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Information in Plants: The Informational Model of the Plant Cells and Plant Structures

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Abstract: The aim of this paper is to analyze and discuss the informational activity in plants, showing the unitary functionality on the entire scale of evolution and organization. For this, it is shown that matter-related information play a basic/fundamental/key role in living organisms, and allow to unify under a unique concept – that of information, the understanding and description of the structuration and functionality of living organisms, from the most humble structure – the prokaryotic cell, to multicellular organisms, plants and animals, via eukaryotic cells, the basic unit of them. The initiation of plants' development, from the small compressed / "zipped" seed grain, according to an apparent *a priori* "knowledge" / "know-haw" designed project, would be impossible without a continuous/rigorous communication between the "knowledge" and execution components, supported by matter-related informational mechanisms, consisting in embodiment/disembodiment of information during the structuration/destructuration processes. Information is therefore the powerful tool assisting the body growth/development/maintenance, and more than that, the dynamic inter-communication with the environment and body itself. Experimental evidences show that plants are sensitive/sentient to temperature, humidity, concentration of nutrients and their gradients, chemical substances and their gradients, gravity, tissue damage/mechanical pressure, to the neighbors light-competition, memorizing and deciding the optimal plastic tropism among the alternatives of confrontational vertical growth, shade tolerance and lateral-avoidance, or on the preferential direction of the root development, according to the neighbor architecture. An operative informational system OIS=CASI+CDC+IRSS can be thus defined, where CASI is the center of acquisition and storing of information, CDC the center of decision and command, IRSS the info-reactive sentient system, which can modulate the programmed informational system PIS=MIS+GTS+IGG for adaptation, where MIS is the maintenance informational system, GTS the genetic transmission system and IGG the info-genetic generator. The info-connection (IC) is defined as specific informational center, allowing to selectively distinguish the characteristic/valuable information of species/cell tasks among multitude of informational signals. On this basis, it is defined and discussed the informational system of plant cell and plant structures, showing that plants, although non-nervous organisms, actually as well as the eukaryotic cells, but with elaborated mechanisms for sensorial and info-communication between their components and with external environment, dispose of their own cognitive system, and therefore are able to make decisions and to adapt their structure and functions to the environment conditions. These evidences and cognitive behaviors are discussed in terms of informational of the informational system of plants.

Keywords: Information, Matter-Related Information, Informational Agents, Cognitive System, Informational Model of Plants

1. Introduction

The most part of the scientific community acknowledges that only the physics and chemical laws are not sufficient to describe the life processes, and even less the life as a specific phenomena, compared with the non-living structures [1]. Although the information concept is intensively used in communications and increasingly more in animals as the nervous system is concerned, it is still not well understood the role of information and informational mechanisms at the microscopical and global level of the organisms, and even less in plants, and how the informational processes at these two scales are correlated. Significant advances were registered recently on this line to understand better the life phenomena in living structures [2] at the unicellular level and in the human organism, within the frame of the informational system of the human and living structures [2, 3] by the introduction of the structuration/destructuration as a mechanism involving/assisted/determined by information, or by embodiment/disembodiment of information in the living organisms [3]. It was shown also recently that information play not only a determinant role in structuration and functioning of the living organisms [4], but also a contributing role in structuration of matter itself [5], so that an Universal Triangle of Reality could be defined, showing that information is a fundamental constitutive element of nature, together with matter and energy. This is a new viewpoint, allowing to approach from the informational perspective the living, and to successfully explain and understand various older unsolved problems, such as the mind-body relation [6], nature (inherited predisposition) or nurture (training) dilemma in psychology [7] and others in psychiatry [8, 9], neuroscience [10-13] and geriatrics [14].

In spite of their apparent passive presence in our world panorama, some older [15, 16] and more recent [17, 18] significant experimental and theoretical studies on plants' behavior shown that these are also a “vivant" partner of the living world, and on this basis it can be defined an (even if controversial) protomeural network for communication in plants [19-21], and even to debate the concept of a minimal consciousness in plants [22, 23]. In order to cover the mentioned gaps, in this paper it is presented an informational model of plant cell and plant structures, showing the coherent structuration of the living organisms at the basic and global level, allowing the multicellular development and multivalent diversification of their behavior as a function of the local natural conditions of environment, referred basically to the matter/food resources and informational stimuli acting to their informational system of connection with the external and internal reality.

2. Information/Matter-Related Information and Info-Related Mechanisms in Plants

Differentiating the plant kingdom from that of the animal organisms, we have to note that although the multicellular structuration is based for both of them on the eukaryotic cell, the non-moving, stationary state of plants, fixed into their soil, don’t shows evident possibilities to refer to their functions and behavior from informational perspective. However, if we observe the growth of a plant, initiated by the development process in the small compressed “zipped" seed grain – according to an apparent *a priori* “knowledge"/”know-haw" designed project, that drives a “blueprinting” building algorithm, we will realize that such a development would be impossible without a continuous and rigorous communication inside of the body organism, between the “knowledge” and execution composing components. Such a communication is possible by matter-related informational mechanisms, as it is shown below. Information is therefore the powerful tool assisting the body growth and development, the maintenance of the body, and more than that, the dynamic inter-communication with the environment and body itself.

Entropy can be used as a thermodynamic quantity to measure the degree of disorder inside of a material system composed by micro-particles with energies distributed statistically, according to Boltzmann distribution [1, 24]. Information in the theory of information [25], refers to a distinct property, concerning the communication in the electronic systems composed by a source of information coupled with an encoder of information, a communication channel and a receiver, coupled with an information decoder. In a larger sense, we can refer therefore at information as a result of an operation, of a knowledge process or communication, detectable as a change event within an interacting emitter/receptor partnership system, each partner disposing of own coding/interpretation capability. Whereas information refer to the certainty of an event or knowledge, the informational entropy is associated with uncertainty and unknown state, within a binary YES/NO complementary system, expressed in statistic terms. Accounting for a basic informational mechanism that consists in the interaction/communication between two component A and B, the structuration (=>)/destructuration (<=) process takes place with the intervention of information (I), and can be represented schematically by the elemental basic relation:

$$(A + B) + I < = > AB(I) \quad (1)$$

where (I) is the hidden / “embodied” information [26] in the new configured structure, absorbed/integrated by the structuration / “embodiment” (=>) process. The information can be released / “disembodied” during the destructuration (<=) process, according to relation (1).

The core activity in an eukaryotic living cell, the basic building unit of the animals (Figure 1 upper side) and plant (Figure 1 bottom side) structure is informational, because the main basic processes which assure the body building/maintenance and reproduction within the strict designed parameters are driven by informational processes. The replication of the deoxyribonucleic acid (DNA), composed basically by double helix strands with a huge number of sequences of nucleotides – i.e. adenine (A), thymine (T), guanine (G), and cytosine (C), bonded each other by a binary YES/NO Bit-type complementarity, is the primary step for the reproduction of the cell to form two mother-daughter identical units. Within such a process, A can be associated only with T, and G only with C, to form chemical bonds base pairs, which connect the two DNA strands by means a hydrogen atom. The first step of the DNA replication is the splitting of the DNA molecule in two strands, which serve as templates for the two DNA molecules (DNA => 2×(½ DNA complementary strands), followed by the reconfiguration of each strand in a new DNA molecule by the intervention of polymerase enzyme, i.e. ½ DNA + (DNA Polymerase) => (DNA duplicated structure), with identical informational properties like those of the initial DNA molecule, according to informational processes schematically represented by relation (1). The accuracy of the replication process is extremely high, of the order of one mistake for every 10^{10} nucleotides copied. All information library with the entire vast quantity of genetic information – the instructions for the cell building and functional activities, is stored there, the stable/genetic memory of the cell [27]**.** Actually, the origin of the first living organisms, with about 3.5 billion of year ago, was probably initiated with the replication of the RNA molecules, which is a fundamental mechanism of the living structures, able to catalyze their own replication process [27].

The release of the genetic information in the cells from the genetic stored "library" – the DNA molecule, is achieved therefore by an informational assisted unidirectional (=>) process, in a specific "language", allowing to copy various DNA sequences and to transmit them as "words"/"knowledge"/messages, operated by the messenger ribonucleic acid (mRNA), and "communicated" to proteins, the basic "bricks" of the organism body, in a four-"letter" "alphabet" of the DNA nucleotides, within the transcription and translation processes, from nucleus to cytoplasm of the cell (Figure 1 upper side). The organization complexity for various species, arranged in ascending order, measured in Bits [28], can be evaluated from the following comparative data: *Reinhardtii* (green alga) 3.97e7, *Aegypti* (mosquito) 1.08e8, *Vitis vinifera* (grape) 1.89e8, *Salmo salar* (fish) 3.02e8, *Oryza sativa* (rice) 4.10e8, *Gallus* (chicken) 4.13e8, *Aestivum* (wheat) 4.89e8, *Zea mays* (maize) 4.93e8, *Bos Taurus* (cow) 5.28e8, *Sus scrofa* (pig) 5.49e8, *Homo sapiens* (human) 8.38e8. These findings show that although immobile, plants (grape, rice, wheat, maize) exhibit a complexity degree comparable with some species of animals (*Aegypti*-mosquito, *Salmo*-fish, *Gallus*-chicken), evaluated in terms of genetic information. The strategy of living organisms to increase their organization level on the evolutionary scale by the minimization of entropy, counted in terms of thermodynamics, is referred especially to the compartmentalization as one of the main way, but this process seems to decrease however the organism entropy with reduced quantities in comparison to the lost entropy eliminated as heat in the external environment [24]. However, absorption of information is a serious factor of organization, which should be taken into account [1, 24].

The energy in the animals cell is obtained by the quantum breakdown of the chemical bonds of carbohydrates (glucose), fats, proteins, and in the plants cell by the quantum-assisted (photon-absorption) photosynthesis in the plants chloroplasts, which reacts with oxygen obtained from a respiration process in mitochondria organelles, excretory wastes products (carbon dioxide, uric acid, water and small molecules) being eliminated outside [1]. More explicitly, the metabolic process of the conversion of the adenosine triphosphate (ATP) in adenosine diphosphate (ADP) assures the energetic necessities of the eukaryotic cells, the basic life unit of plants and animals, as it is schematically shown in the upper side of Figure 1. The concentration balance between ATP and ADP works as a binary (YES/NO) informational factor [1], determining the metabolic process of additional production of ATP in mitochondria of the eukaryotic cells, if its concentration is lower than that of ADP, or stop it in the contrary case [29, 30].

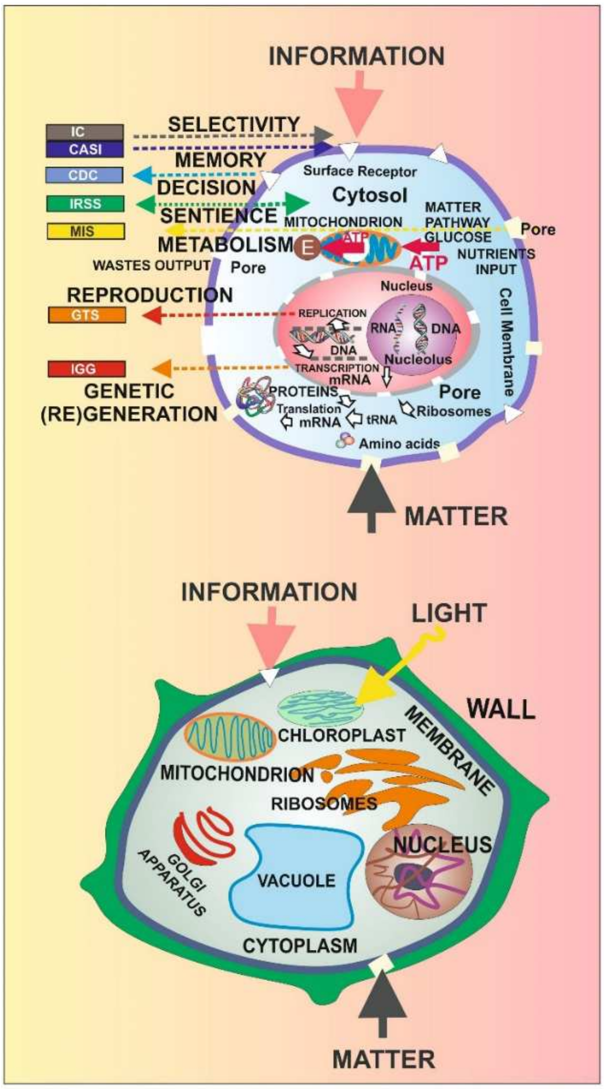

Figure 1. *Schematic representation of the informational system of the eukaryotic cell, for animals and plants; the plant cells possess walls providing the structure support and chloroplasts, as a specific food provider by the light-assisted photosynthesis process.*

The unicellular organisms (bacteria, yeast), although with an independent life, communicate between them by a specific process called "quorum sensing", coordinating their common behavior, such as the mating/sexual conjugation, motility, or even antibiotic production [27]. In animals, the nervous cell transmits information by ionic (YES/NO – ALL-or-NOTHING) Na^{+}/K^{+} pulses along the axon and furthermore by competitor species of stimulatory/inhibitory (YES/NO) neurotransmitters within the synaptic junction gap of the neighbor nervous cells [31]. All these living structures act therefore as informational self-coordinating organisms, able to communicate with the external environment, with themselves, and with the collaborating partners. We have to observe further that the communication in the living organisms can be discussed in terms of information and informational circuits, by using the concepts earlier proposed in the theory of information [25], applied in a system composed by an informational source and a codifier, which can correspond in the cell of the living structures with DNA molecule, a channel of communication, which would be the chemical reaction routes/pathways (so circuits) in the cell nucleus/cytoplasm, and a receiver (specific target), decoding the detected information, which is basically represented by the proteins achieved from DNA.

If we refer to the inter-communication between cells, the informational source is a cell which secretes into the extracellular fluid the signaling molecules that act as informational agents, assuring the local (paracrine) communication with other receptor (target) cells, generally of different type, or with themselves (autocrine communication). The external information is detected by the surface receptors, as mentioned above, but the diversity of the cell response is given rather by the combination between signals, than the high number of signaling molecules [27].

Although have a common origin – eukaryotic cell, the plants and animals followed divergent development routes, the eukaryotic plant cell acquiring the chloroplast (Figure 1 bottom side), a specialized organelle which converts light into chemical energy products (glucose) by light-assisted photosynthesis process, but the general features of communication are frequently very similar in plants and animals. In particular, the mechanisms of reception of the external signals on the membrane surface are based on chemical complementarity between the two partners, although the classes of proteins (surface receptors) and ligands (signaling agents) are different. Some species of hormones operate as intracellular growth regulators, and light plays a determinant role in plant development by means of a variety of light-sensitive photoproteins (sensors), and with a fundamental role in the preparation of glucose in chloroplast [27], the energetic “fuel” used by mitochondria to produce energy in the cells, as mentioned above.

Plants are sensitive to temperature, to humidity, concentration of nutrients and their gradients, chemical substances and their gradients, gravity, tissue damage/mechanical pressure [32] and even to the neighbors light-competition, memorizing [33] and “choosing”/“deciding” optimal plastic tropism among the alternatives of confrontational vertical growth, shade tolerance and lateral-avoidance, or on the preferential direction of the root development, according to the neighbor architecture [33]. The temperature is a fundamental, key parameter, which triggers the initiation of the seed germination [34, 35] and the vernalization process (the inflorescence period), when a temperature threshold value is exceeded [36], operating as a YES/NO type informational factor [1].

3. The Informational Model of the Plant Cell and Plant Structures

According to the above discussion, information is an active participant to the functionality of the living organisms, and information is matter-related under various forms, as absorbed embodied/hidden information and released information, ready to be transported by various chemical or electrical agents, as schematically represented by relation (1). Analyzing the genetic functions of the living organisms discussed above, we have to distinguish two main groups: one of them refers to the genetic activity for reproduction of cell by replication process, another is referred to the development/(re)building of the body cell by transcription/translation processes to produce the necessary proteins, the basic building “bricks” of the body of unicellular organisms and of animals and plants. A distinct group concerns the metabolic processes to maintain the material structure and its functions, by the processing of the incoming foods (nutrients, air, water) to produce energy and micromaterial components for the body maintenance.

On the other hand, as the existence of the living organisms depends on the permanent change of matter, energy and information with the external worlds, an active info-communication with the environment is absolutely necessary for the food finding/access to the food resources and adaptation to the external changes. Within the multicellular organisms, the permanent communication between the cells of the body assures the coherent and coordinated functions of the entire organism, as an independent functional structure. We can distinguish therefore between a programmed informational system (PIS) dedicated to the fundamental tasks of the organism, and an operative informational activities, dedicated to the adaptation to the changes of the environment, as a response to the external received information. The programmed informational system (PIS) concerns the following functions: (i) the body maintenance, based on metabolic processing of the necessary incoming matter (food, air, water); (ii) the info-inherited genetic generation for the body growth and development according to the age; (iii) the reproduction of a new generation for species proliferation.

More evident at human, the informational functions of the organism can be described by the Informational System of the Human Body (ISHB), recently reported [26], which could be synthetically represented by the following relation:

ISHB = > (memory) + (decision) + (emotions) + (self-status/health/vitality) + (biologic reproduction) + (genetic inheritance/predispositions) + (info-selection/certainty) (2)

An attentive examination of the functions of the eukaryotic cells [37] reveals that these comply with similar functionality like human multicellular organism: the eukaryotic cell disposes practically of organelles similarly with the organs of the human body (Figure 1 upper side), the plant cells being enveloped moreover in walls that support the architecture of the plant, and including the chloroplast organelle for glucose preparation by a sun light-assisted chlorophyll reaction (Figure 1 bottom side). By comparison, we have to observe therefore that the cell outer membrane of the eukaryotic cell corresponds with the skin, the Golgi apparatus with the heart (distributing "engine" of nutrients and oxygen to the body), the rough/smooth endoplasmic reticulum is equivalent to the pancreas/blood vessels functions in animals, with specific role also in detoxifying processes in liver [34] and steroid hormones (testosterone, estrogen) in the reproductive organs, the vacuoles are the "stomach" of cells, storing food and water for further use, very well developed in plants, the ribosomes and mitochondria (with membranes specialized for aerobic respiration) corresponds with bowels and lungs, because they produce/extract proteins and oxygen-assisting energy from foods, whereas the cytoplasm correspond to the muscles, and cytoskeleton with bones in the human body [37]. The metabolic process supported by organelles in cell is automatically managed, so a maintenance informational system (MIS) of the cell could be defined. Similarly, a genetic transmission system (GTS) and an info-genetic generator (IGG) of the cell can be also defined, managing the multiplication/reproduction of the cell, initiated by the replication process, and the transcription/translation process to construct/reconstruct the body cell during the life cycle of the growth/development, respectively. According to recent researches [27], the cell-cycle is controlled by a system consisting in a series of biochemical switches, each of them initiating a specific cell-cycle event, which determines/increases the accuracy/reliability of cell-cycle progression in an irreversible fashion, so that we have to observe that such a control is assured by chains of informational YES/NO (ON/OFF) binary elemental informational steps, acting similarly with the info-processing in our informational devices, by the commutation transistors. On the other hand, we have to note that the replication is an informational process, acting by (destructuration (<=)) / (restructuration (=>)) mechanisms with release/absorption of information, described schematically by each of the partial reaction of the relation (1). Like in the human and subhuman organisms, a programmed informational system can be thus defined as above, indispensable for the maintenance of life and long-time survival by means of the offspring in cells and all living organisms, including plants.

The functions of PIS are not sufficient however to assure the momentary and even neither of the long-term survival. As permanently dependent on the external environmental conditions, first of all necessary for the connection with the nutrients (food, air, water), the eukaryotic (like prokaryotic cell too) [37], are connected also to information, necessarily to detect the food recourses, to compete with other rivals if necessary, and to defend against the danger. Therefore, indifferently if we acknowledge the capacity of plants to informationally drive or not their "fate" [37, 38], we have to agree that in a form or another, plants should dispose also of an OIS, even if in a form not so evident like animals. A first evidence is offered by the evolution itself, showing the huge variety of plants, from aquatic to terrestrial, and from plants limited to use only the nutrients from soil to carnivores plants, adapted each of them to the surrounding possibilities. As a prelude of adaptation, which is actually a decisional act, these organisms must detect/"know" the informational panorama of the surrounding situation, by an OIS intervention.

Referring to the cell, as it can be seen in Figure 1 upper side, and previously argued [37], the semitransparent membrane plays a fundamental role for a selective YES/NO binary mechanism of the transfer from/to the cell of the necessary matter-related informational agents for the interchange with the environment, in particular in the multicellular organisms, including plants. The direct cell-cell contact become a fundamental sensorial mechanism of the transmission of information and intercommunication between cells in plants, which allow the coherent correlation for the macro-cellular development and reactive processes of the entire plant organism. The role of a center of acquisition and storing of information (CASI) in cell is played primarily by the network of surface receptors, each class of them receiving only a previously proved fitted information, actually interpretable as a local memory, and the YES vs. NO choice as a local elemental decision. The surface receptors are sensitive info-detecting elements, so CASI is related to sensory signaling network also, able to detect information. The role of a center of decision and command (CDC) is played by a final result of the cascade of successive/subsequent events inside of the cell cytoplasm near the receptor, going deeper inside along the reaction pathways (informational 'circuits') toward the target, for a reactive decisional response. Instead of an info-emotional system (IES) in human and animals, an informational reactive-sentience system (IRSS) can be defined in cells and multicellular organisms (plants, animals), appropriate to make the cell/plant/animal to "feel" itself the result of interaction with the input information. The role of an info-connection (IC) center in cell/plants/animals is played by surface receptors/specialized systems organized to detect among a multitude of signals only the specific ones, developed to assure the living existence within the specific surrounding informational scenario, favoring the certainty/experienced (YES/ACCEPTANCE) information among others (NO/REJECTANCE). In multicellular organisms like plants and animals, each cell is engaged to serve certain type of functions according to specialized functions/tasks of the organ which they belong to, so IC is related to such type of communication/info-selective sensitivity. Consequently, an informational system of the plant structures (ISPS) can be therefore defined as follows:

$$ISPS = [(CASI+CDC+IRSS) + (MIS+GTS+IGG+IC)]_{ISPS} \quad (3)$$

Experimental evidences [39] show that plants, these silent creatures, without obvious expressiveness, dispose of such a sensitive/cognitive system connected to CASI, with a development degree and specificity according to the local development conditions. They are able to detect humidity/humidity gradients, light/light intensity, gravity and electromagnetic fields, volatile chemical components, used as a communicating channel with insects and animals to attract them for polination (GTS), or as defense against the predators (danger sentience/decision – (IRSS/CDC), electrical signals and vibrations. In animals, the sentient-reactivity to danger (in human felt as fear), is one of the primordial necessary signal, triggering the defense system, so it is reasonably to admit that the detectable reactions to danger at plants, would be a consequence of their IRSS activation. The beauty of flowers in colors and smells, are also a channel of communication with the others surrounding creatures, for pollination, which also indicates a special sentience of plants to "know" how to be "appreciated"/attractive by surrounding cohabiting partners in their local ecosystem. Plants are able also to recognize the parents and family provenience (IGG) by their sentient-cognitive system (CASI/IRSS), covering more than twenty different sensorial capacities [39]. Roots are selective and decision makers, which can discriminate kin in competitive interaction of root allocation [40, 41]. This behavior is actually a natural consequence of selective proliferation of own genetic/development (IGG/MIS) system in the IC-detected environmental competition. In other words, each species is able to distinguish selectively through IC the characteristic "values" of species among those of the partners, and to interact with them (CDC) in a differential fashion.

The time scale reactivity, slower in comparison with animals, is a reason of weak relevance detection of the plants response to information, but not always. The defense against the predators (danger sentience – IRSS) can show selective and decisional operability (CDC), by the choice of the place and moment to release a toxic compound, only in the leafs attacked by insects. *Mimosa pudica* is a well known plant, which responds rapidly to touch, closing suddenly its leaves. The touch is an evident and basic sense of at least 600 species of carnivore plants (like *Venus flytrap* for instance), able not only to detect the prey (CASI), from insect to mice or even birds, but also to trigger a rapid motor response (CDC) and mechanical "devices" – execution elements (EE) – to catch, hold and devour the animals, and an appropriate digestion metabolism (MIS). Based on electrical signal dynamics of Ca^{2+} ionic channels and calcium concentrations in the leaf cells, common otherwise in plants [27], the catching mechanism is performed in two steps: one after a first sensor activation, insufficient to trigger the trap, but sufficient to initiate a short-memory process (CASI), and a second sensor activation, when the trap should finally snap shut. In this way, it is obtained an optimized process of catching, with an energy spent only for a sufficiently big insects, necessary for the digestion [42, 43]. The roots of the (terrestrial) plants seems to be more adaptive to the surrounding situations, both concerning the detection capabilities (CASI), decision making (CDC) and executive engagement (CDC/EE), because they are able to organize their route accordingly, even with anticipative operability (IC), before to meet physically an obstacle, avoiding it, leaded/driven by a basic objective/intentional force, that of the optimization of the searching (CASI/CDC) and catching/intake of the food resources (MIS). The plant tropism and the capacity to memorize (CASI) and to choice between variant alternative (IC/IRSS/CDC) [32], i.e. vertical growth, shade tolerance and lateral-avoidance [33], demonstrate the cognitive operability, memory and decisional capability of the plants.

The capacity to learn, well distinguished to animals, was also revealed in sensitive plants like *Mimosa pudica*, showing the defensive leaf-folding behavior in response to repeated physical disturbance, a clear habituation and even a relatively long-lasting learned behavioral change as a result of previous experience, suggesting therefore some elementary form of learning [44]. Learning by association with other previous experiences (CASI), induced during/after repetitive and/or informational actuation on an organism, triggers epigenetic adaptive/evolutionary mechanisms, as it was earlier stated in the informational model of consciousness (IMC) [26] and informational model of leaving structures (IMLS), with transgenerational (GTS//IGG) consequences [45]. Such experiments revealed in plants, which are also able to acquire learned associations to guide their foraging behavior, in particular regulated by metabolic demands (MIS) [46], confirm the application of this finding in plants. As it was also shown recently, the ability to structure/memorize and recall new information/relationships established via associative learning (CASI), constitutes a valuable premise to understand that this is a universal adaptive mechanism shared by all organisms [45, 46].

The network of mechanoperception sensors (CASI) within plant cells is similar to the network in animal systems, and is crucial for the plant development and adaptation [47]. Such a sensory network is the basis for a unifying hypothesis, which can be extended to understand the perception of numerous mechanical signals referred to gravitropic, thigmomorphic, thigmotropic, self-loading, growth strains, turgor pressure, xylem pressure potential, and the mechanical vibrations of sound [47]. As light is not only a source of energy for plants by photosynthesis process, but also a sensitive way to detect (CASI) reality, to inner "feel" (IRSS) and to respond (CDC) to the surrounding status, changes and vital resources, the plants evolved sophisticated light receptors and signaling networks to detect the light intensity, duration, spectral quality and localization, that allow the drive developmental transitions such as germination and flowering, and continuously shape development for adaptation, based especially by the light modulation of auxin signaling that elicit local responses, long distance signaling, and coordinated growth between the shoot and root [48]. The long-distance communication process between plants was demonstrated showing that the wounded leaves signalize their damage status (IRSS), which stimulates the production of *jasmonates*, potent regulators of defense responses [49]. The plant defense against the attack of the herbivores or pathogens is represented by a sophisticated signaling network, involving the danger communication within the entire organism (IRSS), elicited and driven by both herbivore-induced factors (e.g., elicitors, effectors, and wounding) and plant signaling (e.g., phytohormone and plant volatiles), in rapid response (CDC) to arthropod factors [50], by cascade of molecular activation/suppression (YES/NO) mechanisms.

The interpretation of external and internal information in living structures is referred not only to analytical comparison and selection with respect to the needs and earlier experience (CASI/CDC), but also as "feeling"/sentience response of the internal sensitive reception, by IRSS, as pointed out above. Emotional sentience for internal/external adaptation and for an adequate choice (YES/NO) between GOOD/BAD experiences [37], is an expanded definition of emotion on the entire biological scale, including plant behavioral agency (despite being rooted in place) [51]. This is supported by a regulatory phenomenal mechanism, orienting any vegetal toward a meaningful self-relevant environmental awareness, toward evaluative preferences and trauma remembering within the interaction with environment [51]. In consensus with ISPS and with the information system of the living structures (ISLS) [1] such a capacity of the living systems to adapt their functions, shape and architectural structuration to the ambient conditions, to correct incidences or accidents in their organizational intimate processes, displaying complex regulatory networks for adaptations to stress conditions that maximize the probability of survival under inevitable ecological changes, cannot be possible without a cognitive capacity [52].

As we live in our own system, and therefore we take it as a reference to evaluate/judge other systems, in this case plants, we are used to compare the organization of the plant structure with the human organization. Like human but differently, plants have organs, but much less. Roots keep plants securely in the ground, assuring not only mechanical stability, but also water and nutrients from the soil (matter connection). Stems, assuring the support of leaves and flowers, act also as transit channels for the basic nutrients to branches, leaves – (MIS), flowers/seeds – GTS//IGG products, as an architectural "neck" of the plants. Roots, stems and leaves are organs dedicated to the metabolic (MIS) processes, but not only. As stated earlier, because the living matter, in any of its surface or volume unit receives and transmits information, can be defined as informed mater, supporting the info-communication processes, both as embodied/disembodied or transit informational streams [28]. Therefore, in particular, the plants are sensitive on their body. However, contrary to the organization in human and animals, where the centralized informational system is in the head, which is provided also with the main perception system – eyes, ears, smell and taste sensors, it seems that roots in plants are provided with centralized decisional/sensorial capabilities. Indeed, the root apices behavior of plants are often compared with 'like-brain' decisional center, because this vital organ is able to make timely decisions and solve problems concerning the optimal orientation [53], according to the local conditions, and also to transmit executive commands of plasticity to the root body, to work as a lung-like respiration system, besides stem and leaves (energo-laboratory), and a 'heart'-like pumping/distributer of water and nutrients toward the entire plant structure, maintaining physiological balance throughout the plant and hormonal info-communication (by auxin like 'neurotransmitter' and plasmodesmata like neuro-gap-junctions [27], to acquire and store nutrients like a 'stomach' (potatoes/carrots/tubercles-type). The light-exposed superior components of the plants wear the sexual organs (flowers and seeds – GTS to IGG) for the reproduction of the offspring, and photosynthesis – light-assisted/chlorophyll reaction (Carbon Dioxide + Water → Glucose + Oxygen), in many ways opposite to respiration (Oxygen + Glucose → Water + Carbon Dioxide and Energy), in metabolic laboratory (leaves and stem – MIS) [53-57]. In the seed (IGG), in particular in that of a plant called *Arabidopsis* (or *thale cress*), it was shown that this contains two groups of cells, one of them promoting the dormancy, and another germination, with a communication by a hormonal mechanism [58], so with contrary/complementary excitatory/inhibitory YES/NO functions like in the brain [8]. The protoneural activities in plants are revealed actually in various forms, as electrical and synaptic-like/neurotransmitter-type communication [53].

Working in seven informational registers, the living cells can associate and organize themselves in various forms in complex multicellular structures, can solve problems of adaptation to the environment and in correlation with the existing conditions, (even if) through various forms of structural architecture, interpretation of the surrounding reality and reactivity, demonstrating thus their endowment with a cognitive/sentient/predictive/reactive informational system (OIS). This is capable to react/adapt the living organisms, sometimes adding new traits, even if more slowly (in plants) or more rapid (in animals), often transmitted in multi-generational steps, driven/assisted by mechanisms of epigenetic processes, which change their behavior and even their plasticity. Such unique/unitary biological property/capacity manifested on the entire living organizational/evolutionary scale, referring it to a minimum (cell) or to a maximum level of development (human), manifests/demonstrates actually the powerful intervention/contribution of information in the development/maintenance/evolution of the living/plants organisms, as revealed by the activities of ISLS/ISPS. Such a property is supported by informational processes of communication within every cell and between them. The extent to which this activity is reflected in a certain way, with a certain amplitude and under a certain fashion and degree of integration in the individual/species detection system, allowing the local and/or global evaluation/decisional-reactive intervention on own system as an adaptive response, represents the level of cognition/awareness of each living structure. As the living cell, the elemental unit of all other living multicellular structures, shows the same basic informational structure like the multicellular organisms with more evolved organization, communicating/collaborating all of them for the survival of the whole, even if the individual sacrifice is necessary, indicates the possibility to define a conscious level, even if rudimentary, in the inferior organisms, which can be defined as proto-consciousness.

Whereas some behaviors can be biologically programmed (synthetically represented by PIS) [37], cognition requires a minimal form of autonomy of the organism that involves memory, choice, and decision making [23], which is actually represented by OIS, on the entire living structures range [37]. We may understand therefore that the informational system of the living structures (ISLS), from eukaryotic/prokaryotic cells to plants (ISPS) and animals, actuates not only to assure a "blind" execution of the metabolic/reproduction tasks inherited from the anterior generations of a species, but works also in function of the actual, time-scaled conditions of environment and of own status, adjusting the parameters of internal actuation (growth, development, movement, to specify only a few of them), expressed accordingly by their attitude/informational output [59], as a reaction of OIS for short-term period, but also on a long-term scale by epigenetic processes, transgenerationally transmitted [45]. Actually, the evolution could not be possible without an individual informational system, interconnecting the living structures with their environment, which allows the adaptive adjustments of their functions/operability. Each organism/species lives in its own world, developing its own proper characteristic informational features and IC orienting system in their environment [34], according to the local conditions [60], as the information system of the living structure shows. Therefore, within the debates evoking pro [61] and contra [62] arguments of a minimal consciousness in plants, it should be taken into account the definition of a proto/minimal consciousness promoted in this work, valid taking into account the fundamental characteristics of the informational system on the entire scale. Human consciousness cannot be taken thus as a reference and cannot be compared with other forms, because each species lives in its own system of reference, with own perception and interpretation level/model, but what is common is the similar structure of the informational system and its components, expressed each of them in specific way/fashion on the organizational/evolutionary scale.

4. Conclusions

Information is a key component of the living structures, in particular in plants, operated/manifested by structuration/destructuration in the living organisms, absorbed/embodied into the compound structures and released/disembodied by decomposition. The unicellular organisms and the cells of the multicellular living organisms/plants structures communicate permanently with themselves, from DNA to proteins, the bricks of the body, for gene expression and body growth/development during a transcription/translation process, and for replication to form a new cell. Such a communication consists in messages/instructions sent by chemical/electrical agents/signals from some cells to another, or with participation of various signaling molecules and chemical cascade reactions/pathways in cell, with a functional scope, so the living organisms/plants can be regarded as active informational systems, changing information with the external environment and with themselves. The energy and the substituting elements for metabolic maintenance of the body are processed by connection with matter – foods, air water and with solar light in plants, so the living structures are connected to matter/energy and information.

The comparison analysis between the functions and organization of the human organism and the eukaryotic cell, which exhibits distinct organelles with respect to the prokaryotic cell, shows a great similarity between each other, revealing seven informational cognitive registers/activities of interaction with reality and themselves: memory, decision, sentience, self-status/health/power, biologic reproduction, inherited genetic information, info-selectivity, as a result of corresponding driving activity of the informational systems defined as CASI, CDC, IRSS, MIS, GTS, IGG and IC respectively, each of them involved/manifested in various behavioral forms, experimentally evidenced. Although not provided with a nervous system like animals, with a slower reactivity but not always, plants dispose of the full range of informational capabilities to lead/manage their development in relation with the local environment conditions and emergent events, detecting them, sometimes in advance, making decisions for plastic adaptation, for defense against the predators, or attraction for pollination, and they are even able to differentiate the kin among other surrounding partners and to behave accordingly. These evidences strongly support the informational model of plant cells and plants, and add contributive arguments to those referring to all living structures. However, distinctly of them, and in accord with the common structure/functionality of the informational system, we state and define in this work the existence of a primitive/rudimentary cognitive system and consciousness of all living structures, strictly related to the informational system, with various degrees of development according to particular endowment sensorial/cognition tools and interpretation of surrounding reality, from proto-consciousness level of unicellular organisms, to human consciousness, as commonly interpreted in this case.

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