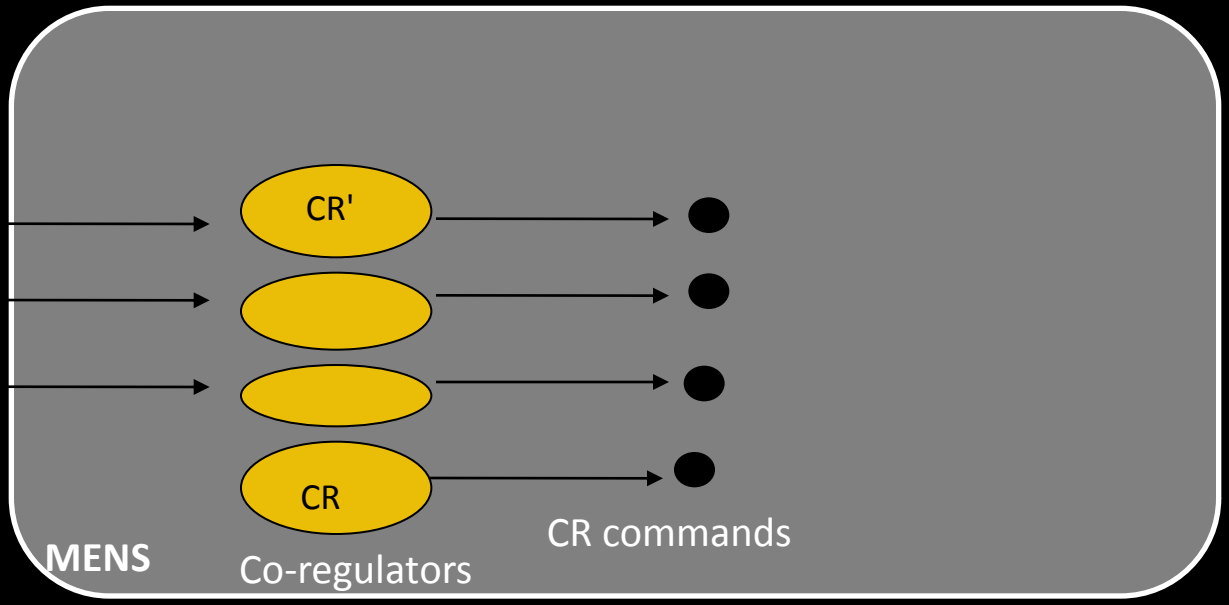
(iv) Evaluation by comparing AL and $L_{t'}$ at t'. *S*torage of the result.

THE GLOBAL DYNAMIC OF MENS



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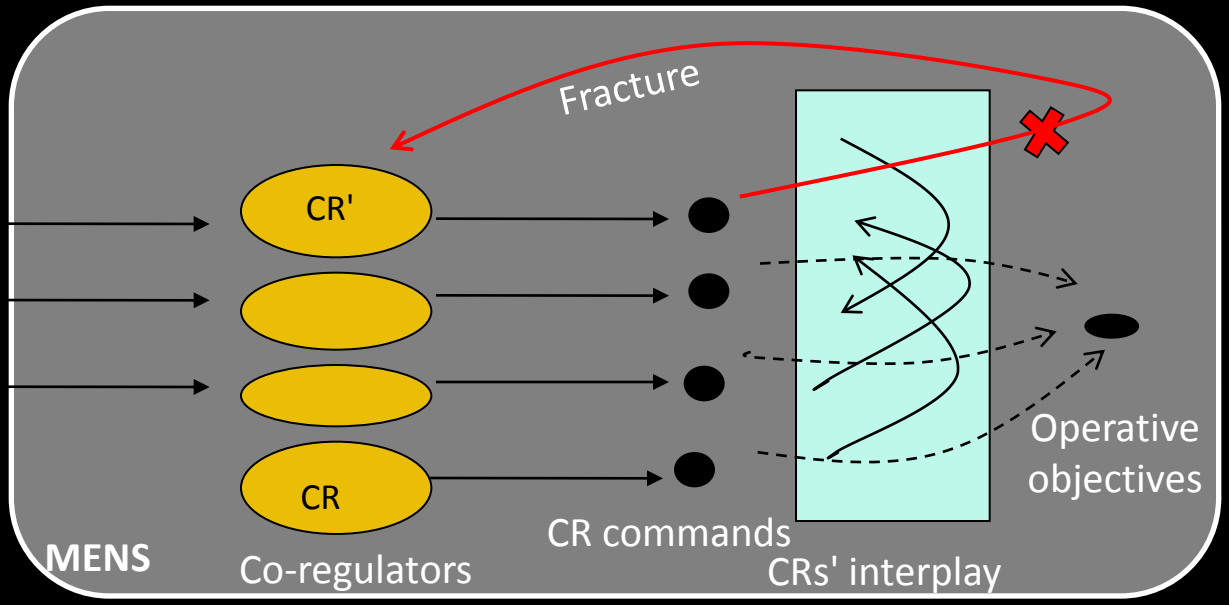


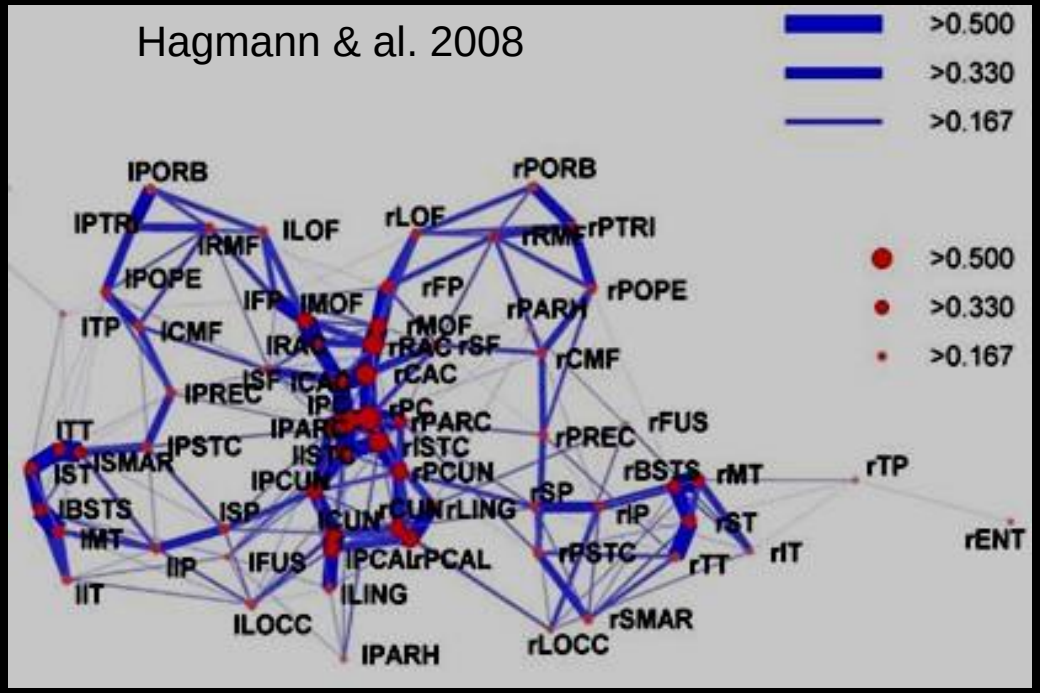
Commands sent by all the co-regulators at *t* may not fit together

===> Equilibration process to coordinate them, the *interplay among the Co-regulators*, made flexible by the possibility of switches (MP), and constrained by the temporal constraints (synchronicity laws).

It may by-pass some of them, thus causing a *fracture*.

Problem: Can this interplay be 'computed' (e.g. by unconventional computation)?

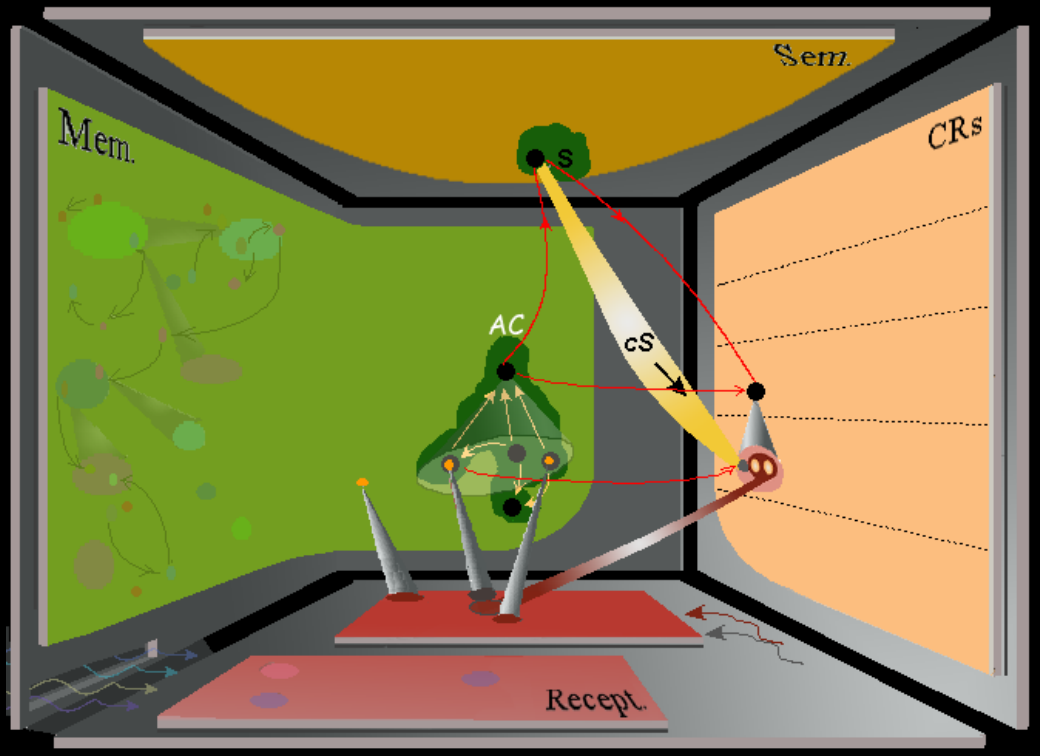
STUCTURAL CORE OF THE BRAIN



" existence of a structural core in human cerebral cortex [...] both spatially and topologically central. [...] an important structural basis for shaping large-scale brain dynamics " " linked to self-referential processing and consciousness."

This core is a central sub-graph of the graph of neurons which forms a "rich club", with many strongly connected hubs.

THE ARCHETYPAL CORE



AC = subsystem of **Mem,** based on the structural core, formed by higher order cat-neurons integrating significant memories, with many ramifications and possibility of switches. Their strong and fast links form *archetypal loops* self-maintaining their activation.

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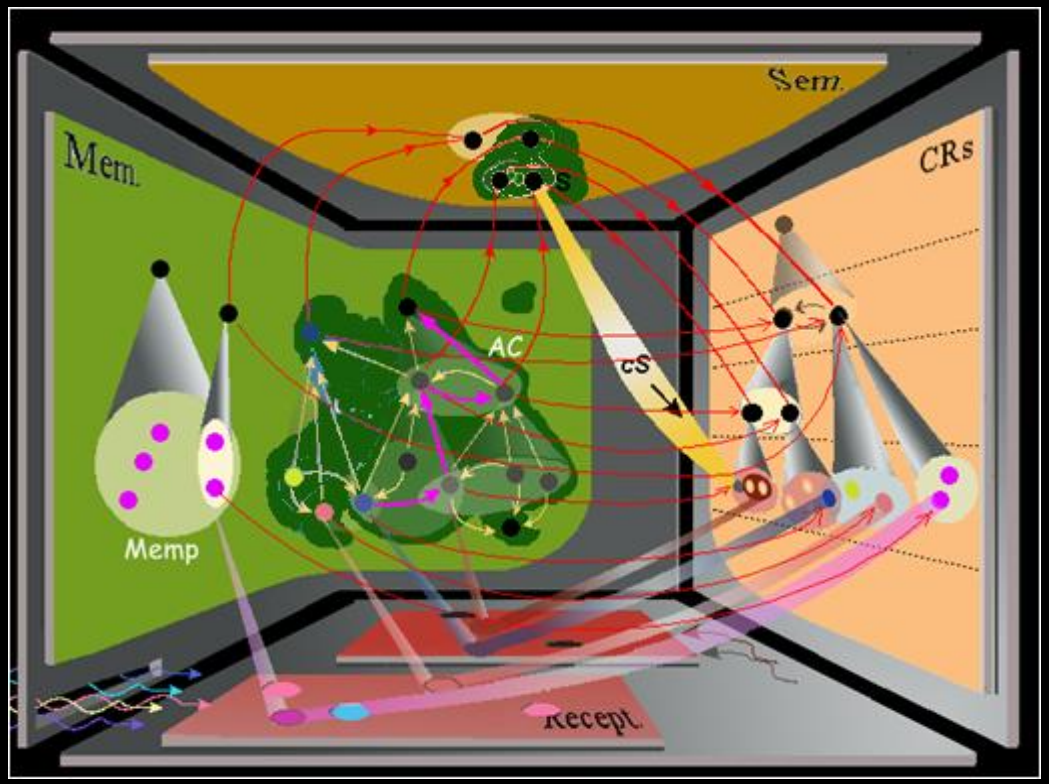
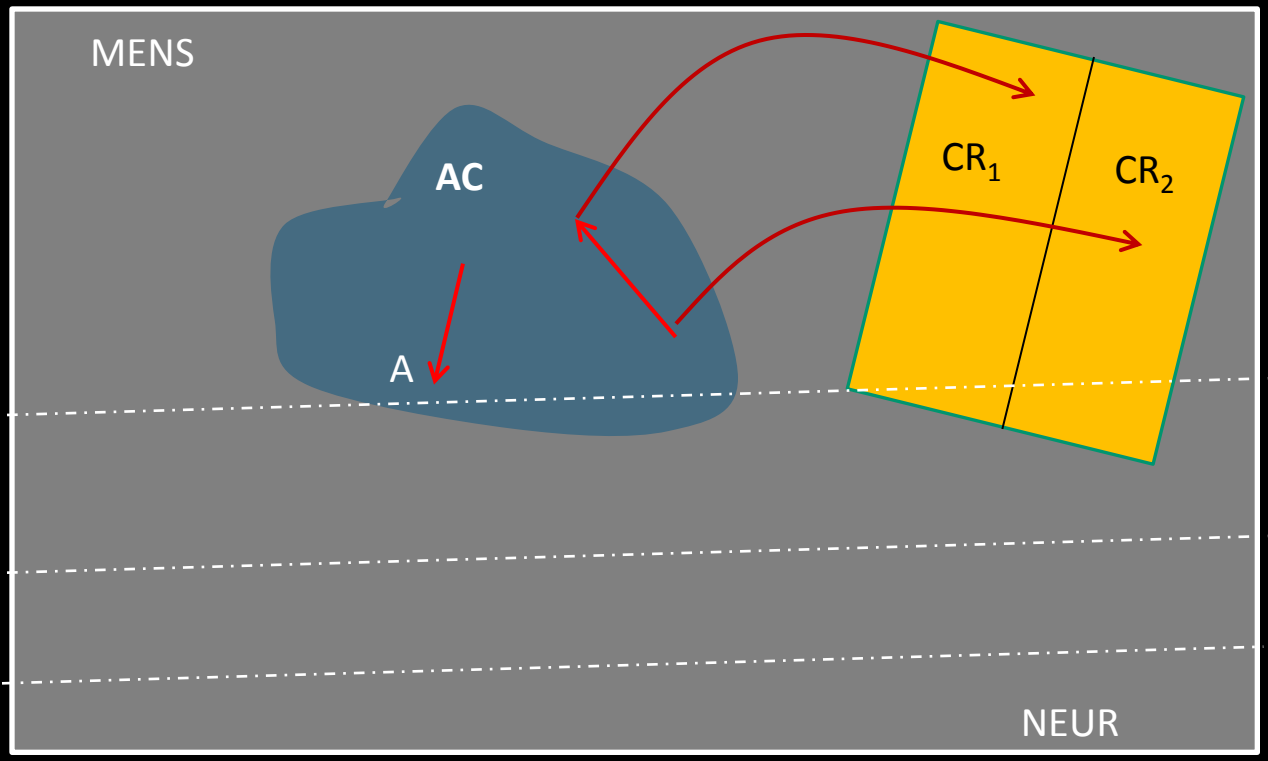


AC = subsystem of **Mem,** based on the structural core, formed by higher order cat-neurons integrating significant memories, with many ramifications and possibility of switches. Their strong and fast links form *archetypal loops* self-maintaining their activation.

AC embodies the complex identity of the system ('Self'), and acts as a *flexible internal model.*

GLOBAL LANDSCAPE



Intentional co-regulator = CR_i based on associative brain areas, linked to **AC**. Activation of part of **AC** diffuses through self-maintained archetypal loops.

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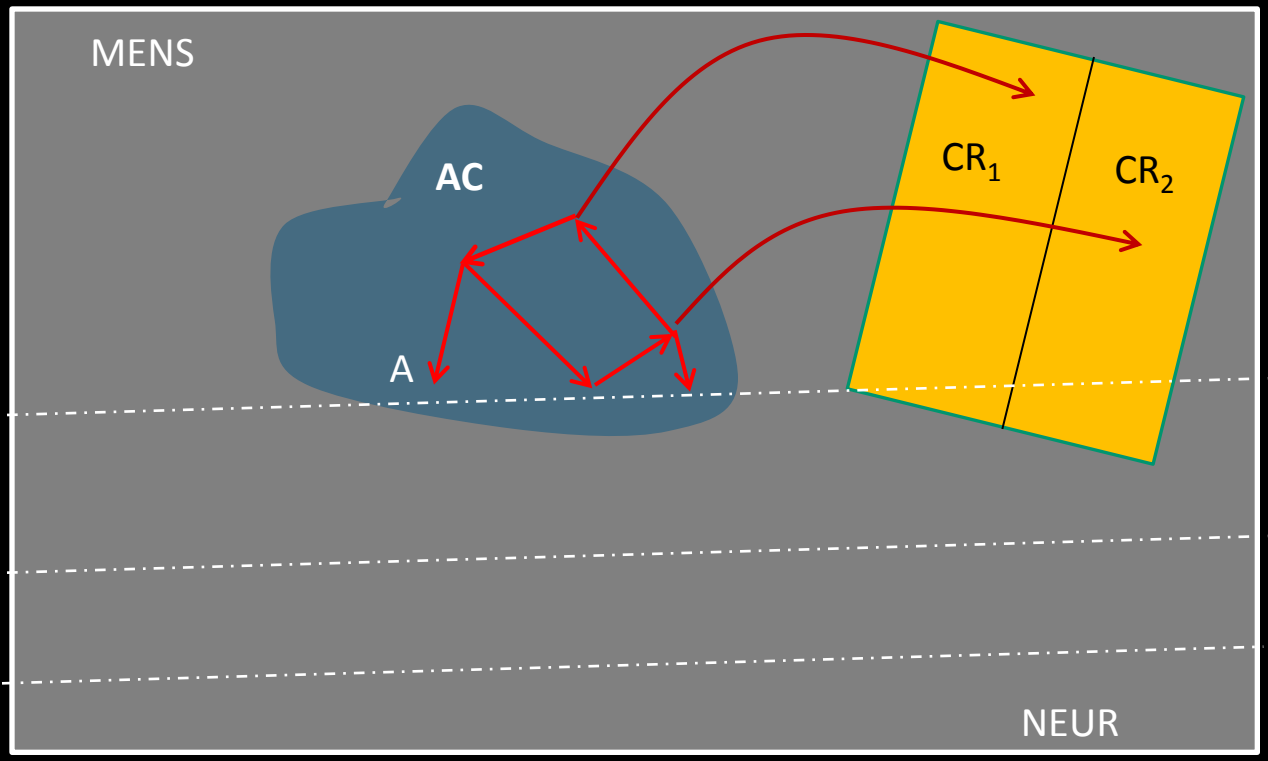

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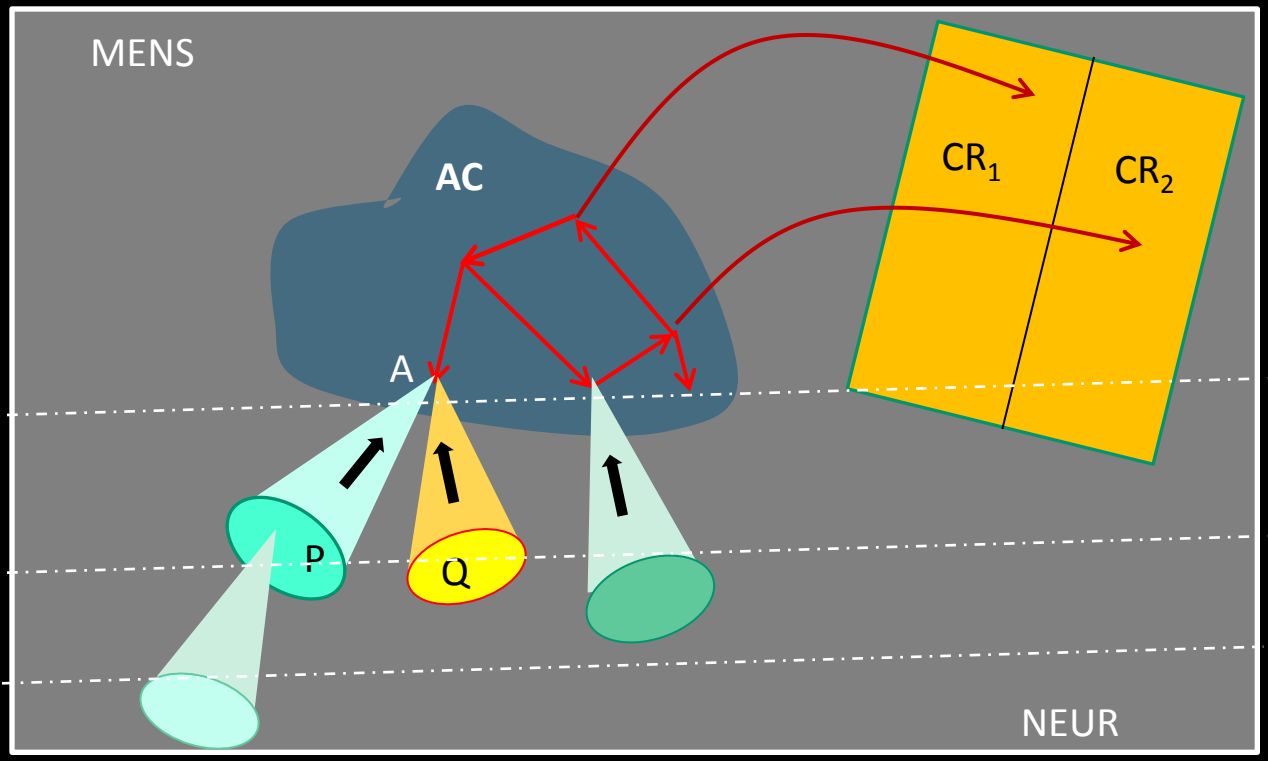

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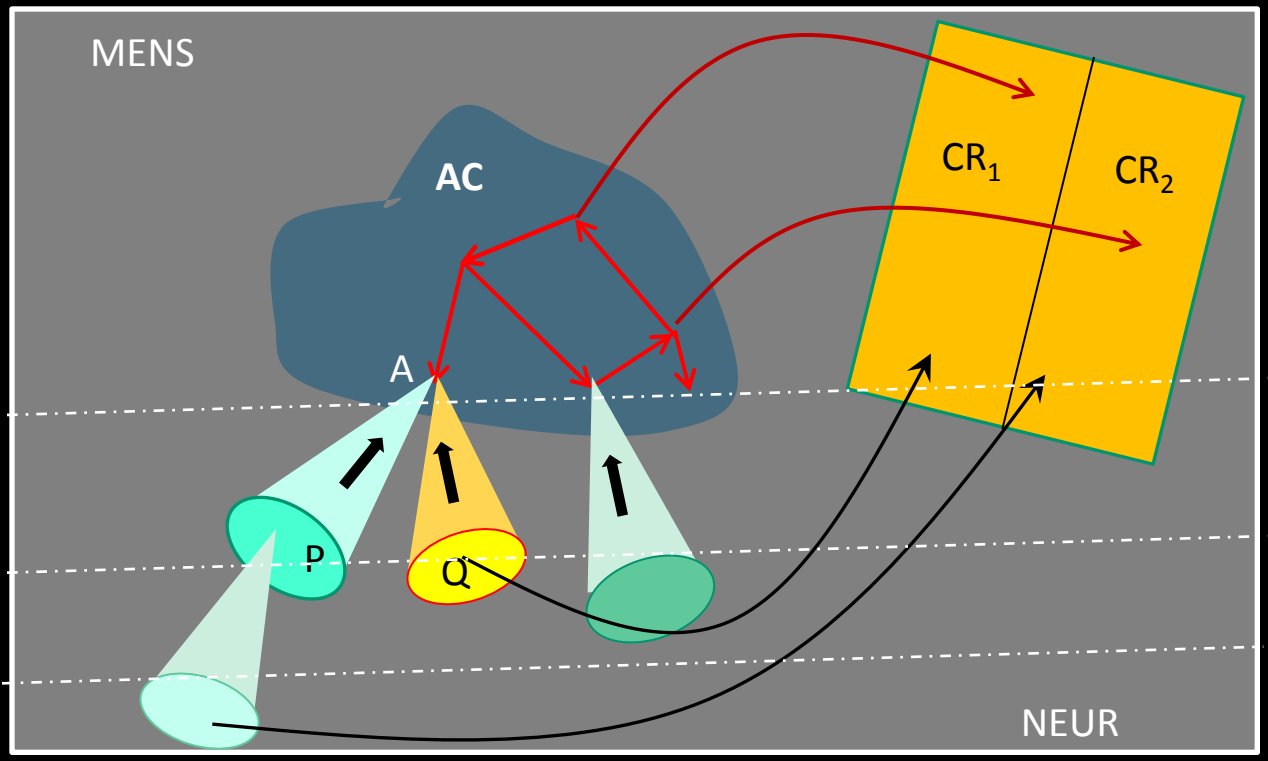

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Transmitted back to intentional CR_i, it allows the formation of a *global landscape* **GL** uniting and extending spatially and temporally their landscapes .

REMARKS ON THE GLOBAL LANDSCAPE

GL provides for the *retention* and *protention* processes considered by Husserl :

"Il y a dans le présent une *rétention* du passé (rétention primaire si c'est un passé immédiat, rétention secondaire si c'est un souvenir plus lointain) et une *protention* du futur (de ce qui va immédiatement arriver). "

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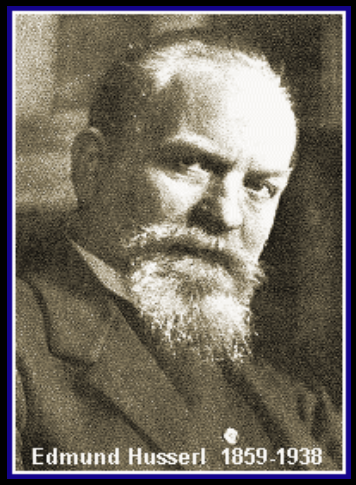

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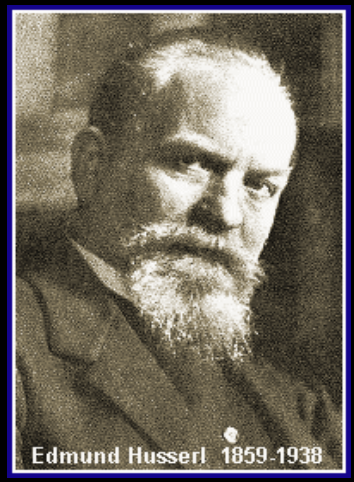
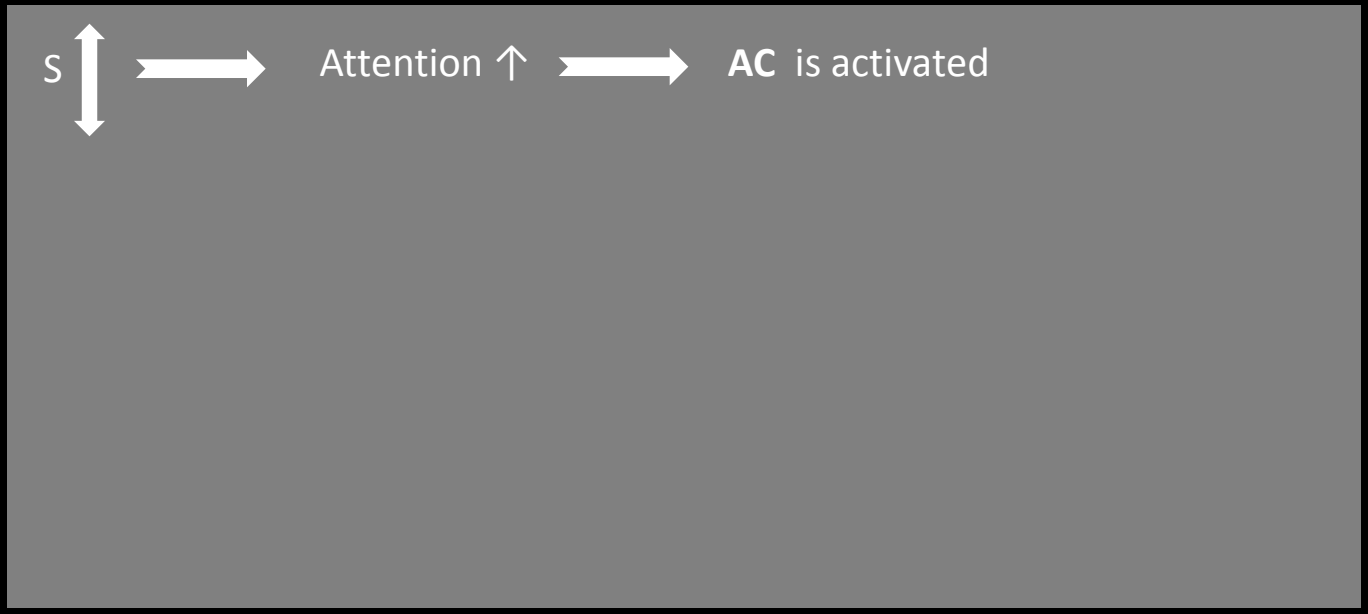


The global landscape can be compared to the "Global Work-space" of Baars (1997), "closely related to conscious experience, though not identical to it", that he illustrates by the metaphor "Theater of Consciousness"

CONSCIOUS PROCESSES



Unexpected or striking event S activates part of AC

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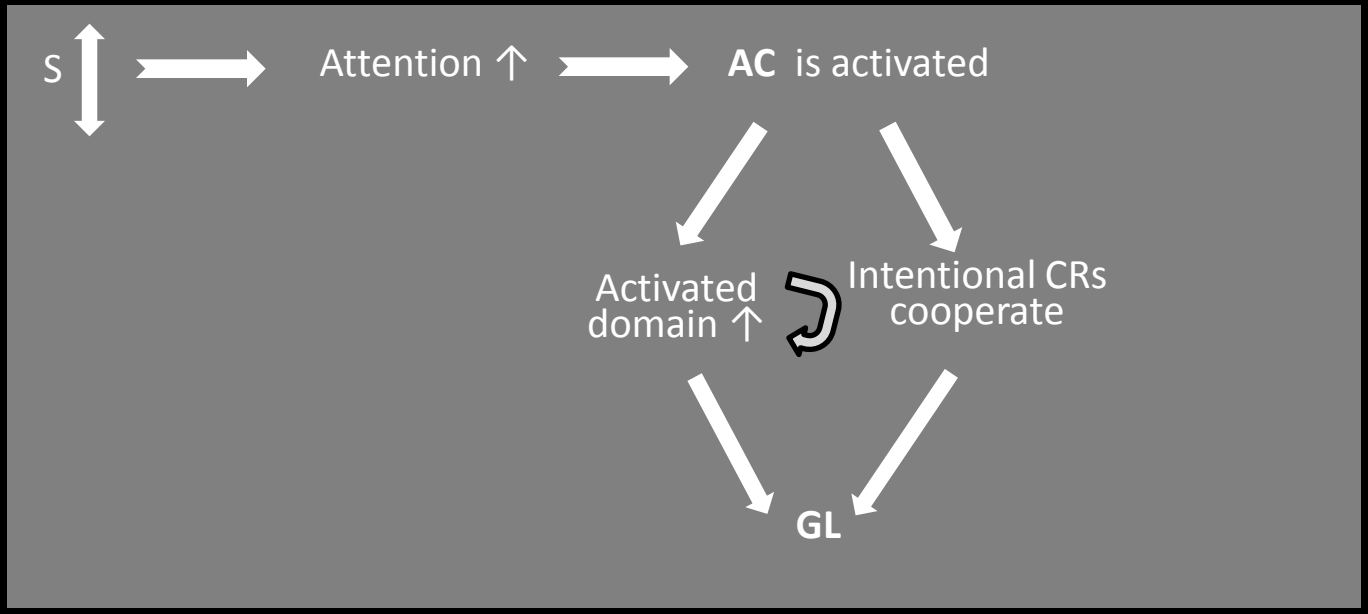

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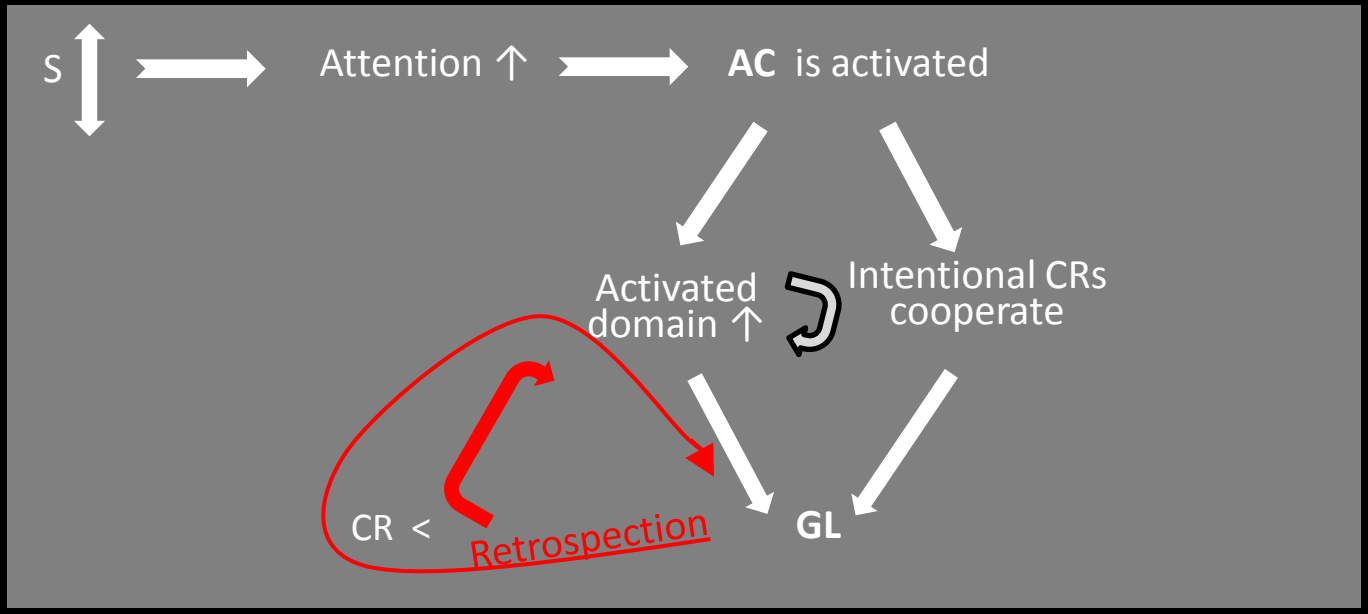

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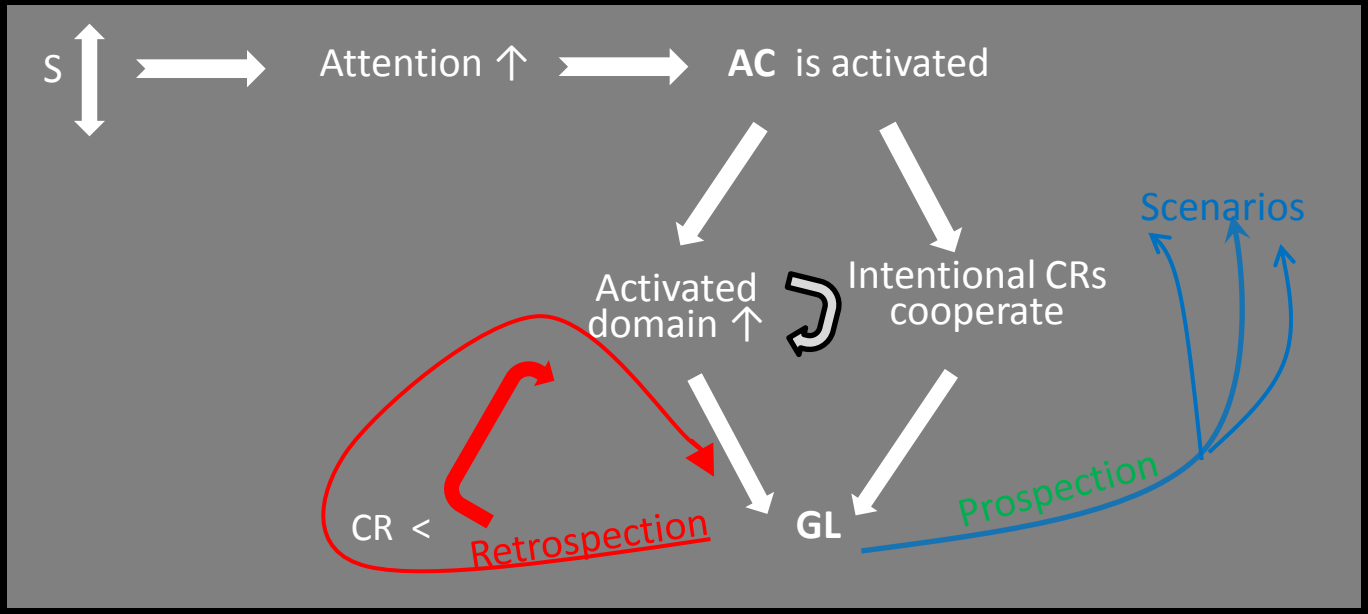

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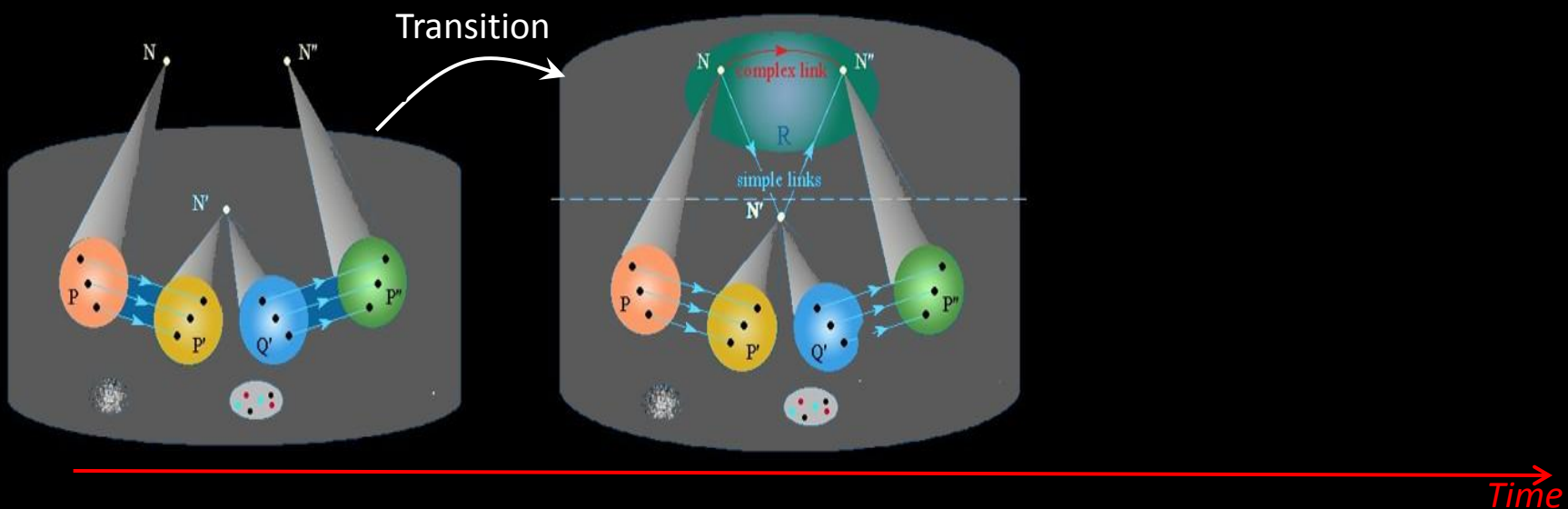
2. ***Prospection***: search of "scenarios" by iteratively constructing virtual landscapes ("mental spaces") in GL in which sequences of procedures are tried, by evaluation of the corresponding complexifications.

ANTICIPATION. CREATIVITY



They depend on overlapping retrospection/prospection processes in GLs. 'Simple' scenarios are obtained by complexification of a virtual landscape ('mental space') in **GL** ===> "combinatory" creativity (Boden), "coherent blending" (Fauconnier & Turner).

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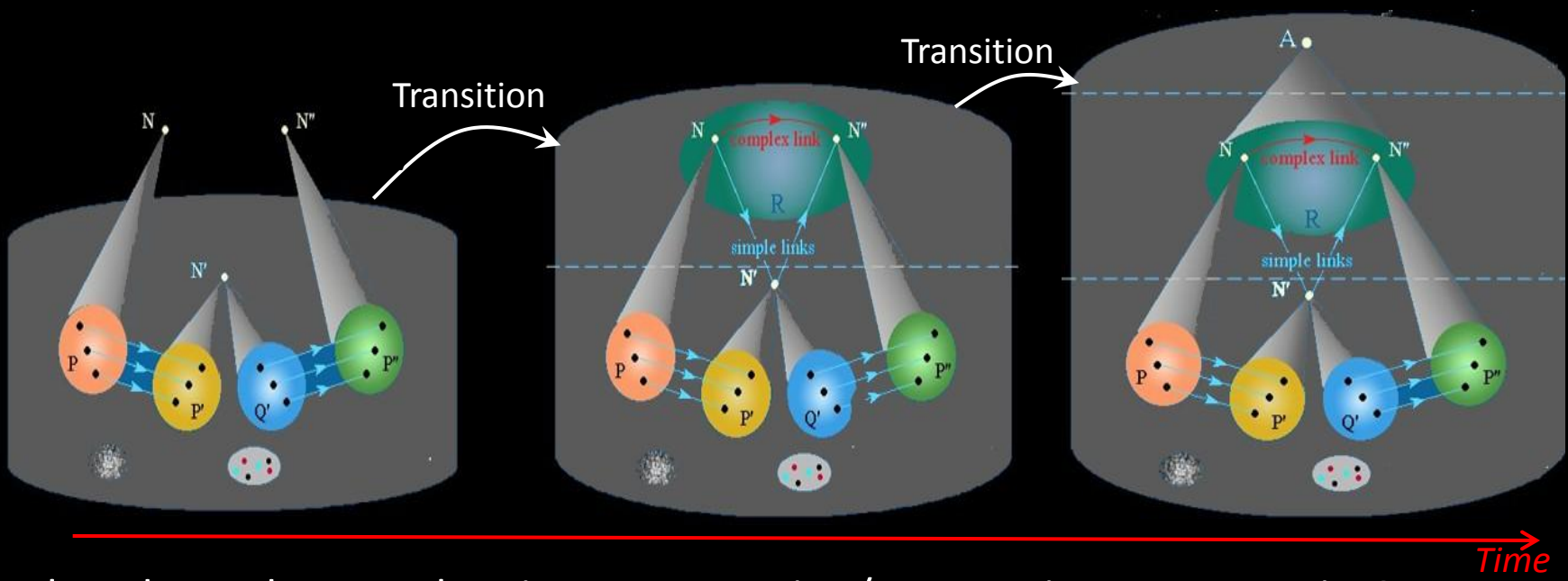

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'Simple' scenarios are obtained by complexification of a virtual landscape ('mental space') in **GL** ===> "combinatory" creativity (Boden), "coherent blending" (Fauconnier & Turner).
More 'innovative' scenarios ("transformational" creativity of Boden) are obtained by iterated complexifications of virtual landscape, since:

THEOREM. ***A double complexification where complex links play a role cannot be reduced to a unique complexification, and it allows the emergence of components of increasing complexity order.***

FUTURE PROSPECTS: ACS. NBIS

An *Artificial Cognitive System* could be modeled by a MES constructed by the same iterated complexification process that leads from NEUR to MENS; its level 0 should satisfy the characteristics of NEUR used here:

(C) 1. Hebb rule; 2. Degeneracy ===> MP; 3. Existence of a structural core.

The results would extend.

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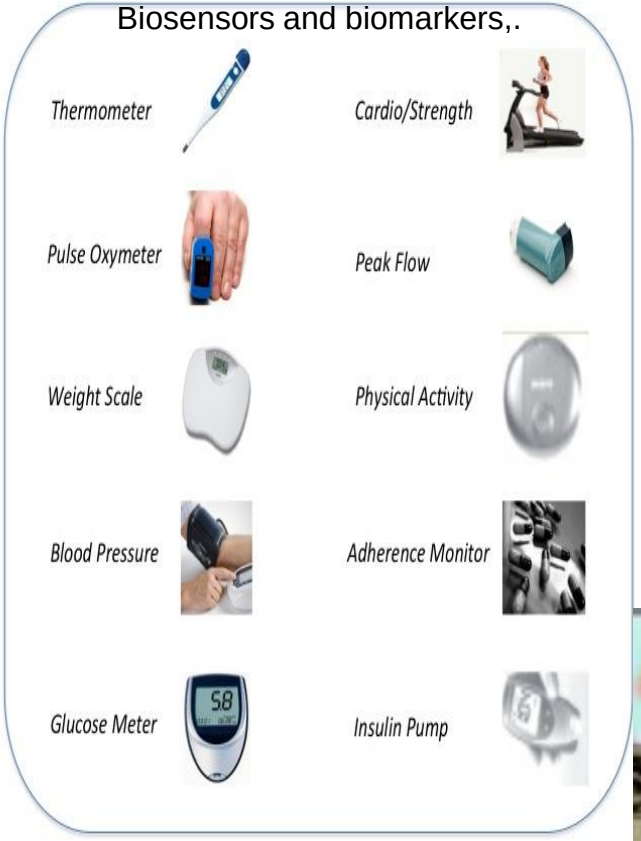
Example: **NBIS** (for *Neuro-Bio-ICT System*):
It is an ACS having for level 0 an evolutive system E-NEUR obtained by connecting to NEUR a computer-like processing system E acting as an "Exocortex"; E and the links between E and NEUR should be such that E-NEUR satisfies (C).

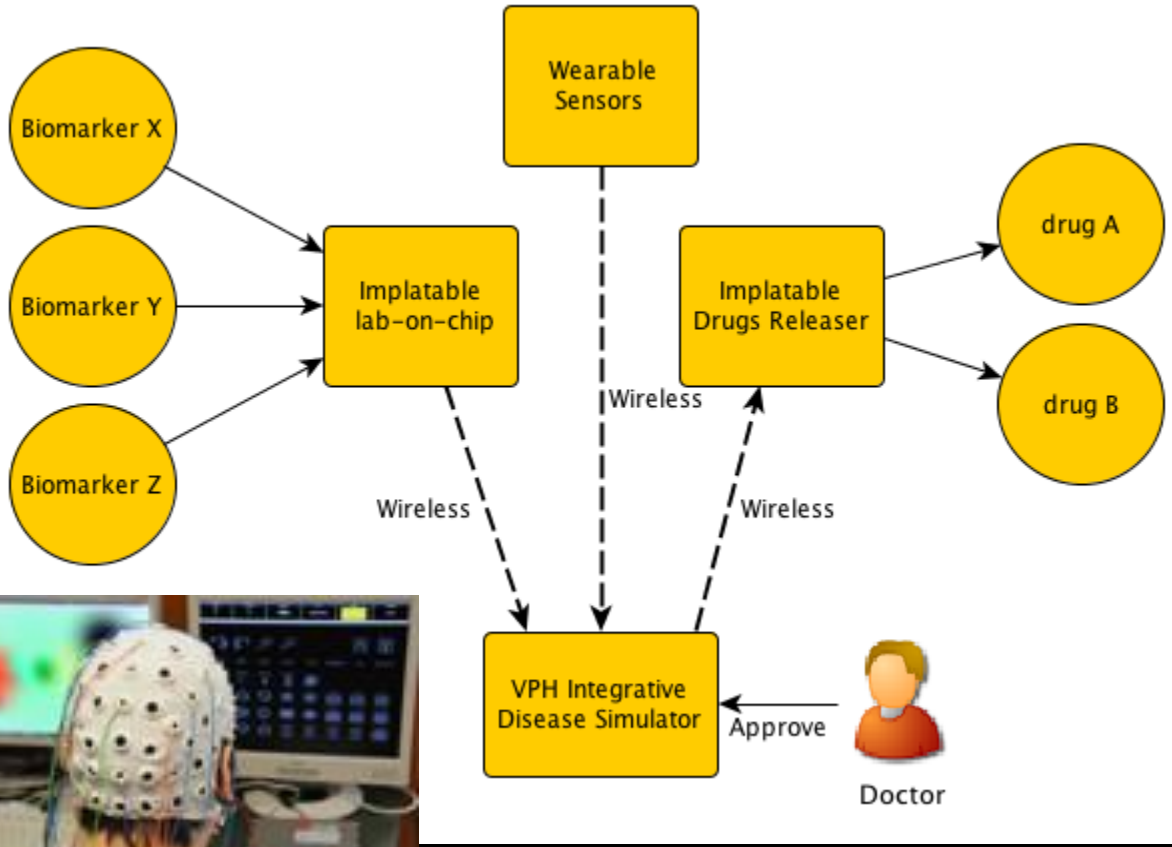
NBIS could enhance human abilities or/and monitor dysfunctions.

(Cf. Ehresmann, von Ammon, Iakovidis & Hunter, IEEE CAMAD 2012, Barcelona:
http://www.complexevents.com/2012/06/17/ubiquitous-complex-event-processing
-in-exocortex-applications-and-mathematical-approaches/

APPLICATION: NBIS MONITORING AGING PEOPLE

Biosensors and biomarkers,.





Extract from R. von Ammon's slides

CONCLUSION. PROBLEMS

MENS is a mathematical model for neuro-cognitive systems, inspired by 'nature', and allowing for the emergence of higher cognitive processes.

It is 'hybrid' in different senses:

1. neural + mental + their links;
2. 'local' dynamics of the co-regulators + 'global' dynamic modulated by their interplay.

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Problems submitted to specialists:

1. *Computability*. Can the following operations be amenable to some kind of '(unconventional) computation':

MP, emergence of complex links, interplay among co-regulators?

2. *Philosophically.* To what kind of philosophy does MENS resort? For instance could we say it is a mix of:

connectionism (through the dynamic during one step of a co-regulator) + computationism (cat-neurons acting as 'symbols', e.g. in complexification)?

FOR MORE INFORMATION

Memory Evolutive Systems: Hierarchy, Emergence, Cognition, Elsevier, 2007.

MENS, a mathematical model for cognitive systems, *JMT* 0-2, 2009.

Internet sites where most papers can be downloaded

http://ehres.pagesperso-orange.fr

http://vbm-ehr.pagesperso-orange.fr

THANKS