Perceptive Levels in Plants: A Transdisciplinary Challenge in Living Organism's Plasticity

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Is a minimal 'cognitive' perception of the world by lower organisms possible? The aim of this paper is to evaluate the ability of plant kingdom to treat information without nervous system. On the basis of experimental results on plant bioelectrical potentials and on the analysis of extended cognitive levels defined in the emergent plant neurobiology paradigm, these organisms are considered: (1) as possessing dynamic integrated perceptive systems close to those of animals, (2) as self-organized entities with protoneural abilities and (3) as expressing primitive generic processes which have nonlinearly conducted to complex brain networks. This approach permits a new bottom-up investigation of plastic interfaces, particularly at the level of perceptive and knowledge accumulating systems. Providing the great value of early sensory processing in plants is accepted, the only way to progress would be to read the emergent behaviors of complex informational systems co-creating the world through a transdisciplinary framework.

Keywords*:* Plasticity, Protoneural networks, Sensory biology, Nonlinear dynamic systems, Transdisciplinarity, Information levels, Cognitive processes, Plastic interfaces, Plant behavior.

1 Introduction

The question of a common evolutionary tree before the divergence of plants and animals today arose, as shown by the discoveries of a lot of plants' functional receptors or enzymes with fully conserved amino acid sequences or transmembrane domains analogous to animal receptor proteins [1]. In the same manner, as recently clarified by Professor Balŭska, many data show that such neurotransmitters homolog, long-distance electrical signals, phenotypic plasticity, memory of developmental stages, coordinated hormonal transport through specialized tissues as well as rapid motility, insect-plant communication or social behaviors are preponderant in plants [2]. Our early work on Kalanchoë's extracellular potential variations (Debono & Bouteau, 1992) has shown that spontaneous electrical activities as well as responses to stimuli occur widely in plant tissues, being correlated with classical action potentials or resulting macroscopic currents sustained by plant receptor-channels and organic activities like those of root apical systems or Auxin transport [3]. Our hypothesis was that these network activities could, in analogy with animal whole organ bioelectrical activities, represent the by-product or the algebraic summation of derived activities of a great population of plant cell tissues. Several other kind of biopotentials are described in plants like Mac Kinnon's surface local electrostatic fields, electrosensory activities during thunderstorms (Goldworthy et al.) [4], endogenous fields and cellular dipoles during tip growth of root hairs or pollen tubes (Weisenseel et al. or Cooke & Racusen) [5], localized calcium influx mediated by electrophoretic or cytoskeletal mechanisms for Very [6], induction of stomatal closing by hormonal mediation described by Davies [7] or finally morphogenetic activities implying transcellular fields and biophysical or gravitational forces described by Nuticelli [8].

All these mechanisms of action could be directly or indirectly related to the microvolted spontaneous variations that we have recorded at the level of polarized groups of cells or tissues [3]. However, the precise functional role of these 'surface potentials' in the plant relation life remains to be found since they have not really been studied until today. Their physiological confirmation, correlated to other fine regulatory bioelectric mechanisms, would imply a minimal centralization and diffusion of the information without highly integrated structures like heart or brains. Historically, when I detected these field potentials in the 70s, I was totally isolated. Doing the bibliography on the subject, I discovered that two contemporaneous studies made in Russia (Paszeusky & al. 1961) and especially in the USA (Karlsson 1972, Pickard, 1973) independently found the same bioelectric potentials [9-11]. Then, the subject was progressively given up. It means: 1/ that they are still not directly linked to a clear physiological process; 2- that if signal transmission is well understood at the level of electrical or chemical coupling between cells by botanists, that of global behavior of plants - even finally becoming nowadays a preoccupation for a majority of scientists considering the great potential of plants in the ecosystem - is still either underestimated or not considered as a priority. Sensibility exists, plasticity exists, communication also clearly exists at plant level. So what? Plants are not animals, dont move quickly and dont communicate with us. We have then two solutions: to wait science advances or to treat the problem with a transdisciplinary point of view, which is one of the purposes of this paper.

Indeed, neglected during a long time, these hypotheses are now audible by biologists. It is the consequence of two main discoveries. Firstly, advanced works emerged from the XVI international botanical congress of St Louis MO (USA, 1999) showing five main trunks of complex "nucleated" organisms, from which four are classified as plants and the confirmation of the plants' synthesis and use of neuroactive chemicals typically known to mediate fast excitatory synaptic transmission in the central nervous system of vertebrates [1] were strong arguments in favor of the hypothesis that a primitive signaling mechanism existed before the divergence of plants and animals (Baum et al., 1996; Chiu et al., 1999) [12, 13]. Plant genomic complexity discovered during the same time was also intriguing.

Secondly, the new assertion of plant prototypic intelligence initiated by Trewavas in 2003, even controversial, had a lot of impact in the scientific world, and, interestingly, in distant disciplines from plant biology like behavioral, cognitive and social sciences, ecology, semiotics, autopoiesis or information theory [14]. Indeed, the semiotics of the term 'intelligence' (used to describe the sensitivity and the complexity of plant signal transduction as well as their ability to learn, memorize, communicate and compute responses at the whole plant level) was clearly redefined or resituated, and for the first time applied to the complexity of plant signaling and communication. It was the same for the term 'cognition' to there almost exclusively used for mental act processes implying knowledge processes, whereas decentralized or extended cognition take into account cellular computing, dynamic emergent properties from complex systems and more precisely "plant qua information-processing systems" as well as "plant-coupled-with-its-environment" levels (Garzon, 2007). This recent paper is in a instructive way titled "The quest for cognition in plant neurobiology" [15]. Another from Barlow describes the auropoietic and cognitive functions of plant roots [16].

All together, these discoveries and the recent recognition of the concept of network information in plants resulted in the development of a new paradigm called 'plant neurobiology' by Balŭska et al. (2006, 2007) clearly involving a transdisciplinary field of research in this area [2, 17]. These authors clearly say concerning this subject: "Neuronal informational systems allow the most rapid and efficient adaptive responses. Therefore, it should not be surprising that neuronal computation is not limited to animal brains but is used also by bacteria and plants". Balŭska and Mancuso conclude, one year after the publication of the plant neurobiology paradigm as an integrated view of plant signaling, that plants act, as any living and evolving system, as 'knowledge accumulating systems [18]. that plants act, as any living and evolving system, as 'knowledge accumulating systems'. Our aim is therefore here to show how the proximity of both plant and animal integrated biosystems: (1) conduct to common protoneural dynamic behaviors including complex sensory perception and communication (Debono, 2013), (2) is closely linked to information theory and the development of different adaptive and cognitive systems during evolution and (3) implies a transdisciplinary reading grid opening to nonlinear dynamic analysis of biological and cognitive processes [19].

2 Common Sensory and Protoneural Dynamic Networks in Plants and Animals

2.1 Bioelectricity as Universal Signaling Pathway used by Biological Systems

At the beginning of the 20th century, Sir Jagadish Chandra Bose, that created the first scientific research Centre in Calcutta realized before Marconi pioneering works about electromagnetic waves. He also studied plant physiology, being interested in the growth of plants and their reactions to stimuli. He was the first to describe the neuroïd properties of *Mimosa pudica*, a plant endowed with a fast motricity visible to the naked eye, about which we know since the Riccas work (1916) that it is closely linked to a circulating hormone [20], and more precisely to parenchymatous excitable cells propagating action potentials before cell deturgescence and the motor phenomenon itself (Stoëckel, 1976, Desbiez, 1985) [21].

During the 1970s, best selling authors C. Bird and P. Tompkins, a journalist, as well as an US military intelligence officer cast confusion with their pseudo-scientific assertions of "telepathic recordings between plants and humans" obtained with the Cleve Backster's lie detector [22]. It caused considerable damage to this research area until now, stopping any serious research in the area of 'surface potentials' and more generally to the comparison of bioelectrical properties of both plant and animal cells. Happily, these times are over. All the biological data obtained since these period, concerning as well field potentials as endocellular events recorded by patch-clamp technics [23] clearly show that electrical activity is a general property of excitable cells, and is not restricted to nerve structures. Moreover, it is an evidence to assert that neurons used electricity long after plants. Wildon, Thain et al. (1992) have published data in *Nature* explicitly showing for the first time with molecular biology a direct link between the emission of propagated electrical signals produced by a tomato plant after a wounding (an insect playing naturally a natural role of mechanical stimulator) and the induction of a biochemical response (protein synthesis of a trypsin inhibitor) [24]. The authors conclude in another review (1996) and almost exactly two centuries after Burdon-Sandersons' discovery of electrical signaling in plants, that "*it is now clear that a wide range of plant species can generate action potentials in response to electrical or other stimuli, and that these action potentials can propagate through the plants tissues*" [25].

As we stated in the introduction, many other mechanisms of action underlying tropisms, high sensitivity to any kind of stimuli, "self recognition or adaptive behaviors", fast motor reactivity or insect-plant very fine interactions are described more and more precisely every day, asking more acutely the question of a convergent evolution between plant and animal species not contradictory with the divergence of the two reigns. In other words, if evolution has finalized electrical signaling in neural structures, conferring great advantages to animal and human brains in terms of speed and precision of the information flux, it seems likely that elementary cell properties as well as elaborated communicative strategies are common to both living systems. Indeed, electrophysiological data clearly show that the main difference between plant and animal cells is the time duration of events, plants being in the same range as cardiac cells (hundreds of milliseconds) of animals, compared to fast synaptic transmission of brain neurons during one millisecond (Figure 1). So, the first question that arises, related to complexity and evolution is how and why organisms lacking high integrative functions or specialized structures like brain cortex or central nuclei have developed such complex behavior? (Debono, 2004).

2.2 Complexity, Evolutionary Processes and Nonlinear Dynamics

As we stated in this paper considering the entire perceptive scale, the growth in complexity is not a

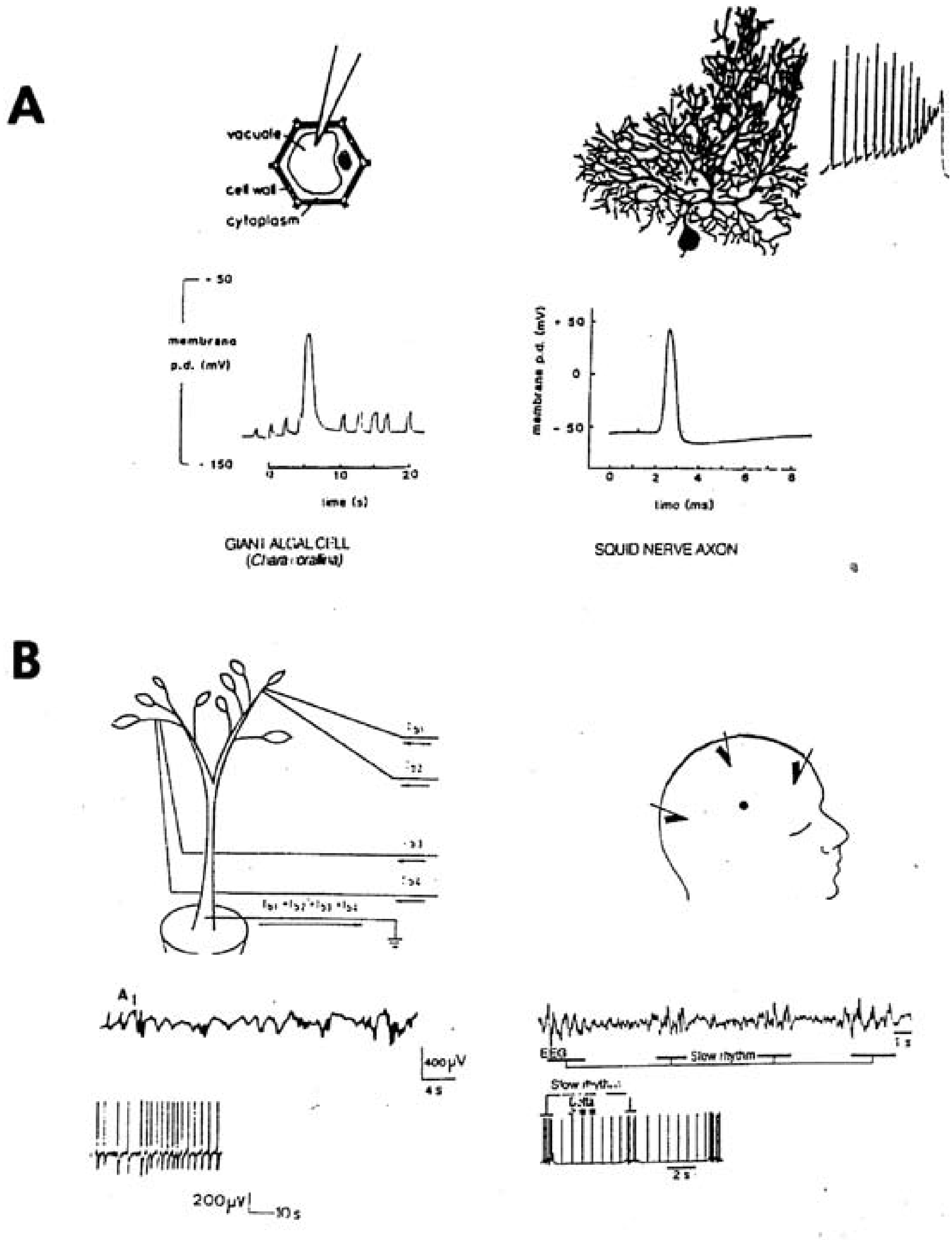

Figure 1: BIOELECTRICITY AT LIVING SYSTEMS. A: Endocellular recordings in a giant algal cell (left) and in a squid nerve axon (right). Note the delta observed on the timescale. B: Extracellular recordings (slow waves and spikes in response to chemical stimulation) at the whole plant level compared to brain EEG. This comparison is purely analogical and must be interpreted within our plastic reading grid (brain synchronized activities being related to highly specialized structures compared to plant sensitive organs). The new emerging transdisciplinary field called 'Plant Neurobiology' is now trying to discover whole integrated sensory, communicative and adaptive mechanisms underlying such activities.

single exponential [26]. We need to consider that each integrated living systems presents: 1/ a potential degree of reactivity, of communication and of informational level, and 2/ is aware of or as to be considered within its own limits. Cognitive and preconscious states in animals and man would have then to be seriously interrogated in this way. Preceding the classical definition of immediate or minimal consciousness in lower animals, protoneural systems could have started the complexity process by permitting the conditions of emergence of the access to experience. These states probably include and memorize the preceding ones. They may also correspond to independent evolutionary steps served by identical functions at plant and animal levels. Indeed, many examples suggest a common evolutionary tree before the divergence of plants and animals. For instance, markers like ubiquitous proteins or hormones have a common pathway before being expressed in many species including animals and plants. Roth et al. (1986) show that "the breakdown of the barriers for the hormonal molecules between the vertebrates and the rest of the metazoans, between metazoans and unicellular organisms, between the eukaryotes and prokaryotes, or the eubacteria and archebacteria is concordant with findings in multiple other systems" [27]. The case of hemoglobins present from bacteria to man, of photosynthetic proteins of plants having their homologues in bacteria, of many common receptor gene superfamily or of heat shock proteins of eukaryotes and prokaryotes are also extensively studied today.

A review made by Kohorn in 1999 addresses various signaling paradigms across kingdoms as constituting a new approach "in which characteristic proteins are used in a variety of ways and combinations to transduce a signal". Potential ligands activated by specific enzymes regulating cell division in the plant meristem are then described, concluding that this discovery "appears to shuffle" the paradigms used for cell communication in unicellular and complex organisms [28]. Signaling is also used like in animals for plant embryogenesis where positional information has a major role for sporofitic cycle and embryonic axis (Harada, 1999) [29] or for defense signaling pathways where apoptotic cells and conserved disease resistance genes may be related to functions in animals (Pifanelli et al., 1999) [30]. Finally, as previously evoked, recent discoveries of plants' use of calcium binding proteins and of glutamate receptor channels typically found in animals are a strong argument in favor of the hypothesis that a primitive signaling mechanism existed before the divergence of plants and animals (Lam et al., 1998). This discovery explains also probably why neuroactive drugs synthesized by plants are able to work at neuronal level, and may act as endogenous ligands regulating cell to cell signaling in higher plants [31].

Another important point concerns, as quoted in the introduction, recent phylogenic studies showing: 1/ that there are five main trunks of complex "nucleated " organisms, from which four are classified as plants and 2/ that animal and plant kingdom are categories no longer relevant. Thus, many authors dare say now: 1/ that plant cells could act like 'nerves' and 2/ that a common unicellular ancestor before the divergence of species is confirmed. These discoveries can be interpreted as a prerequisite for the emergence of complex differentiated systems. They strongly comfort our experimental data describing the common bioelectrical profiles of animals and plants. This major kingdom has thus for us a precise message for further species. This message can be translated as follows: our evolved treatment of the information is the result of a series of primitive generic processes which have progressively and non-linearly conducted to perception, immediate consciousness, and far away to the self-conscious mind.

2.3 How Plants Treat the Environmental Signals?

Among these primitive processes, biosensors like plants - lacking brain - could have progressively developed some level of integration or global states of receptivity without any representation or conscious activity. That would constitute a good reflect of the dynamic protoneural ability of the plant kingdom to react to the environment with adequacy, using sensing effectors to translate information into function. The original etymology of the term neuron indicates a biological matter of fibrous nature. It fits well with the emergent plant neurobiology paradigm taking as framework the whole integrated ability of plant signaling, including complex behaviors. Indeed, following the algorithmic information theory, there is a positive relation between complexity and the amount of information required to describe a system (Maze, 1999). This relation involves the emergence of new properties and of time-related irreversible changes. The direction of these changes is determined by the historical boundaries of the system which is considered as a whole rather than its parts [32].

As both parameters are related to emergence increase, there is a concomitant flow of energy and information in plants. However, the biologic differentiation between animal and plant species does not always mean complexification, inasmuch several authors like Miller et al. (2001) described very sophisticated organic functions in plants or in co-evolving species [33]. Indeed, the complexity process is not an absolute criterion because the thresholds reached by both species are high but differentially expressed. As a classical example, plant cell compartmentalization (several membranes) shows a more complex profile than animal cells but their evolution or "behavior" is clearly different in terms of complexification (organs, brain development, etc.). For these reasons, plants have probably developed several strategies of communication without possessing nervous system. These Darwinian or biosystemic strategies are basically linked to high sensitivity and adequate responses to environmental or endogenous signals influencing growth, morphogenesis and behavior, but concern also memory or stock and recall of information. They could involve spontaneous and preponderant electric fields that were used in the fusion and orientation process of membrane cells and vesicles (Zimmerman, 1982) [34], and then by whole plants, far before fast neuronal transmission use them with a great efficacy (Turrigiano, 1999) [35]. These fields are clearly due, as in animal cells, to the electrochemical conduction of excitation through specialized tissues, including long-distance communication (via the plasmodesmata or due to electrical propagation between adjacent excitable cells) and responses to external stimuli.

Indeed, all these common features about the way from which plants and animals perceive and respond to the environment would explain why the rise in complexity is neither observed as an absolute criterion nor as a single exponential (Debono, 2004). At each bifurcating node, a big evolutionary step is made to reach a new plateau, but common pathways were taken to reach these new states or levels, being memorized in cells and reitered in each genomic species with respect to its descent. With this interpretation, the emergence of consciousness in animals could be a result of the progressive nonlinear integration of previous protoneural generic systems getting faster or more specialized, but above all differentiated. Then, the nature of complexity is probably not uniformly extended to living systems, and following the Morinian concept of 'complexus' (Morin, 2008), we can assume that plants exhibit more quantitative than qualitative complexity compared to animals [36].

So, plants have not only a large common genetic and biological background with animals, but also a large communicative repertory that contributes to biodiversity and adaptation. This panel is very useful to control their environment, their social interactions with neighboring plants or insect (as for instance in bee pollination) or still to prevent themselves from injury or climate changes. They are also able to develop phenotypic plasticity, evolved behaviors and cognitive abilities that were underestimated until a recent date. It is not a proof of intelligence *stricto sensu*, but a proof of high perceptive and informative level. This defines new plastic interfaces and new transdisciplinary pathways to understand cross-species evolution and to explore knowledge and information theories (see chapters 4 and 5).

3 The Bio-dynamics of Plants as an Upstream Model for the Study of what precedes the emergence of Cognitive Systems

3.1 Do Primary Centers of Sensory Integration Could Exist at the Plant Level?

It is clear that plants do not have any nervous or conscious system corresponding to classical assertions or definitions of animal or human consciousness. However, as we had made the hypothesis in 1991, their protoneural organization allows them to develop high perceptive capacities. Recent advances in plant biology show many evidence implicating possible primary centers of integration located at foci of interaction of sensible and richly interconnected zones like specialized tissues as phloem or meristem where plasmodesmata ensure excellent intercellular communication (a symplasmic field), at roots and/or at sensorimotor structures [2, 16]. These recent data in plant molecular biology comfort our pioneering work, showing that these integrated states are mainly sustained by proteins, calcium channels or receptor gene superfamily similar to animal neuronal systems at cellular level, and polarized tissues or sensing effectors (like pulvini, traps, stomata or growth cone) translating information into function at the whole plant level (wound responses, reproducing, flowering, interspecies communication).

Several structures could thus be implicated instead of one "central nervous system". Our electrophysiological data particularly suggest that a primary integration of information, whose role is probably to coordinate basic activities, could possibly be reflected by spontaneous potential variations representing at tissue level the mathematical algebraic derivative or summation of intracellular activities sustained by classical receptor channels and/or electrogenic pumps. These field potentials (FP) are assumed to be a sign of "binding activity" or of global dynamic reception reflecting the ability of the plant kingdom to react to the environment with adequacy and sensitivity. FP have then to be studied as pseudo-'EMGs' or 'EEGs' i.e. like nonlinear dynamic systems able to detect transitional states during perception and responses of living organisms (Figure 1). In brain cortical structures, we can easily separate primary regions that treat unimodal signals like visual or auditory inputs and motor function linked to associative structures that treat more complex information like language or visual memory. In plants, neither attention mechanisms nor significance or representation is possible, but does it totally exclude a certain form of sensory integration (maybe present in several loci)? Does this integration is relevant of a basic adaptive or selective mechanism or of more sophisticated mechanisms implying interactive modes of communication?

Analogically, we know for instance that circadian rhythms observed as quiescent or dormancy states represent the slowing down of vital processes in plants. Does an extraterrestrial would qualify that of a simple oscillation, a sleeping state or a biological clock that progressively led to sophisticated aware-sleep cycles including paradoxical dreaming states in vertebrates? More seriously, these types of communication would more likely be interfaced with the environment from which we take part in a cognitive mode. A similar analysis of the auto-organization of living systems can be made about the development of electrical signals in plant and animal cells. It seems clear, on the basis of all the data presented in this paper that plants exhibit a well-structured bioelectricity, and that this ability was developed far before that of animals and man. Now, let us consider that in early brain development, gene expression was first controlled by biochemical messengers, and only later, by a selective addition of bioelectrical activity. This activity is considered 1/ to differentiate the brain from other organs and 2/ to be capable of influencing gene expression as post-translational genomic modification (Turbes, 1993). Neurons then use selective action potentials to "enlarge the range and complexity of the "environment" available to self-organization process" says Turbes, concluding that electric signals which convey messages are used by the brain as information carriers for cyclical computational processes including reference, sensory feedback and inference systems [37]. We can then consider with this point of view that plants have exactly the same self-organization properties, but that they are limited to immediate access to experience and non-reflective activities.

Indeed, plants possess complex signaling paradigms and have a precursor role in the development of further elaborated systems. To enforce this consideration, we can briefly quote precise mechanisms of action at the transmembrane level, including protein-channels complexes and symplasmic fields associated with morphogenesis. Electrical, but also hormonal and hydraulic signals are known to modulate gene expression through transcription and translation via calcium-dependent cytoskeleton-protein-channels (Davies, 1993). Spatiotemporal and intercellular information are treated at specialized structures (Rinne & van der Shoot, 1998) [38]. Beyond voltage-dependent ionic currents from excitable cells (cytosolic calcium waves similar to those of animal cells), many examples of electrocoupling of transporters involving nonlinear oscillations of dynamic systems and providing long-term osmotic regulation are available like in the guard cells of the plasmalemma of certain plants (Gradman et al., 1993, 2001) [39, 40]. Finally, at the whole plant level, many sensitive systems are described from which *Brionnea* is an excellent example of strong and fast thigmoreactivity to touch. Although these citations are not exhaustive, they are intended for neurobiologists and readers misreading the high level of intra- and intercellular communication in plants.

3.2 Could Plant be Considered as Biosemantic & 'Embodied-Cognitive' Entities?

> *"The relations that define a system as a unity, and determine the dynamics of interaction and transformations which it may undergo as such a unity..."*
>
> **Maturana & Varela, 1980**

One answer to our question about the potential cognitive precognitive ability of plants is that plants do probably possess a rich receptive field or global dynamic perceptive states (GPS) without any central nervous system. That this field is not comparable to animal or human perceptions is evident, but it is probably a form of non-local integrative capacity conferring advantages during evolution. We have now to classify this perceptive capacity (an outer perceptive one) that could be attributed to this kingdom regarding its communicative mode of life. In animals, the central nervous system is the primary transductor between receptors and adapted responses, whereas in more primitive forms like plants, a protoneural network (i.e. having neuroïd properties without elaborated nervous system) is probably responsible for that, with a lower discriminatory window of reality. As propagated action potentials (APs) are able to modulate the intensity or the frequency of stimuli, showing an adaptive behavior in both kingdoms, we can argue that this common mode of treatment of information is compatible with the observation that decentralized or pure "embodied-cognitive entities" like plants challenge our conception of computation of the information and of non conscious vs. conscious processes. The distinction between autopoietic or operationally-closed systems as stated by Maturana and Varela (1979-1980) [41] and embodied-cognitive structures [42] in term of autonomy and level of information would be important questions to answer, particularly regarding information theory and new theoretical bottom-up scales of perceptive, aconscious and conscious systems.

Indeed, our discovery about spectral-coherent analysis in evaluation of plant functional activity as well as the emergent plant neurobiology paradigm confirms that the key role of electric fields was underestimated at plant level, probably because it was not considered in an epistemic vision of evolutionary processes (Debono, 2004). To my knowledge, it is the first time that plants are supposed, on the basis of bio-electrical data and heuristic arguments, to possess some elementary degree of integrative perception or cognition. But it is probably natural that this assertion is made (or is able to be heard) at the time where consciousness and perception in man are really questioned by science (Searle, 1998). Indeed, the coherent treatment of signs by plants reflect a complex bioelectrical patterns (action potentials, field potentials, etc.) would now be considered as a fundamental area of research to explore the multiple faces of *primitive and global dynamic outer perceptive states* that have probably been used during evolution to elaborate further divergent conscious and *a-conscious* constructions [43].

Soren Brier, editor of *Cybernetics & Human Knowing* and co-founder of "*The International Association for Biosemiotic Studies*", gives as title to his post-doctorate thesis ≪*Cybersemiotics: why information is not sufficient by itself?*≫ (2006) clearly showing the fundamental rule of biosemantics in the analysis of all autopoetic and auto-organized systems. Following Pierce and Luhman, he reallocates the information sciences creating a new cybersemiotic field taking into account the auto-organization of closed systems to survive showed by Maturana & Varela, but also the Luhman's generalization of these states to human consciousness and socio-communication and the Pearce triadic semiotics (2012) [44]. Considering the biosemantics of plant life during evolution and their active rule in the ecosystem (cell complexity, protoneural activities, hormonal activities, social behavior, etc.) it would be urgent to reconsider the scale of perception and information of biological systems.

3.3 The Phenomenological Point of View: Blind Access to Experience vs. Structured Perceptive & Conscious Activities in Animals and Man

Following the exploration of closure and re-entry of signals in biological systems, the phenomenological experience, as defined by cognitive neuroscience research, is shown by Varela et al. not to be spatially and temporally homogenous, but discontinuous in the brain, showing synchrony in different brain regions whatever the activity of the neurons in these structures [42]. This discontinuity is described to explain global dynamic patterns of synchrony from which emerges consciousness and related to embodied cognition and enactive behavior. It implicates, as noticed by Kurthen et al. (1998) that "a phenomenally unified experience is not necessarily based on neurophysiological homogeneity" [45]. It is the same case for mental imagery where many experiments describe the same sites of activation in brain regions whatever the type of processes activated (perception of stimuli, memory and representation of images). So, why not speculate that GPS in simpler biological organisms lacking brains are still remaining in the desynchronized state, explaining polymorphic bioelectrical activities that we have recorded and several other bioelectrical events at different loci with physiological significance different from tropisms or survival, but not synchronized by evolved mechanisms such as centralized sensorimotor activities or at higher levels by attention giving the alpha rhythm of brain EEG?

GPS, including spontaneous activity and specific responses to stimuli or injury expressed by bursts of miniature APs correlated to classical intracellular APs rather than a centralized nervous activity, would typically reflect protoneural organizations highly sensitive to environmental changes, so literally having some access and experience of the world, but not able to integrate (and even less represent it) the semantics of these changes. This does not exclude intercommunication and some cellular memory (for instance recorded by proteins implicated in stress) or recall of information to be active in the whole organism, but they are limited to the contingency of the specie, never becoming 'attentively or affectively' related to the world. The recognition of such dynamic 'perceptive states' (several organic structures could be implied) in simpler organisms would be a great advance for the comprehension of plant ecosystem and to apprehend cognition and the access to experience differently.

3.3.1 From Protoneural to Neural Activities: Brain-Mind Interactions

Even speculative, this assumption could help to answer a crucial question today squeezed by the "correlation paradigm" or the evidence of neural correlates of consciousness in man: why physiological processes are accompanied by experience and why experience is accompanied by consciousness? It is now clear that if considered as a protoneural one, the aconscious and silent world of plants could nonlinearly help to answer the interrogations of the neuroscience field about the nature of consciousness. We can then leave now without ambiguity this vegetal world to treat the phenomenon of consciousness as a by-product of brain activity. Recent discoveries in the field of cognitive sciences or neuropsychology show that there is a plurality of conscious and subconscious states. For instance, human visual consciousness may treat asynchronously motion and color attributes whereas a hypothetical binding system is able to link these two systems (Zeki & Bartels, 1998, 1999) [46]. Numerous plastic behaviors of neural circuits reflect a sensorial knowledge and have some biological substrates, but does that explain the feeling of Churchills dog before his death? Self-reflective consciousness is also not easy to characterize: if awareness and self are often considered as the working definition of consciousness, the notion of self and qualia still remain unclear [47]. For Casler (1976), the concept of consciousness is not a problem from the point of view of behavioral scientists. It is not necessary and may be defined as "the very short-term memory of a just completed perceptual act" [48]. So, this author considers that the real question is not that of brain-mind interaction but that of "the relationships between brain and perception, memory and the mental processes that precede consciousness". We think that it is a right frame of analysis, and that our plant model may serve as an upstream demonstration of it (far before conscious activities). It would also be very useful for a better understanding of evolving systems to take into account protoneural and aconscious systems.

The hypothesis of Mitterauer (1998) suggesting multiple ontological self-organized loci in the brain, and qualia as a self-conscious qualitative experience may serve this view in that more simple organisms logically lack these integrated states [49]. Armstrong (1989) distinguishes three types of consciousness perceptual consciousness which is perceptual activity; minimal consciousness which is "the occurrence of any mental activity whether or not the subject is aware of this activity" and introspective consciousness as "perception-like awareness of the subjects' own current mental states and activities..." including "introspective consciousness of introspective consciousness itself". In this classification, where memory and the self appears only in introspective consciousness, it seems clear that plants would have some perceptual and local memory abilities, but lack centralized nervous-like systems to integrate these perceptions. As a heavy consequence, the brain would not be a necessary condition to integrate perceptual processes, as currently admitted, but only for higher brain functions [50]?

In other words, brain activity accompanies our perceptions and permits us to make sense, creating a self, which is not the case for computers or for non-cognitive entities that have only access to a basic informational level. *But plants do have strong perceptual experiences without any representation.* Moreover, as shown by Llinas and Paré (1991) to demonstrate the role of thalamocortical loops in binding activities of the brain [51], our working hypothesis also challenges the Jamesian description of the brain where consciousness is considered to be "an exclusive by-product of sensory input", in that the intrinsic activity of cells (like oscillations for neuronal long-range correlations) have a central role to play. Indeed, our findings, together with a great amount of data in plant biology, show that the treatment of stimuli in organisms like plants lacking centralized structures clearly identified, is very sophisticated, and that bioelectrical measurements of macroactivities could highlight the presence of some integrative processes. At brain's level, Aurell (1979) more simply separate an *outer sensory-produced* and an inner conceptual consciousness [52]. As neural assemblies instantiate mental representations in evolved primates or man, why would a large amount of specialized plant tissues not be able to instantiate a perceptual event having sense in their biotope (critical environmental information for their survival)?

Theoretically, a form of perceptual or outer consciousness or perhaps of a restricted "core consciousness" as recently defined by Damasio (1998), i.e. "the transient process that is incessantly generated relative to any object with which an organism interacts", both related to brief short-term memory, have no reason to be excluded. Damasio associates this state "to transient core self and transient sense of knowing automatically generated" in man, and differentiates it from a more complex extended consciousness [53]. Plants are naturally not concerned by this aspect of core consciousness complexification, but it is not useless to recall that plants "reactivity" existed far before man's self-conscious mind, and that it is too easy to classify this kingdom as blindly receptive or just showing tropistic abilities. We can hypothesize in this way that, as evolutionary steps of the emergence of primary perception and interoceptors were detectable at the brain level in higher organisms, a set of cognitive properties potentially present in lower organisms were not actualized. The same could apply to preconscious processing of sensory inputs existing in the waking and REM-states in man, possibly regulated by thalamocortical loops (Llinas and Ribary, 1993) [54].

However, from our point of view, it is more interesting to show that breaks of some residual brain microstates are able to produce or not conscious macrostates. It means that consciousness might perhaps have some survival value by itself, as proposed by the interactionistic theory of James and Popper, but also, that an intrinsic operational memory of living systems plays a key role in evolution. A common tree, and probable bifurcations related not only to complexity, but to the specific dynamic content of life processes themselves might therefore be found to exist at this plastic interface.

4 Nonlinear Relationships between Perception and Integration: the Level of Information

Another important point, clearly linked to our analysis of evolutionary processes, concerns the central concept of the levels of information interrogated by GPS up to CCS (complex conscious systems). Conscious activity is assumed to create information, so the self-conscious mind is justified, but what about a-conscious entities? Do they create and/or integrate information without meaning and only to survive? Do they respond to stimuli and particularly to wounding without integration of the information of wound or stress? Is the adequacy of their responses, their adaptive morphogenesis, their sensitivity, their states of dormancy or motor activity, their immune, hormonal and social behavior totally blind?

4.1 Plants as Sensitive or 'Knowledge' Accumulating Systems

To try to answer to these questions, we can assume that if consciousness is essentially assimilated with experience, a lot of brain processes occur without consciousness. Moreover, if consciousness is synonym of knowledge, we have to define whether adaptive behavior, adequate response to stimuli and to environmental changes are or not a part of the knowledge (Balŭska, 2006)? Another point is that if phenomenal consciousness is different from physical consciousness as proposed by the Gestalt approach, an isomorphic running would be observable, not only for brain events, but also for any sensitive perceptual system. Now, if consciousness "is neither structure nor function" and has a subjective and irreducible content, as described by Chalmers (1996), sensitive and perceptive systems would have a clear justification [55]. Indeed, one can describe a positive feedback between complexity and the amount of information and/or energy required to describe the world of plants. In this way, classifying plants as, knowledge accumulating or outer a-conscious systems seems an adequate way to describe their world.

Let us now examine some other aspects of the information process. A first classical example is the interpretation of conscious states in terms of energy levels where classical quantum sources of information are fundamentally and qualitatively different from macrostructure experiences. We cannot develop these hypotheses further, but according to quantum physics, they are based on long-range coherent quantum phenomena (or quantum wave functions) occurring as non-local communication in a holographic brain, or with special conductivity of some biological structures such as electric dipole fields or microtubules. However all pure physically descriptions of consciousness are limited to an explanation of why and how some structures might play a key role in a function, but this does not answer to the question of the genesis of the process leading to the elaboration of conscious systems.

Another information treatment process concerns the current comparisons of the brain to computers, which is clearly a reductionist point of view, but is instructive in that the brain is assimilated to a computing function able to display and monitor, for a great part automatically, through the different senses. This 'blind' ability cannot be exclusive of machines and might be quite the same for lower organisms like plants or bacteria, although they have absolutely no capacity to demultiplicate this mechanism using evolved feedback information, volition and awareness construction vectors of the self and the reality. However, plants can move and communicate each other or with insects. Except this inaugural capacity to move common to plants (in a lesser speed) and animals, the previous selection of items represent then a clear evolutionary step, but does not permit us to depreciate the quality of sensory inputs and of information processing by lower organisms. In this way, plants show efficient, harmonious and 'intelligent' relationships with the ecosystem.

4.2 Access to Experience without Representation: Sensory Streams of Information

More generally, meaning does not seem to be definable *per se*. What would be the concept of chair without the semantic and representational capacities of it? The chair is included in a creative loop where the man is the creator and the observer. Only, the functional association of an item with a symbolic function, like the creation of life or of a significant world is available. Baars (1993) quotes the global workspace theory suggesting "that conscious experience emerges from a nervous system in which multiple input processors compete for access to a broadcasting capability; the winning processor can disseminate its information globally throughout the brain" [56]. These global workspace architectures (parallel distributed processors) are unconscious but able to account for different levels of consciousness from perceptual to attentive behaviors. Biophysical experiments also show that the link between matter and conscious states is more complex and dynamic compared to the classical Cartesian cut (Rossler and Rossler, 1993) [57]. Artificial interfaces between a biological substrate (the neuronal fluid been assimilated to an internal observer) and the rest of the world produces non-local effects and possible microscopic changes in the perceived world. So, what is valid for nervous system could be also valid for protoneural systems. A crucial point is now to define perception and symbol acquisitions itself behind plant, insect and human filters.

Another more extended paradigm would be to consider the relationships between universal patterns of organizing principles. Indeed, one can suppose that when consciousness exists, it is possibly one face of a state of information with the other face directly engrammed in the biological substrate, i.e. the somatic expression of a coherent subject. In this way, our concept of metaplasticity would be adequate to describe non conscious systems as different to unconscious and conscious processes involving different levels of knowledge (implicit, explicit and metaknowledge) as recently described in the literature (Feinberg et al., 1995) [58]. The different approaches of artificial intelligence are also very useful to understand the behavior of virtual and real thinking systems, if they do not have as objective to reduce virtuality to reality. Shannon's theory of information thus corroborate two majors ideas of this paper: 1/ the great value of early sensory processing and of global physiological perceptive processes (i.e. not only involving brain treatment of the information); 2/ the evidence of metaplastic levels involving vertical processes that re-express antecedent generic states (Debono, 2008) [59].

The first point recently developed by Buracas & Albright (1999) shows the high temporal precision of sensory streams of all systems possessing sensors and treating changes in the environment [60]. They produce a stream of information that is a product of the ecological niche of the organism. This stream is essentially described for individual neurons of different species, showing the progression of information high rates or abstraction in evolution. Indeed, if we accept that the perceptive capacities of living systems are not linearly related to their integrative ones, the potentiality of protoneural entities like plants to express what precedes consciousness is fundamental to be explored. This paper suggests that the fine comparison of macroscopic electrical fields at the crossroads of the plant and animal kingdoms would be a first mean to understand the common mechanism of perception of both species.

More globally, we must search all *primitive signs of perception at complex systems.* At the human level, we can take the example of the acquisition of the language. For Piaget (1950), the representation of events or objects is a prerequisite for the acquisition of the symbolic function linked to experience [61]. Generative semanticists suggest that the meaning of a word is based on invariant semantic features and that children acquisition of the language begins by perceptual and functional elements. Other theories consider "case prototypicality as a semantic primitive" to participate in the construction of "a non-procedural representation for word meaning" (Yang et al., 1999) [62]. Finally, neuropsychologists like Pinker (1999) suggesting reverse engineering of the mind, or Laplane (1997) observing aphasic patients, also consider that the language only participates to a partially pre-formed thought [63, 64]. A positive explanation for these observations would be that qualia and cognitive tasks admit a parallelism in the horizontal direction, but diverge in the vertical one, explaining thought without language or the cognitive abilities of children preceding their linguistic expression. At the level of living and non-living systems, it would mean that the gap of materiality would always be situated in the horizontal plane whereas the growing level of perceptivity is able to reach the vertical plane (Debono 2004, 2008). For plants, it would mean that experience without any meaning or representation is possible. A kind of raw or *per se* experience conferring advantages for the specie, but also permitting a fast transmission of information at the organism level, but also for interspecies communication.

To resume this chapter, many different lines of evidence are consistent with our basic hypothesis which is to assimilate biological entities like plants to highly perceptive systems having an access to experience and to what precedes the emergence of cognition. Following this hypothesis, GPS could reflect the expression of primitive generic processes that progressively and nonlinearly led to the conscious systems of vertebrates. This classification is comforted by recent advances in plant biology showing a common evolutionary pathway of plant and animal species until their divergence, and that extracellular biopotentials intensively participate to morphogenesis, cell to cell coupling and transduction of stimuli. It suggests firstly the necessity of new bottom-up experiments on such simpler organisms able to express what precedes perceptive and conscious processes, and secondly, the consideration of a new concept of plasticity (Debono 2007) in which all different forms of perception and information processes are taken into account. We have shown that these plastic interfaces bind to form dynamic complexes respecting the level of expression of each binding state [65]. Several interfaces could be then defined following this paradigm, from matter-form to experience-consciousness. In the light of the present various conflicting hypotheses concerning the nature of perception and consciousness, it would be a means to broach the neuroscientist hard problem in a different and constructive way.

5 The Transdisciplinary Challenge: Defining a Core-TD Biosemantic Research Area

One must argue that to progress in this area, we must be humble because we do not know what exists before the emergence of consciousness. Is it a kind of perceptive experience *per se*, a kind of closed communication or a kind of identity? We must also keep in mind, as raised by philosophers like Chalmers (1996) or Searle (1998) that science is reductionist and cannot explain all. From tree to man we thus have to use the metaphoric mode as a philosophy and the informational mode as a scientific model (Debono, 1991). Finally, we must integrate the trans-objective as the trans-subjective state of natural systems (particularly in human relations) and practice transdisciplinary research, being careful to investigate the generic and/or ontological contents from the whole evolutionary processes, whatever their levels of expression.

Transdisciplinarity is unambiguously adequate to describe these different levels of knowledge and also a metaknowledge enlacing all subtypes or subcategories: here, specific and distinct dynamic perceptive systems of plants, animals and humans, and global states of perception as metafields including all steps from tropisms to emotions. Indeed, the important challenge that remains today is then to understand the common basis of perception at both species. By combining theoretical analysis of networks expressing early sensory systems and primitive generic processes with it in vivo experiments at the dynamic 'cognitive' interface of plants, some of the puzzling questions about evolution and the emergence of complex systems could be uncovered.

An excellent initiative in this way was the reviewing of the fundamentals in bioelectricity and the questions recently put by the organizers of the first symposium on plant neurobiology held in Florence (Italy) in May 2005 and then the third international symposium on plant neurobiology (Slovakia, May 2007). The researchers centered the symposia on the concept of information in biology and the paradigm of 'Plant Neurobiology' treating without taboo of plant ionic channels, sensory signals (photoelectrical, mechano- or magneto-reception), rapid movements and neuronal-like behaviors of higher plants, memory (insect-plant interactions), processing and integration of information or intelligence (Trewavas, 2002-2005), but also fundamentals in molecular signaling, neurotransmitters or gene involved, cell membrane activities. We must go far away, considering plant biosemantics (Brier, 2012) in a world of human communication of which the ecosystem is strongly threatened.

5.1 Metaplasticity: Defining the Levels of Information of Knowledge Accumulating Systems at each Plastic Interfaces

As previously shown, we need to better understand the metadynamics from emergent behaviors of complex systems leading to the ontological human consciousness, some misleading "tunnel effects" as that of brain & mind being able to hide the real processes (Debono, 2008). As a matter of fact, on a plasticogenetic scale, plants possess dynamic perceptive systems and animal consciousness is obviously centered on survival whereas human creativity is expressed as a wide kaleidoscope oriented by emotions, self and feelings. In this way, we propose that instead of classifying conscious processes in order to determine gradual states of perception, we must examine their actualization into a living system as a measure of their level of *epistemic access to the world*. If we accept this model, a large metaplastic scale is now available and permits us to analyze a plurality of perceptive states containing or not consciousness, to establish a common perspective and going beyond artificial gaps

This paper clearly shows that only an approach integrating, going through and beyond the disciplines, taking into account a third term enclosing non-cognitive and cognitive entities - the intelligibility of life - will be able to permit such a discovery. This transdisciplinary paradigm as stated by Lupasco (1947, 1970, 1989) and Nicolescu (2002) [66, 67] will cover system theories, biological and genetic approaches, physics applied to the study of bioelectrical fields in plant and more generally in developing systems (like growth in plants), biosensors and energy transfer (like thermodynamics of short distance translocation (Tyree 1969, 2003) [68, 69], but also evolutionary sciences, informatics, bioengineering, information & cognitive sciences, ethological and anthropomorphic fields and finally epistemology. We cannot treat all these cross-disciplinary links here. It involves clearly different levels of knowledge, of culture, of transverse approaches defining the core-TD research constituting our collective approach. A process that turns biosystemic data into information and then knowledge. So, we chose to treat here two levels: the phenotypic and epigenetic plasticity recently developed at the plant level and then the noetic plasticity as a global transdisciplinary approach of all plasticogenetic processes (Debono,

2012) [70].

5.2 Phenotypic & Epigenetic Plasticity in Plants

Let us consider now the first point. This research area could indeed conduce to seriously reconsider monolithic views upon the whole plant as a living entity having its sensibility and interacting with its congeners and upon the "rigidity" of the genetic code of all species, including humans. The first point regards the consequences of phenotypic plasticity for plant communities. Callaway et al. recently studied trait-mediated interactions (TMI) among plants regarding variation in the abiotic environment, in the presence or identity of neighbors and in herbivores [71]. They conclude as following "We consider how plastic responses to these factors might affect interactions among plants. Plastic responses to the abiotic environment have important consequences for conditionality in competitive effects, to the point of causing shifts from competitive to facilitative interactions."

Because plants show a high degree of plasticity in response to neighbors, and even to the specific identify of neighbors, phenotypic plasticity may allow species to adjust to the composition of their communities, promoting coexistence and community diversity. Likewise, plastic responses to consumers may have various and counterintuitive consequences: induction of plant resistance, compensatory growth, and increased resource uptake may affect interactions among plants in ways that cannot be predicted simply by considering biomass lost to consumers. What little we know about TMI among plants suggests that they should not be ignored in plant community theory. Although work to date on the community consequences of phenotypic plasticity has been hampered by experimental constraints, new approaches such as manipulating phenotypes by using signals instead of actual environmental conditions and the use of transgenic plants should allow us to rapidly expand our understanding of the community consequences of plant plasticity. This is a good example of the consideration of the whole plant organism and its interaction with other plants and the environment.

A second approach regards a very recent discovery from the Salt Institute of biological studies publishing a paper in Science about transgenerational epigenetic (TE) instabilities in plants (Schmitz et al., 2011) [72]. The researchers of the Ecker's laboratory show after a mapping of the epigenome of Arabidopsis thaliana upon 30 generations, that successive TE methylations were able to generate new allelic transition states altering transcription without genetic mutations in this characteristic plant specie. As *Science Daily* titles, it is the first time that a "hidden" code in DNA (an epigenetic active and flexible code) evolving more rapidly that the genetic code is discovered. Moreover, functional and morphological modifications were observed in some generations, indicating a high plasticity in a short period. That could strongly and quickly influence biological traits and be highly predictable not only for plants, but for any organisms, including humans and their children. It could also be the case for human twins exhibiting different biological traits with the same DNA sequences. Other demonstrations about epimutations are clearly needed. They can turn off or turn on some genes, so be reversible. Some contemporaneous genetic studies are controversial, arguing that these effects are probably limited on long-term evolution (Becker et al., 2011) [73]. However, new epimutations, even transitory, could give better advantages than selection and sometimes win.

5.3 The Plastic Code of Life: an Epistemic Access to the World

Together, these discoveries reflect common mechanisms at living cells and a great phenotypic plasticity. They may lead to a new lecture of the frame separating lower from higher organisms and to a consideration of the nature of the plastic processes involved at every level of knowledge acquisition. We propose this sequence: 1- consider living organisms as plastic entities evolving in the same way - interact intelligibly with the environment; 2- consider plasticity not only as a systemic property but as a logical principle registered in reality (Brenner, 2008) [74] and the "complex of plasticity" (Debono, 2010) [75] as the natural binding between matter and form, subject and object or brain and mind, i.e. an universal co-inherent or co-signification principle (CIP or CSP) ontologically linked to the Lupascos ternary logic and the Nicolescus levels of reality, 3- consider inseparable plastic interfaces (PI) and plasticogenesis as a dynamic process acting at each informational node or knowledge accumulating system (Table 1).

Each plastic interface - from the unformed-formed to the subject-object, from experience to consciousness - corresponds to a level of reality, as described

Table 1: Plasticogenetic Processes & Transversal Emergence of Noetic Systems.

Generic Principle	**Articulation**	**Semiotics**	**Translation**
Fundamental property of the matter	**Active binding** dynamic link (CP)	Informational levels	Noetic epicentre included middle **Tierceity**
Plastic Interfaces	*'The Plastic Code of life'*	**Ontological Crossroads**	Imaginaries, memories Metalanguages Individuation
(Unformed-Formed, Matter-Form, Percept-Concept, Subject-Object, brain-mind...)	Irreversible Processes inseparability	**Co-signification Processes** Co-inherency, Co-implication Co-evolution (CIP-CSP)	**Metadynamics** transversality transdisciplinarity transculturality
Plasticity	**Complex of Plasticity**	**Metaplasticity**	**Plasticity of Mind**

by Nicolescu (2011) and is ontologically linked to the other [76]. The plasticogenetic grid that we purpose will permit to more easily articulate these levels in a unique plastic scale. Four PI are concerned so far: the percept-concept one, the reality-consciousness one, the matter-psyche one, the brain-mind one and finally the noetic interface regarding a global 'noosphere' (Debono, 2012). The issue could be the *informed* or a series of co-creating worlds. It depends of our onto-epistemologies, of the plasticity of our memories and particularly of the archetypal ones (Debono, 2009) [77] and finally of our trans-objective & trans-subjective interactions with the created forms, with a-thinking (perceptive) or thinking (noetic) worlds or universes.

More globally, we must consider that plasticogenesis is a generic process in which we are inscribed as human beings like any living organisms. The basic sequence is linked to an observation: plasticity is a fundamental property of the matter that could be turn into form and vice & versa, this indicating an "evident" but crucial first plastic interface binding at the level of all morphogenetic processes (a plastic code of life) Debono (1999) [78]. Contrarily to elasticity, this binding is irreversible and dynamic, permitting co-evolution of matter-form aggregates or complexes being able, for the most evolved systems, to induce co-signified processes (Debono, 2010). These metaplastic steps necessarily create information, even at the lower scale, that can be translated into ontological, epistemic or phenomenological events by biosystems. The plasticogenesis describes all these states from minimal acquisition of information in plants to imaginary or metalanguages defining individuation processes and human consciousness (Table 1).

5.4 The Plasticity of Mind

The different grades of information were recently stated by Wu (2012): information in-itself, for-itself and regenerated information constituted by the first two, these basic forms establishing the essence of information further developed in social communication [79]. Moreover, as Brenner (2011) said it concerning the Wu's metaphilosophy of information constituted by these different grades, it constitutes an informational stance in which "the positioning of information as encompassing a critical component of disciplines, beyond the scientific content specific to them" is preponderant [80]. This attitude, also named *informational thinking* by Wu, allows a new glance on the rule of information in complex systems and defines an emerging field between science and philosophy of information fitting well with the concept of plasticity (Debono, 2007).

We have recently redefined "The plasticity of mind", in opposition to the classic philosophy or theory of mind, as a generic term designing the whole process of plastic dynamic acquisition of knowledge or consciousness (Debono, 2010, 2012). The plasticity of mind acts at three main levels: the plasticity of the process (from generic form to the plastic code of life), the plasticity of the subject included in the world and the plasticity of the mind in its extended noetic dimension. The plasticity of mind has as objective to transform the informed fields that surround us, to extensively use the unique articulation that animals and humans possess at different levels between experience and consciousness, and also to emancipate the self, particularly through Jungs archetypes (Debono, 2009). The expected result could be a better apprehension of the collective unconsciousness of humanity and the birth of new metalanguages or transcultures.

6 Conclusion

To conclude, we need to find a frame of transdisciplinary research to more acutely study the different plastic interfaces described so far, and particularly the informational or knowledge accumulating states reached by the so called simple biosystems like plants. The point of attack of the problem could be not to take into account only the biophysical properties of living organisms, but also to consider the epistemological links between matter and form, between perception and action, between transduction and information theories, and finally to rediscover the plasticity of life. The minimal 'cognitive' abilities of plants and lower organisms showing evolved behavioral and communicative abilities without brain is a good example to open and comfort new transdisciplinary fields combining at least biophysics, cybernetics, ecology, plant neuroplasticity, behavior, cognitive sciences and information theory. We could perhaps have then new insights about the life process itself.

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