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The primal integrated realm and the derived interactive realm in relation to biosemiosis, and their link with the ideas of J.W. von Goethe

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Certain phenomena in Nature which might logically be regarded as indicating biosemiotic communication, with signal, receptor and interpretant, may, in fact, indicate no such thing. Instead, the respective phenomenological observations may point to an underlying system that J.W. von Goethe termed an "Urphänomen". From such Primal Phenomena emerge derived phenomena, or "Types", which are made substantial by processes that uniquely define Life and Living. Biosemiosis arises and takes place within the derived Types. Examples of Primal Phenomena and their derivatives are taken from recent observations on the putative influence of the lunisolar gravitational force upon animal and plant behavior, and from some aspects of plant development that show connection with Goethe's idea of the "Urpflanze".

At a recent biosemiotics symposium, after a presentation concerning the putative effects of the lunisolar tidal acceleration upon plant behavior,[1] the question was asked: "Where is the signal?" Following further analysis of published time courses of behavioral activities in various organisms (plants, crabs, iguanas, mice, gerbils, ...) in relation to the contemporaneous lunisolar tide, it became evident not only that the material presented at the symposium, as well as the question it provoked, were rooted in a "Newtonian" or reductionist approach to science, positing cause and effect, and relying on theory-oriented experimentation, but also that this approach may not be appropriate for dealing with the phenomenon in hand. Since biological material is always and everywhere subject to the lunisolar gravitational force, experimentation in this area is limited. Besides, there are at present only glimmers of hypotheses or theories as to how lunisolar gravity and biological organisms have come to show a connection more substantial than mere folkloric hearsay, let alone of how the two items might interact, either physically or physiologically. But these apparent drawbacks favor the possibility of considering this scientific investigation from another perspective, which contrasts with the former approach: the perspective of "exploratory experimentation".[2] Here, the emphasis is on experimentation aimed at discovering the conditions or influences necessary for the phenomenon under study to become manifest, and to explore the nature of the links between related observations. The latter aspect—the link between sets of observational results or descriptions—requires deep familiarity with, and sensitivity toward, the phenomenon under study, as well as openness to the faculty of intuition. In particular, the methodology of exploratory experimentation comes to the fore in situations where there are no conceptual frameworks for the phenomena under consideration.[2] It also allows sight of the primal conditions from which all ancillary effects proceed. In some ways, these two interpretative strategies, the Newtonian and the Exploratory, are akin to the Apollonian and Dionysian ways of science described by Nobel Laureate, Albert Szent-Györgyi.[3] Moreover, the latter Exploratory/Dionysian way would appear to be in line with the phenomenological attitude to scientific enquiry espoused by the writer and scientist, J.W. von Goethe.[4] The initial problem, therefore, of how the Moon can "signal" to life on Earth, and how Life can "receive" and "interpret" this signal, might benefit from this alternative, exploratory attitude. Then, not only could this guide the relevant observations about plant and animal behavior toward an acceptable, and necessarily novel, hypothesis, but could also indicate how such behavior casts light on the boundaries of biological organization that either permit or exclude biosemiosis—the processes mediated by sign, receptor and interpretation which take place within or between living systems in the broadest sense.[5]

Behavioral patterns often arise out of an organism's search for energy within its environment. Not only does this apply to plants, whose search is for light, minerals and water, but also to both marine and terrestrial animals, which search for similar alimentation, and in so doing also feed upon plant life, either directly or indirectly. In relation to plants and their search for light, a few species (e.g., beans of the genus *Phaseolus* and *Canavalia*) show distinctive diurnal movements of their leaves, which become raised during daytime and thereby maximize the capture of sunlight and lowered at night, though many plant species show analogous, but less evident leaf movement. Although commonly thought of as being regulated by an internal "biological clock", leaf movements are not truly autonomous; they are guided by variations in the lunisolar tidal force.[6,7] With respect to foraging behavior of marine animals, the marine tides are here widely supposed to play an important regulatory role, setting the times of activity and rest, although the foraging activity is also regulated by natural rhythms of light and darkness.[8] In plants, too, entrained rhythms of leaf-movement can be disturbed by brief exposure to light during a dark period.[9]

Marine tidal cycles stand proxy for rhythmic variations in the lunisolar tidal acceleration. This is evidenced in the wave of deformation that travels over Earth's spheroidal form, resulting from the mutual gravitational attraction between the Earth and the Sun and Moon. The magnitude of this attraction varies as these bodies orbit about each other during the courses of both a solar day (24 h) and a lunar month of approx. twenty-eight days, the varying attraction during the latter period being due to the eccentric orbit of the Moon around the Earth. This lunisolar gravitational force may be estimated in terms of minute variations in Earthly gravitational acceleration (units of μGals, where 1 μGal = 1 m s^{-2} x 10^{-8}). Because the lunisolar "gravimetric" tide (as we may call it) cannot be annulled, it can never be proved beyond doubt by experimental means that some types of diurnal variation of biological activity are by chance correlated with suggestive simultaneous temporal variations of the geophysical gravimetric tide or, for that matter, with simultaneous geomagnetic effects whose sources trace to temporal variations in the interplanetary magnetic field and the Solar wind. Studies of biological rhythms do, however, include attempts to annul many candidate entraining influences, such as light/dark cycles, temperature variation, etc., and in more sophisticated studies elimination of variation in both air pressure and geomagnetic fields has also been attempted.[10] Shore-dwelling crabs, for example, can be removed from their native tidal environment and placed in constant, free-running conditions in the laboratory, e.g., in continuous low-level light and constant temperature. Yet under such conditions crabs continue to display activity patterns that appear to track the rhythm of the marine tides to which they were previously exposed. These free-running, transplanted crabs had, therefore, either preserved from their past experience a detailed memory of their native marine tidal timing and could therefore predict the time of future high or low tides, or else they were subject (like their native marine environment) to the inescapable presence of the lunisolar tidal force and its moment-by-moment variation, and hence were able to sense a particular threshold range of rates of gravimetric tidal change which precipitated locomotory activity, or inactivity. Because, as already mentioned, it is not possible to interrupt or interfere with the lunisolar tide, the problem of which factor—marine or lunisolar—regulates animal activity seems insoluble; and, if one were to put aside the naive and prejudiced objection that "it can't be the Moon—its gravitational effect is too weak," then no doubt one would choose the most proximate "cause": that the Moon is the regulator of both the actual marine tide and its biological behavioral analog, which itself is a simulation of tidal behavior.

Acknowledging some old but no less convincing evidence on this point,[11,12] two recent lines of evidence can be singled out which argue for a lunisolar involvement in behavioral rhythms. First, crabs will shed eggs in the constant environment of the laboratory. When these are fertilized, larval development will proceed. The free-swimming larvae, in turn, display a diurnal pattern of vertical migration within a water column. The diurnal rhythm of swimming upwards and downwards follows the rhythm of the marine tide that pertains to the locality whence the progenitors of the larvae were collected on an earlier date, maybe up to one year previously.[13] However, because the larvae had never directly experienced any actual marine tide during their life, it is conceivable that their rhythmic swimming behavior is a response solely to the local rhythm of the lunisolar gravimetric tide, as detailed analysis of the data indeed indicates (P.W. Barlow, in preparation). Second, a completely different set of observations was made in Brazil. It relates to the temporal pattern of spontaneous, ultra-weak emission of photons from germinating wheat grains. This biophoton emission is naturally rhythmic; and this rhythm is synchronised with the lunisolar gravimetric tide experienced at the observation site.[14] Then, in a subsequent experiment,[15] wheat grains were translocated from their source in the Southern hemisphere to the Northern hemisphere. Biophoton emissions were then recorded during simultaneous germination tests in both the Northern and Southern locations. In these tests, the respective rhythms of emission were synchronised with the rhythms of the gravimetric tides at each location.

From each of these sets of observations it may be inferred that there is (a) no retention, or memory, of a rhythm—as in the case of the wheat grains, and (b) no inheritance of a biological analog of the marine tide, or some other associated rhythm—as in the case of the crabs. The biological rhythms are not manufactured within the respective organisms, but seem more likely to be inherent to them, manifesting a compliance with the rhythmic orbital motions of Earth and Moon around the Sun expressed in the gravimetric tide. Moreover, in a number of other experiments with crabs, the level of activity per day, when considered over the course of the lunar month, is found to correspond with the day-to-day variation in amplitude of the lunisolar tide—lower activity on days around the time of First and Last Quarter Moon, and higher activity around Full and New Moon (P.W. Barlow unpublished, though for a plant example see ref. 16).

The rhythmic events mentioned earlier show up at the level of organs (e.g., leaf movements and root growth variations in plants) and organisms (activity patterns in animals and biophoton emissions). Nevertheless, all may trace back to events at a common, cellular or sub-cellular level,[7] possibly in the form of movements of quantal molecular aggregates of water into and out of cells via exosomes. In plants, the aggregates are proposed to be units of 10^8 water molecules,[17] and their putative lunar-driven transcellular movements into and out of cells translate into variations of cellular volume. In animals, there may also be a correspondence between the quantal aggregates, exosomal structures, and the neuronal synaptic vesicles and their contents.[18] Hence, in this neuronal system, the rhythmic movement of the quantal aggregates may be related, more or less directly, to rhythms of neuromuscular locomotory activity, as in the examples for crabs mentioned earlier. The lunar-driven movements of these quantal aggregates are hypothesized to be governed by processes lying within the domain of quantum physical theory,[7,17] and may show analogies with the quantum Hall effect.[19] It is within this quantum domain that Sun-Moon-Earth orbital motions impinge upon cellularized structures and exert their effects upon rhythms of growth and activity of plant and animal organisms.

All the descriptive studies outlined above and, in particular, their interpretation, have as yet no clear-cut hypothesis which can be the subject of experimental testing. This is a situation which is rather unfamiliar to modern science practice. Thus, this category of putative lunisolar-guided rhythmic phenomena of living forms is itself open to the intuitive, phenomenological methodology suggested by Ribe and Steinle,[2] and which was practised by Goethe in his investigations in the area of botany and notably of color theory.

The fact that organisms are harmonized with lunisolar gravitational forces suggests a very primitive phenomenon to be operating upon (or within) them—a force, or primal condition, which was present at the dawn of Life itself. This is exactly in line with the idea held by Goethe: that a special status should be accredited to a key phenomenon to which all associated effects can be traced. He called this an "Urphänomen", or "Primal Phenomenon". As pointed out by Don,[20] Primal Phenomenona are comprised of physico-chemical processes which make use of non-organic materials, and are to be distinguished from a secondary phenomenal class, that of the "Typus", or "Type", which in the case of biology embraces the events accompanying the development and behavior of living forms. Implicit in the idea of a Primal Phenomenon is that it creates the conditions whereby the derived phenomenon of the "Typus" comes into being.

The lunisolar tidal force may comprise such a Primal Phenomenon. Hence, it may also be intimately related to all that is contingent upon it within the derived phenomenon of the living organic forms of plants and animals. The experience, by an organism, of the variable lunisolar tide (Primal Phenomenon) within its own structure, and the manifestation of this, now organic, variation within the pattern of activity of the derived phenomenon of the Typus, is an expression of the organism's integration of the two classes of phenomena within what might be referred to as a "systemic tetrad" or holon, of Organism–Sun–Moon–Earth. Put another way, and to paraphrase a statement of Henri Bortoft in connection with the topic of "wholeness", the universal [i.e., the holon] is seen within the particular [i.e., the expression of activity], and the particular is a living manifestation of the universal.[21] Thus, the answer to the question, mentioned at the outset, of where the semiotic elements for the putative lunisolar-driven biological rhythm are located, is that they are both nowhere and everywhere. The rhythm is intrinsic to the holon.

Taking into consideration, therefore, not only the above-mentioned theoretical ideas but also the observations on organismal behavior in relation to lunar orbital movements and lunar phases, which are manifested, respectively, in the gravimetric tidal rhythm and its monthly amplitudal variation, it is evident that the world of biology is comprised of two interpenetrating and co-located realms. The first realm is of Primal Phenomena, the second is of derived phenomena. The ability to perceive the former is integral to the very substance of the organism. The latter, interactive realm is derived from the particularities and behavior of the organism, the Typus; and these features of form and function not only interact internally among themselves but also externally with their immediate environment, or "Umwelt" (a term which also traces to Goethe, but now adopted in a technical sense by biosemioticians[22]), which they and other organisms have themselves helped to create. It is, moreover, within the realm of both derived phenomena and the embracing Umwelt that biosemiosis operates and within which it brings into being the higher organizational levels, ranging from individuals and pairs, up to demes, clans, nations, and so on, not to mention the biosemiosis that pervades the cellular level.[23,24]

The interpenetration of the two realms often renders the Primal Phenomena 'invisible' under the cloak of the derived phenomena. This is a difficulty which Goethe noted. He remarks[25] that "The difficulty is... to recognize a primitive phenomenon [i.e., the Urphänomen] in phenomena that are conditioned and concealed [in] a thousand different ways... and not to be misled by phenomena that contradict our senses. For in Nature there is much that contradicts our senses and is nevertheless true." And it is a difficulty also discovered while interpreting the published time courses of diurnal activity of crabs and isopods, for whereas activity patterns receive some entrainment from the immediate abiotic environment, such as periods of light and dark,[8] and the swirling of sand grains from the sea shore at low and high marine tides,[26] the manifestations of the Primal lunisolar-regulated Phenomenon can only occasionally and partially be glimpsed. Under free-running observational conditions in the laboratory, however, the influence of the native Umwelt is diminished and the play upon the system of the Primal Phenomenon of the lunisolar tide is more clearly manifest.[7,8,11,12] In some cases, the Primal Phenomenon has penetrated the organism so deeply and for so long that its effect has now become assimilated into the temporal expression pattern of certain genes.[27]

Primal Phenomena are also embedded within morphogenetic processes which bring about development of organic form. Processes such as free diffusion, reaction-diffusion systems, oscillations, gradients, and other purely physico-chemical features, are fundamental to morphogenesis of multicellular organisms.[28] They, too, are further examples of Goethe's Primal Phenomena for, as already noted, they are coextensive with "pre-life" forms and materials, and rely upon interactions between chemical molecules, and local physical and geophysical forces. They then set in train derived phenomena, such as polarity and positional information.[28]

Into this cluster of Primal Phenomena could be placed the events that lie behind and support the autoreproductive origination of cellular patterns. With respect to plant tissues, these patterns can be formalized via interactionless D0L-systems.[29] L-systems, therefore, appear to take the form of symbolic representations, or analogs, of Primal Phenomena of a physico-chemical nature which facilitate both the formation and the transformation of the organic structures that may bring about the development of the Typus. In fact, auto-generative, D0L-system-derived cellular patterning also underlie the generation of new organs as well as the branching pattern of the whole plant body. Because of the transformatory properties of L-systems, they can also reach forward to determine the derivation of the more terminal, or late-formed, structures, such as the stomatal complexes which arise from meristemoids in the epidermis of leaves,[29] organs which, in their turn, were formed earlier in the shoot-branching process. Thus, we see that the Primal Phenomenon represented by L-systems bears within it the potentiality not only of rules for cell division that apply in two dimensions,[30] but also rules for the topologically more complicated three-dimensional branching of plant parts.[31] To this latter is joined a derived system of internal, hormonally-mediated "correlations".[32,33] The correlative system is the inevitable output from the organs which branching and its derivative physiological systems have created (see below). This system of symbolic L-system transformations, as it applies to plant ontogenesis and also to speciation,[34] is focused upon, and radiates from, a symbolic form which Goethe would have recognized as a "Primal Plant" or "Urpflanze".[35] Moreover, the continuum of transformations inherent to L-systems finds a parallel in what Goethe proposed for his "Attempt to Explain the Metamorphosis of Plants" (*Versuche die Metamorphose der Pflanzen zu erklären*) of 1790. In addition, an important derived phenomenon attendant upon plant morphogenesis, and which is linked with the Umwelt and biosemiosis, is observable in the plasticity of plant form, examples of which were noted by Goethe during his "*Italian Journey*".[35]

At this juncture, it should be remarked that the morphogenic "correlations"—which, in fact, take various forms, such as hormonal, nutritional, hydraulic, and mechano-physical—are agents of biosemiosis. Although morphogenesis can be modeled with the aid of L-systems and Petri net formalisms,[36] the interrelationship between these formalisms and the processes of biosemiosis, which itself can be regarded as a modeling procedure,[22] remains to be explored. The project envisaged in a posthumous publication of Aristid Lindenmayer (whose initial gives the "L" to L-systems) was, perhaps, inspired by the spirit of such an exploration in its concern for the relationship between communication and developmental rules.[37] However, as Donald Favareau has pointed out (personal communication to P.W.B.), "semiosis involves not just following the rules, but—far more importantly—the creation of the rules to follow and, again, the destruction and creation of new rules as conditions change."

The systems mentioned so far have been deterministic, interactionless D0L-systems, which are autonomous and give incontestable results. However, the outcomes of L-systems which include interactions are also feasible for the simulation of morphogenesis,[38] as are those which are probabilistic or stochastic.[39] The adjectives defining the latter systems may mesh with analogous qualifying features of the Umwelt, either denying or allowing further development of the corresponding biological forms which are the bearers of such systems. Certainly, there can be destruction of signs (in the semiotic sense), though in plants those destroyed can arise again in a new generation of modular parts—for example, the (putative) sign-bearing red leaves of autumn trees[40] which, while destroyed in winter, will return in the autumn of the next year. In the longer-term of phylogeny, the semiotic element (if for argument's sake we include here the transformatory alphabet of the L-system rules) may not so much be destroyed but transformed, mutated,[34,41] or added to,[42] thereby becoming a new element, thus creating a new rule.

One may question the notion of linking a symbolic system such as L-systems with a Primal Phenomenon. For, as Walter Kaufmann has remarked, "Almost everybody tries to be profound; where the Germans in the nineteenth century sought ideas, the twentieth century American seeks images and symbols."[43] Thus, it may be asked whether Goethe's "idea" of two hundred years ago can be truly projected upon the "symbols" which are the currency of today? Or should each be discussed in relation to the culture from which it was born? It seems likely, however, that the Goethean "idea" of "Urpflanze" lends itself to represention in symbolic form; the one stands for the other—the symbol for the idea. Analogically, the exchange of "idea" for "symbol", or "semiotic element", is also evident in the development of "Primal Language" and, thence, in the invention of written symbols, familiar to us as letters and words.

The Urpflanze sought by Goethe is an idea: it is an entity endowed with a generous power of creativity and transformation—a symbol of unity within multiplicity and multiplicity within unity—but, at the same time, maintaining a property that enables any of its transformed derivatives to be known as a plant. If it were real, as it might be if it were the founder of a lineage of taxonomic classes, it would possess, as its inner Bauplan, an analog of an Ur-L-system from which could be derived, by transformation of that system's rule, numerous other transformational rules. Indeed, Goethe[35] reasoned thus, concerning his "Primal Plant" and its derivatives: "The Primal Plant is going to be the strangest creature in the world... With this model and the key to it, it will be possible to go on for ever inventing plants and know that their existence is logical; that is to say, if they do not actually exist they could, for they are not the shadowy phantoms of a vain imagination, but possess an inner necessity..."; and here, for "model" read "the Urpflanze and its derivatives", for "key" read "the Ur-L-system", and for "inner necessity" read "the transformatory L-system rule". Nevertheless, there may be limits to such rules, as exemplified by extinct lineages within which further transformations were no longer possible. For example, the morphogenetic rules of Ediacaran organisms (e.g., Charnia), with near-static morphologies,[44] may have been underpinned by an Ur-L-system analog that was insufficiently creative.

In conclusion, we are left with questions about (a) whether Primal Phenomena had a role in the origin of Life and, if so, what were these phenomena; (b) whether they give rise to derived phenomena of the Typus; (c) whether Primal Phenomena, such as lunisolar regularities, can be assimilated to co-operate with derived phenomena, and can also lead to possibilities for semiosis; or, put another way, whether (d) life forms can "semiotise" Primal Phenomena, such as the ones mentioned, and thereby become immured within life forms and enhance their semiotic capabilities. The genetic code may be one other momentous example of this assimilation of the Primal into the derivative state. Biosemiosis is an important derived phenomenon of the Typus, and is clearly integral to the development of the above-mentioned holon of the systemic tetrad. In this respect, biosemiosis is a vital process for furthering the evolution of high levels of organization—of societies on Earth, and beyond, within the Cosmos.

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