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SYNTONIC DIVERGENCE OF PLANTS AND ANIMALS

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Plants and animals are described as opposimilar organisms, inasmuch as they exhibit polarly contrasting morphogenetic processes revolving around a common principle. In effect, the basic morphogenetic logics of plants and animals respectively correspond to those of branching upon branching and invagination within invagination. Repeated morphogenesis thus allows describing both organism types through their several fractal systems and the sequential iteration of said systems. In this context, a striking morphofunctional correspondence reveals that these fractal systems perform opposimilar functions in plants and animals, including extremely precise topological distributions of polarly contrasting biochemical effectors. Due to the complexity of these opposimilarities, so far they constitute an unexplained phenomenon clearly going beyond the Darwinian paradigm. In fact, they call for a revision of the concept of homology, since there seems to be “continuity of information” (cf. Van Valen, 1982) between two natural kingdoms that are said to have diverged from unicellular common ancestors. Some fields with potential explanatory power in this respect are considered.

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It might all be written down, and I get it wrong while decoding

Excerpt from a Colombian anonymous poem

INTRODUCTION

Plants and animals are said to have diverged from unicellular ancestors (Irimia et al., 2007). Yet, among the authors who have considered their similarities (reviewed in Barker, 1995), Carl Linnaeus established an integral morphofunctional comparison between the two kingdoms, in which analogies are established between the root and the digestive system, and between the leaves and the lungs (Linnaeus, 1751, p. 93). In effect, an overall morphological similarity can be observed between leaves and lungs, coupled to the fact that they both perform gas exchange. Likewise, nutrients absorbed by the root, which converge towards the primary shoot, are quite similar to those coming from the intestines and converging into vessels, be they blood or lymphatic ones.

On the other hand, and from a rather analytical standpoint,

complementarity by opposition is suggested by the relation between photosynthesis and respiration in plants and animals (*P&A*). Said notion is aligned with the philosophy of the opposites in nature as expressed both by Heraclitus (Patrick, 1889) and Lao-Tse (2008), respectively in the west and the east; and more recently by Lupasco (1951). As it can be expected, this philosophical standpoint has been poured into scientific perspectives, as exemplified by the works of Niels Bohr (1928) in physics, Saint-Hilaire (cited in Gerhart, 2000) in zoology, and by Sinnot (1923) in botany, among others. Furthermore, a recent analogical model by Rapoport (2013) equates many biological examples to the Möebius strip and Klein bottle shapes, both of which are featured by continuity between opposite surfaces, since moving along either of them leads to the other one. The mentioned author proposes, then, that nature is pervaded by a non-dual logic (actually "logophysics") *linking* opposite trends. He poses a particular emphasis on inside-out continuity, as in *Volvox* spp. (plant kingdom) and *Hydra* spp. (animal kingdom), both of which perform ontogenetic processes in which the outer surface of the organism is swapped with the inner one.

Along these lines, numerous additional examples can be observed in works not intentionally oriented by the idea of polarity in nature. A recently proposed comparison between modular and unitary organisms suggests the complementarity of *P&A*. Notov (2005, 2016a, b) characterizes modular organisms (actually colonial animals and *most plants* and fungi) as opposing unitary organisms (*non-colonial animals* and a few plants) respectively through open vs. closed growth, mobility versus immobility, external form-and-function building system vs. central functional control, coldness vs. warmness, low vs. high integrity of developmental processes, and cyclic vs. non-cyclic morphogenesis.

Likewise, the action potential of the nervous system in animals – which is mediated by sodium and potassium – has been compared to a somewhat corresponding plant function, also known as action potential. The latter is mostly mediated by potassium and calcium (Pietruszka et al., 1997), although both *P&A* systems also involve other minerals. What is quite suggestive is that sodium and potassium belong to subsequent periods (namely, 3 and 4) in group I of Mendeleev's table of the elements, whereas potassium and calcium belong to subsequent groups (namely, I and II of the fourth period). As it can be noted, these three elements are located at an electrochemical crossroads of the table (the crossing of group I and period 4, which corresponds to potassium). Hence, *P&A* can be said to have resorted to contrasting electro – chemical properties (i.e., the number of electron layers and the number of electrons in the outer layer of the atom) revolving around potassium, in order to handle electronegativity in their corresponding action potential systems.

All the above-mentioned data suggest the existence of a non – random pattern linking *P&A* beyond the constraints imposed by common functional requirements. Such a pattern would seemingly correspond to some sort of structural (rather than just functional) commonality linking both groups, which we preliminarily conceptualized as “opposimilarity”, i.e., similarity by complementary opposition around a common principle.

For another thing, the idea of plant fractality (Arber, 1950; Rutishauser, Sattler, 1985; Lacroix et al., 2005) constituted another epistemological antecedent of Syntonic Divergence of plants and animals (*SDpa*). In effect, since the leaf is considered to be a fractal reiteration of the shoot (Zimmermann, 1976), we wondered (based on all the above-mentioned considerations) if plant fractality was complemented by an animal correlate, which, to our understanding was provided by the relation between the digestive tube and the gastric cavity, both of which result from invagination, as opposed to plant branching. Some confirmation of this idea was added by the functional coincidence of both the *P&A* fractal systems (i.e., the leaf/shoot system in plants, and the gastric cavity/digestive system in animals) which corresponds to energy capture; and by the transition from leafless to leafy plants, paralleled by the shift from non-coelomic to coelomic animals.

To the best of our knowledge, no *P&A* opposimilarities have been reported so far, let alone the development of a corresponding theoretical framework. Currently, the only available theoretical development regarding morphological relations between *P&A* is provided by the Darwinian perspective, from which several morphological coincidences between these two groups are attributed to coevolution (Bascompte, Jordano, 2007) or parallelism (Arendt, Reznick, 2008).

METHODOLOGY

The current exploration of *P&A* likely opposimilarity, inasmuch as it is framed in a general philosophical perspective, is neither deductive (since it lacks an actual theoretical framework on which to support hypotheses) nor inductive, since it is not purely empirical, due to the philosophical influence under which it is conducted. This particular epistemological situation in which an intentional bias is introduced to the research process is not usual in mainstream science. Yet, it corresponds to what Charles Peirce (1891) termed “abductive” research, as it proceeds to explore the fitting of empirical data into a general idea instead of a sound hypothesis (Andrade, 2011).

Thus, the current study must be framed into a more general perspective, in the same way Kant stated that reflexive judgment is a general condition of rational deductive thinking. Reflexive judgment allows justifying a systems perspective, in which mechanical thinking. A reflective judgment allows justifying a systems perspective, in which mechanical thinking is just

one particular local situation of causally connected cases, but the whole picture would imply to show how those seemingly unconnected pieces are actually connected and integrated in a higher order system. That is the way to construct a working hypothesis, for example the one that assumes that everything is connected and makes part of a system in which parts and whole codetermine each other, and/or are determined by a more general principle. With the development and success of the mechanistic thinking framework, the systemic approach was put aside on the claims of its being too philosophical and not empirically verified. Yet, other authors like Bohr (1928) suggested that perhaps the systemic approach was not sufficient and formulated, instead, a Taoist inspired principle of complementarity as a more general framework that would allow making sense of quantum physics and alike living phenomena. Furthermore, Lupasco (1951) developed this idea and suggested that the very more basic logical principles inferred by energy transformations would justify a principle of dynamic opposition, needed to make sense of the gathered scientific data on evolution, development, physics and quantum mechanics.

Hence, Peirce's abduction is a development of Kant's idea of reflective judgment, which he considered necessary to justify objectivity. A subjective scheme is necessary before one can justify objective testable scientific facts. Otherwise, it is impossible to make sense of data. None of these general principles are inferred by deduction, nor by induction; they are elaborated by abduction. The result of applying these general philosophical frameworks to the known biology of *P&A* can be observed in the present work, which, methodologically speaking, simply consisted in a brief literature search for the support of the mentioned data.

It is worthwhile noting at this point that the epistemological process we have followed rambles from *ad hoc* speculation to the discovery of new, unexpected opposimilar patterns that may sink again into further complexity as the analysis delves into additional organismic realms. All of this configures a puzzle that only future research may be able to assemble. Such persistent incompleteness, however, gives the current work the character of a rather naturalistic manifesto.

RESULTS

The basic morphogenetic logics of plants and animals are, respectively, those of a solid cylinder that branches constantly throughout its life (open growth), and of a hollow cylinder containing other cylinders, all resulting from repeated invagination (closed growth). Thus, we have branching upon branching in plants, and invagination within invagination in animals. Under this tenet, the current analysis explores *P&A* morphofunctional opposimilarity in three different aspects: energy assimilation (section 1), energy processors (section 2), the transport of energy-carrying fluids and energy processors (section 3), internal and

external movement (section 4), and direct similarities (section 5). In turn, sections 6, 7 and 8, which make up the "Discussion" chapter, attempt to provide an explanation of syntonic divergence.

1. Energy assimilation: The primary fractal systems

The first terrestrial plants simply had a leafless, dichotomous branching system which, at the same time, supplemented the functions of support and photosynthesis (Zimmermann, 1976). In a diametrically opposed way, the simplest multicellular animals have a single internal cavity which serves the functions of locomotion (externally) and digestion (internally) (Fig. 1). With the acquisition of leaves in plants, a new dendroid pattern is supported on the branching stem. As a result, the whole (the branching system) and the part (the leaf) assume separately the respective functions of support and photosynthesis. In animals, the digestive tract results from a new invagination of the single primitive cavity; i.e., the formation of a tube within the first tube. As a result, the whole (the body and the walls of its gastric cavity) and the part (the digestive system) separately assume the respective functions of locomotion and nutrition (Fig. 2). Corresponding fractal systems were thus formed in both groups.

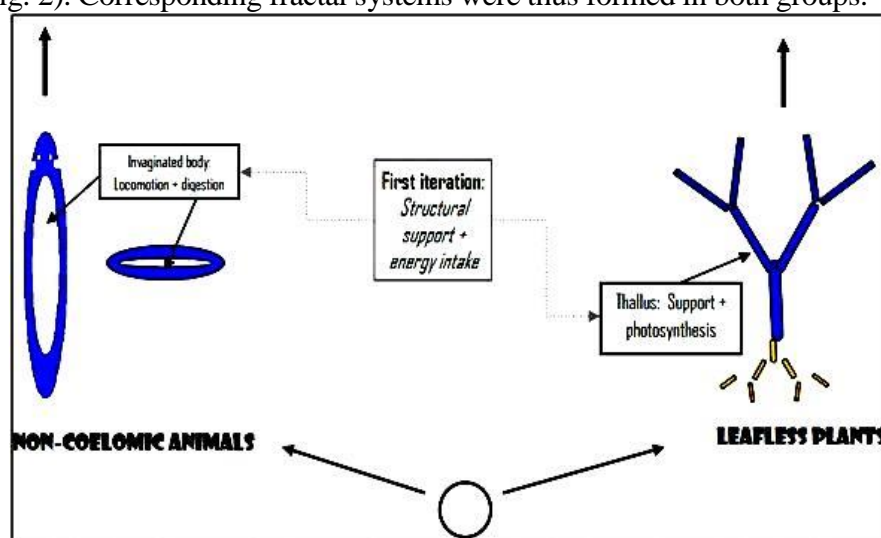


Fig. 1. First iteration of the primary fractal systems of plants and animals: While plants underwent iterative branching processes, animals underwent iterative invagination processes. At a first evolutionary step, plants and animals developed the first iteration of their primary fractal systems: leafless plants acquired a mostly dichotomous branching system, while animals developed a single cavity.

Рис. 1. Первая итерация первичных фрактальных систем для растений и животных:

Для растений характерны итеративные процессы ветвления, в то время как для животных – итеративные процессы инвагинации. На первом этапе эволюции растений и животных произошла первая итерация их первичных фрактальных систем: безлистные растения приобрели преимущественно дихотомически ветвящуюся систему, а животные – первичную полость.

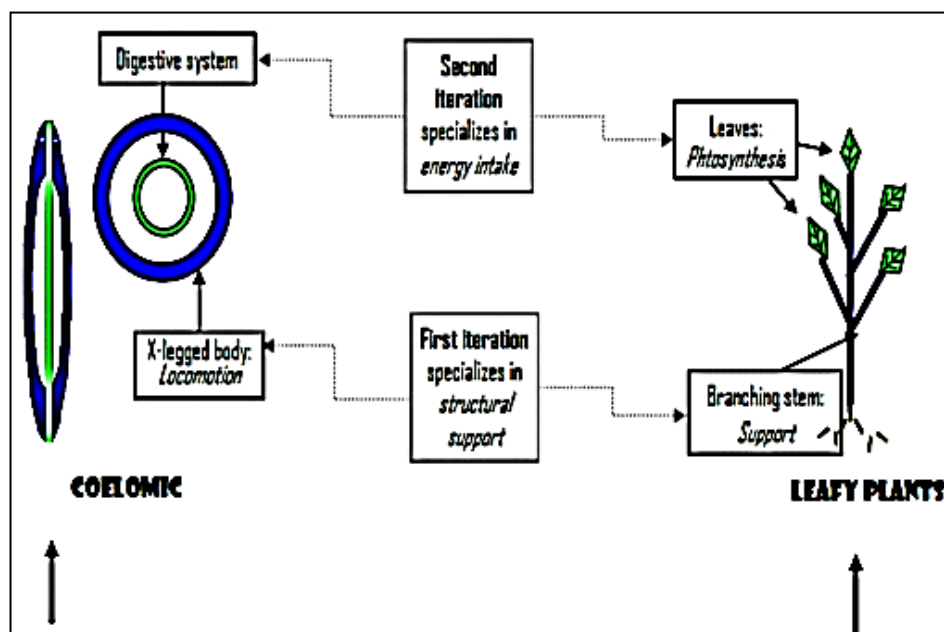


Fig. 2. Second iteration of the primary fractal systems of plants and animals: Within the gastric cavity and upon the plant branching system, we observe the second iteration of the primary fractal system: the leaf and the digestive system. The first iterations specialized in structural support, while the second ones specialized in energy intake.

Рис. 2. Вторая итерация первичных фрактальных систем растений и животных:

В гастральной полости животных и в системе ветвления растений мы наблюдаем вторую итерацию первичной фрактальной системы: формирование листьев (филломов) и пищеварительного тракта. Первые итерации специализировались на опорной функции, вторые – на снабжении энергией.

A plant-animal morphofunctional type arises at this point, the common places to both kingdoms being: (i) the fractal iteration of their polarly opposed morphogenetic processes, (ii) the complementary functions performed by the resulting structures, and (iii) their evolutionary sequence. In this context, both the branching stem of plants and the gastric cavity of animals constitute the first iteration of their corresponding fractal systems. Upon the stem and within the gastric cavity we can find the second iteration, namely the leaves and the digestive system. Interestingly, the functions that were initially united in the primitive, non-re-iterated, energy assimilation systems (support and photosynthesis vs. locomotion and digestion) have been segregated, so that the first iterations specialize in plant support and animal locomotion (i.e., space occupation), while the second iterations (the leaves and the digestive system) specialize in energy intake.

In this way, the notion of opposimilarity presents a different perspective of P&A comparative morphology than the one introduced by

Linnaeus, which is based on direct similarity. The above-mentioned structures make up the Primary Fractal System (PFS) in both plants and animals, which is devoted to energy assimilation. But still, there is a Secondary Fractal System (SFS), which is addressed below.

2. Energy-processors intake: The secondary fractal systems

Later, plants developed a secondary, independent, fractal branching system, namely roots supporting absorbent hairs. Correspondingly, animals developed their own secondary, independent, fractal invagination system: the thoracic cavity and, within it, the lungs.

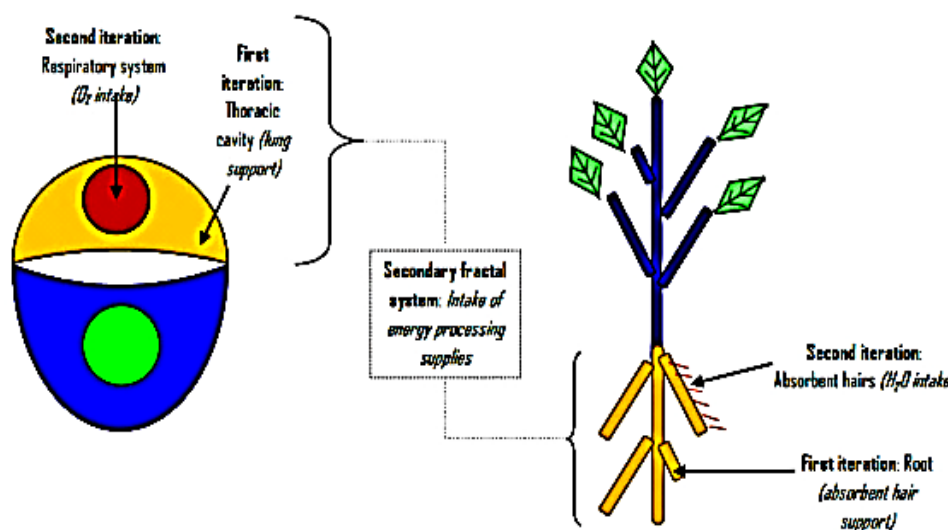


Fig. 3. Secondary fractal systems of plants and animals:

With relative independence from the primary fractal systems, plants and animals developed the secondary ones, both specialized in absorbing energy-processing supplies. In animals, the first iteration is the thoracic cavity, which contains the second iteration, namely the lungs themselves, which perform oxygen intake. In plants, the first iteration are the roots, which support the water-absorbing root hairs. Notably, both water and oxygen are respectively reductive and oxidative reactants for photosynthesis and respiration, which take place in the primary fractal systems.

Р и с . 3 . Вторичные фрактальные системы растений и животных:

С относительной независимостью от первичных фрактальных систем растения и животные формировали вторичные системы, которые специализировались на поглощении веществ, необходимых для снабжения энергией. У животных в результате первой итерации образовалась грудная полость, обеспечившая вторую итерацию, а именно появление легких, которые осуществляют поглощение кислорода. У растений в ходе первой итерации возникли корни с корневыми волосками, обеспечивающими поглощение воды. Примечательно, что вода и кислород служат восстановительными и окислительными реагентами соответственно для фотосинтеза и дыхания, которые представлены в первичных фрактальных системах.

Interestingly, while the root's absorbent hairs intake water, which is the reductive supply of photosynthesis, the lungs intake oxygen, the oxidative supply of respiration, which opposes and complements photosynthesis. Once again, physiological polarity fits morphological polarity, since the energy processors for photosynthesis and respiration are provided by these novel fractal systems.

3. Transport of fluids across fractal systems

As to the fluid transport systems, there also seems to be certain topological and functional correspondence between animal circulation and xylem and phloem flow in plants. While the former is usually pumped by one central heart, the latter is due to many peripheral sucking microsystems which correspond to the leaves. But for the sake of simplicity, we shall take momentarily the pumping systems out of the analysis, just to concentrate on fluid conduction across fractal systems. As it can be seen in Fig 4A. A, vein circulation from the primary fractal system of animals (made up of the gastric cavity plus the digestive system) to the secondary fractal system (made up of the thoracic cavity plus the lungs) is featured by the mixing of energy-carrying blood coming from the intestines, with oxygen-and-energy-depleted blood coming from all organs. Similarly, phloem flow from the plant's primary fractal system (the shoot and the leaves) to the secondary one (the root and absorbent hairs) is featured by the mixing of energy-carrying savia coming from the leaves, with water-and-energy-depleted savia coming from the entire shoot. In plants, this mixing happens not just once (Sinnatamby, 2003), as it does in animals, but at every leaf insertion point, in such a way that, the closer we are to the shoot tip, the purer the fluids will be. Thus, in the two groups currently under study energy-carrying fluids depart from the second iteration of the PFS just to get mixed with fluids depleted of both energy and energy-processors coming from the first iteration of the same fractal system. Then, the mixed fluids are transported to the SFS. Also noteworthy is that the part-to-whole relationship between the leaf and the shoot is also an energy source-to-sink relationship. Just as well, the part-to-whole relationship between the digestive system and the entire animal body is an energy-source-to-sink relationship. Thus, an energy-source-to-sink relation is maintained between the second and first iterations of the PFS in the two studied kingdoms.

At this point, one would expect photosynthesis and respiration to take place at the same iteration of their corresponding fractal systems, but that is not the case. Instead, a different and intriguing regularity takes place. Energy is initially assimilated by plants through photosynthesis (1st step, taking place at the second iteration of the PFS) and then wrapped into more complex sugars than glucose or starch (2nd step, taking place at the first iteration of the PFS) (Fig. 4B).

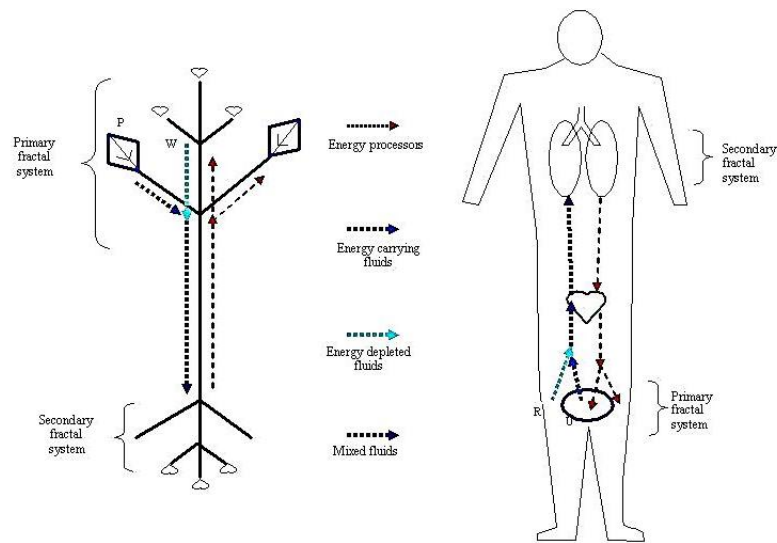


Fig. 4. Energy assimilation, processing and distribution in plants and animals:

- A. Simplified fluid transport systems of plants and animals.* Bluish arrows illustrate the carrying of mixed fluids from the primary to the secondary fractal system in both plants and animals: In the latter, blood containing energy from the digestive system is mixed with blood lacking oxygen (the energy processor for respiration) from the entire body; in plants, savia containing energy from the leaves is mixed with water (the energy processor for photosynthesis) depleted savia from the shoot. For their part, red arrows illustrate the conduction of water and oxygen (respectively in plants and animals) from the secondary to the primary fractal system in both kingdoms.
- B. Energy processing sequence from plants to animals.* Energy is initially assimilated by plants through photosynthesis (P) and then wrapped (W) into more complex sugars than glucose. Later on, it is unwrapped (U) through animal digestion and then chemically released through respiration (R), which is common to P&A, although this is not shown in the drawing.

Р и с . 4 . Поглощение, преобразование и распределение энергии растениями и животными:

- A. Упрощенные системы транспортировки жидкостей у растений и животных.* Голубые стрелки иллюстрируют баланс смешанных жидкостей от первичной к вторичной фрактальной системе растений и животных. У животных кровь, получающая энергию от пищеварительной системы, смешивается с кровью, обеднённой кислородом (энергетической составляющей процесса дыхания) со всего тела. У растений, флоэмный сок, т.е. раствор энергоносителей из листьев, смешивается с водой (энергетической составляющей фотосинтеза) из побегов. Красные стрелки иллюстрируют перемещение воды и кислорода (соответственно у растений и животных) от вторичных к первичным фрактальным системам.
- B. Последовательность преобразования энергии от растений к животным.* Энергия первоначально ассимилируется растениями посредством фотосинтеза (P) и преобразуется после этого в углеводы, более сложные, чем глюкоза (W). Энергия, усваиваемая (U) животными в процессе пищеварения, затем высвобождается при дыхании (R), общим для растений и животных, хотя это не показано на рисунке.

Table 1

Location of energy capture and further processing in the PFS
of plants and animals
Поглощение и переработка энергии в ПФС растений и животных

Step	Plants	Animals	Iteration of the PFS
1	Photosynthesis	Unwrapping	2
2	Wrapping	Respiration	1

Note. The arrows indicate the whole sequence of processes undergone by energy from plants to animals: photosynthesis and wrapping into complex sugars and starch in plants (steps 1 and 2), followed by digestion (unwrapping) and respiration in animals (steps 1 and 2). As it can be noted, in both groups the first step takes place at the second iteration of the PFS, while the second step takes place at the first iteration of the same system. Just as well, complementary processes (photosynthesis vs. respiration; wrapping vs. unwrapping) take place at contrasting iterations.

Примечание. Стрелки указывают на последовательность преобразования энергии от растений к животным: фотосинтез и образование сложных сахаров и крахмала в растениях (шаги 1 и 2), а затем переваривание (ращепление) и дыхание у животных (шаги 1 и 2). В обеих группах первый шаг происходит на второй итерации ПФС, а второй – на первой итерации той же системы. Комплементарные процессы (фотосинтез и дыхание; запасание и освобождение) также происходят на контрастных итерациях.

Later, energy is unwrapped through animal digestion (1st step, taking place at the second iteration of the PFS) and then released through respiration (2nd step, taking place at the first iteration of the PFS). In both kingdoms, step 1 takes place at the second iteration, while step 2 occurs at the first iteration. While photosynthesis and animal respiration take place at different iterations (respectively, the second and first ones), energy wrapping in plants and unwrapping in animals follow a contrasting pattern, since they take place in the 1st and 2nd iterations, respectively again (Table 1, Fig. 4B).

4. Plant form vs. animal movement

As mentioned above, the functional segregation of leaf and shoot is paralleled by the way the digestion of non-coelomic animals - which used to depend on locomotion - has been segregated from the latter in coelomic animals. In the case of leaves, although they specialize in photosynthesis while supported by the shoot, still they are internally supported by their own vein system, which is considered to be a modified shoot system (Zimmermann, 1976). The similarity between branching and venation is such that both plant components are considered by some authors to be partially homologous (Rutishauser, Isler, 2001) or homologous (Floyd, Bowman, 2010). In animals, for their part, with the development of the coelom, the intestines were finally in condition to perform digestion

separately from body locomotion, but still had to develop peristalsis to supply for the effects that locomotion used to provide them with. Thus, in both groups the second iteration of the PFS is not only structurally but functionally similar to the original, unsegregated whole. Now, given that both plant growth and animal movement are space occupation strategies, and that leaf and shoot growth are said to be homologous processes, one might wonder if a somewhat corresponding similarity between the digestive system and the x-legged organism is expressed not by form, but by movement.

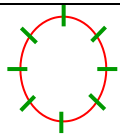
The latter analysis has two implications. In the first place, the segregation of the functions performed by the primitive whole into those of the derived part-and-whole systems is accompanied by the reiteration of said primitive functional integration on the part of the 2nd iterations of the PFS. Thus, there is some morpho-functional fractalization in P&A. In the second place, the stillness and passiveness of plants seemingly contrasts with the dynamism and activeness of animals. Let us explore the latter statement first.

Table 2

Plant linearity vs. animal circularity are shown by internal movements (transport of fluids) and external movements (animal locomotion and closed growth vs. plant stillness and open growth)

Таблица 2

Линейность растений против циркулярности животных, связанная с внутренними перемещениями (транспорт жидкостей) и внешними движениями (перемещение и закрытый рост животных, в отличие от неподвижности и открытого роста растений)

	Internal (fluid) movement	External movement		Planetary scale projection of external movement
		growth	locomotion	
Plants	↑↓	↑↓	none	
Animals	O	O	↔	

Note. Although animal locomotion is relatively horizontal with regards to plant growth, which is rather vertical, at the planetary level, they are respectively circular and radial.

Примечание. Хотя перемещение животных относительно горизонтальное по сравнению с преимущественно вертикальным ростом растений, в планетарном масштабе эти процессы циркулярные и радиальные соответственно.

Separately analyzed, the two kingdoms under study are featured by an intimate morphofunctional association between internal movement (i.e., the transport of fluids) and external movement, namely animal locomotion and plant growth (see Table 2). In effect, plants compensate their stillness with open growth, which is mostly vertical relative to the rather horizontal

displacement of animals. Furthermore, the growth of plants is made possible by the turgor sustained by their open, linear fluid transport system, which corresponds to xylem and phloem. Conversely, animals compensate closed growth with locomotion, which is facilitated by blood circulation through energy and oxygen supply. Furthermore, if we project the respective *P&A* "movements" at a planetary level, we find radially vs. circularity and, hence, a clearer identification with their fluid transport systems (Table 2).

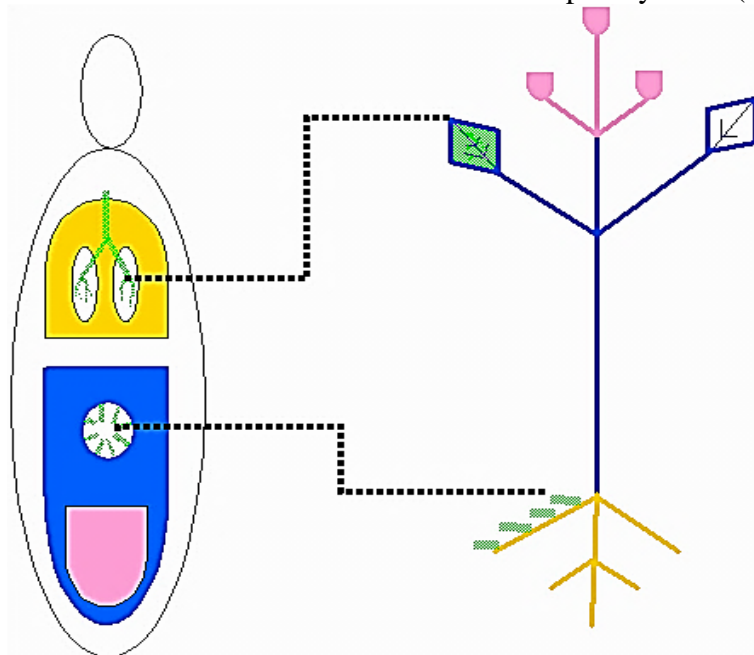


Fig. 5. Longitudinal sequences of direct similarities and opposimilarities in plants and animals:

Secondary fractal systems are represented in yellow, while primary ones are represented in blue. Reproductive systems, represented in pink, are shown as an iteration of the primary fractal systems. Direct similarities are shown in green. As it can be observed, the sequences of opposimilarities (yellow-blue-pink, representing the SFS – (PFS (2' – 2'')) topological sequence explained in the text) are the same, but they run in opposite directions.

In turn, direct similarities between leaves and lungs and roots and intestines are aligned in the same direction, as highlighted by the dotted lines.

Р и с . 5 . Продольная последовательность прямых сходств и сходств по комплементарным оппозициям у растений и животных:

Вторичные фрактальные системы выделены желтым цветом, первичные отмечены синим. Репродуктивные системы, обозначенные розовым цветом, показаны как итерация первичных фрактальных систем.

Прямые сходства показаны зеленым цветом. Как можно видеть, последовательности сходств по комплементарным оппозициям (желто-синерозовая, представляющая собой топологический ряд SFS – (PFS (2' – 2''))), объяснения в тексте) одинаковы, но разнонаправлены.

В свою очередь, прямые сходства между листьями и легкими, корнями и кишечником однонаправлены, что подчеркивается пунктирными линиями.

The considerations made above suggest an intimate opposition between plant form (growth) and animal movement as the axis of *P&A* morphofunctional fractalization. Thus, an exploratory observation allows noticing how, for example, the form of animal feces (in turn related to the intensity of peristaltic contractions) seems to be associated to the overall speed of locomotion. In effect, while cow feces are almost liquid and seem to be shaped by rather superficial peristaltic contractions, rabbit, deer or mouse feces are comparatively drier and clearly shaped by the deepest possible peristaltic contractions (the feces of these animals come in separate, more or less rounded pieces). Needless to say, the overall movement of the latter group of animals is quite fast and frequent, while the scarce movements of cows are rather slow. At an intermediate point between these groups of animals, there are humans or dogs, whose feces and movements do not match either extreme.

The purported plant growth vs. animal movement connection introduced by the current work leads to another interesting temptation, namely claiming to have found the “heart” of plants, which, in this framework would revolve around the leaves, mainly due to their type of pumping activity, location and number, which oppose those of the animal heart. The peripheral location of the heart of plants was predicted by Goethe (Steiner, 1988) as simply opposing that of animals, which is mostly internal. This was later reinforced by the very notion that animal organs may be represented in plants by widespread tissues providing functional integration (Shafranova, 1980, cited in Notov, 2005).

Table 3
Comparison between plant and animal pumping systems

Таблица 3
Сравнение поглощающих систем у растений и животных

	OPPOSIMILARITIES				DIRECT SIMILARITIES	
	pumping mode	location	number	fluid transport mode		
Plants	suction	peripheral	many leaves	linear, open	mediation between internal and external movements	pulsating nature of the plastochron and the heart
Animals	propulsion	central	one heart	circular, closed		

For its part, the pulsating nature of the plastochron (i.e., the alternate production of leaves and internodes at the shoot apical meristem) is yet another aspect that contributes to the present argumentation, as a direct similarity (see section 5) with the animal heart. Although the leaf is not the same as the shoot apical meristem, it not only produces the leaves, but is closely associated with the plant’s fluid transport system, as is also the case

of animal circulation and locomotion. Thus, the connection between the internal and external movements, which in animals is mediated by their heart, is mediated by leaves in plants. Table 3 summarizes the comparison between the pumping systems of *P&A*.

5. Direct similarities

The direct similarities between leaves and lungs, roots and intestines mentioned in the introduction can be further commented in the framework provided by *P&A* opposimilarities, in which they reveal new correspondences. In effect, the further elaborations of the primary and secondary fractal systems of animals exhibit direct similarities with those of plants under an orderly topological deployment. Furthermore, direct similarities match one another in a linear sequence, while opposimilarities run in opposite directions. Finally, the reproductive systems of both kingdoms add up to their direct similarities, although they fall out of their direct similarities.

Table 4

Nominal relations between plant and animal fractal systems

Таблица 4

Номинальные отношения между фрактальными системами растений и животных

ANIMALS		PLANTS	Through ...
PFS (2 nd iteration)	is directly	SFS (2 nd iteration)	intestinal villi and root hairs
SFS (2 nd iteration)	similar to	PFS (2 nd iteration)	lungs and leaves
PFS	is	PFS	lower vs. upper location, respectively
SFS	opposimilar to	SFS	upper vs. lower location, respectively

Note. Direct similarities are cross referenced (PFSs are similar to SFSs), while opposimilarities are directly related (PFSs are opposimilar to one another, and so are SFSs). *Примечание.* Прямые сходства перекрестны (PFS похожи на SFS), в то время как сходства по комплементарным оппозициям связаны напрямую (PFS являются антогонистами SFS).

In the first place, the lungs, which are internal cavities, are further invaginated within, but under the branching invagination mode of the bronchial trees, which resemble the leaves. That is, the bronchial trees as further elaborations of the SFS of animals actually turn towards the typical morphogenetic mode of plants, thus resembling the second iteration of their PFS (Fig. 9Fig.). For their part, the further elaborations of the PFS of animals, actually the intestinal villi, are also due to branching. Thus, they can also be said as well to turn toward the typical morphogenetic mode of plants, wherein they resemble the second iteration of their SFS (i.e., the root hairs). Nominally speaking, these direct similarities are cross-referenced: through the intestinal villi, the PFS of animals turns toward the SFS of plants

(resembling the root hairs), and vice versa (lungs turn toward leaves). As a consequence, they are aligned in the same direction along the *P&A* body plans, while opposimilarities run in opposite directions (i.e., they are palindromic sequences) because they connect the PFSs to one another and the SFSs in the same mode (Fig. 9) (Table 6).

But there is more to these direct similarities. The reproductive systems of *P&A* were compared by Linnaeus himself (1751), who noted the similarity between the stamens ending in the pollen sacs and the seminal conducts ending in the testicles. Also, he showed the resemblance between the animal uterus and ovules and the ovary and ovules of plants.

By delving deeper into these systems, one sees they are both internally polarized, in the sense that the masculine polarity opposes the feminine one. This was observed in plants by Goethe and is compared to animals in the present work, to the point of revealing a striking therapeutic linkage between the masculine polarities of the two groups.

In plants, the feminine/masculine polarity can be observed as a proximo-distal growth polarization of the flower components, namely sepals, petals, stamens and carpels (Goethe, 2009). In effect, while sepals are proximally widened, petals are distally widened. For their part, stamens are more pronouncedly polarized toward their distal end, while the carpels of the ovary are more pronouncedly polarized toward their proximal pole, thus finishing this alternate sequence of increasing proximo-distal polarization revolving around the masculine/feminine principles.

In turn, the animal reproductive systems reveal an upside-down polarity. If one pays attention to the front view of the morphology of the human masculine reproductive system, it closely matches a spiral winding upwardly from the testicles to the penis. Conversely, the feminine system forms a downward winding spiral from the ovaries through the uterus to the vagina. Similarly, the feminine pubic hair points downwards, while the masculine one points upwards. What is more puzzling in all this is that pollen has a specific healing effect on the prostate gland and, in general, on the masculine reproductive system (Cai et al., 2017).

A new opposimilarity arises by considering the position of the reproductive systems of *P&A* along their corresponding body plans. These systems are built *upon* the shoot and within the gastric cavity (actually *below* the intestines). Thus, we have palindromic body plans in *P&A*. In the latter, the thoracic and gastric cavities (the latter containing most of the digestive system *above* the reproductive system) are aligned in a top-down topological sequence running along, e.g., the human body. For their part, plants show the opposite alignment, i.e., the root and the shoot (the latter showing the vegetative portion usually *below* the reproductive one) aligned in a bottom-top sequence. By naming the energy capturing systems (leaves and intestines) and the reproductive systems as iterations $2'$ and $2''$, respectively, of the PFS, we

obtain that the SFS – (PFS ($2' - 2''$)) topological sequence runs from top to bottom in animals, and counter-wise in plants (Fig. 9).

DISCUSSION

Probably the first thing to be stated in terms of explaining *SDpa* is that a strictly Darwinian type of coevolution can hardly be put out as the main driver of this phenomenon, since it would not account for such complex topological, physiological and biochemical connections relating the two kingdoms under study. A similar idea to *SDpa* was exposed by Geoffroy de Saint-Hilaire (cited in Gerhart, 2000) regarding an early embryonic stage shared by arthropods and vertebrates, after which their respective skeletons are formed outerly and innerly on the basis of the *same* embryonic tissue; thus, the interpretation he proposed of both skeletons as homologous. Yet, it is probably too early to make such an ambitious statement with respect to *P&A*. Hence, for the time being, it might be more interesting to look for a line of reasoning aimed at a plain explanation of *SDpa*, aside from the likely straightjacket that homology would likely prove to be in this case.

Another possible interpretation of *SDpa* regards opposimilarity as a particular case of highly complex parallelism. Examples of the latter - although based on direct similarity - have been reported by Notov (2011, 2017a) in modular plants, animals and fungi (which are shown to converge around branching patterns and both leaf-like and scypha-like structures, among others) and by Conway Morris (2009) in different animal groups.

Yet, it is worthwhile pointing out that parallelism might sometimes lead to biological homology (cf. Roth, 1984) in the sense that, e.g., *P&A* may be sharing opposite modalities of a common developmental constraint towards which they may have converged (i.e., a non-homologous distant past) or which they may have inherited from a common ancestor (homologous distant past).

A third explanatory vein for *SDpa* has to do with genetics, since the extreme complexity of this phenomenon is probably not accounted for solely by the epigenetic perspective. However, in the present case this would lead to an extreme case of genetic homology, since all the specifications of the (pluricellular) *P&A* bauplans would need to have been genetically coded in their common unicellular ancestor, in a sort of newly evoked preformism. In turn, such approach would put us in the realm of the so-called anti-scientific “intelligent design” (Marshall, 2015).

Yet, another plausible explanation is available through the perspective of genetic meta-data, i.e., the newly acknowledged possibility that the genome contain background (i.e., non-digital) information that somehow co-determines the phenotype (Rapoport, 2013). However, no genetic explanation of *SDpa* is attempted in the present work.

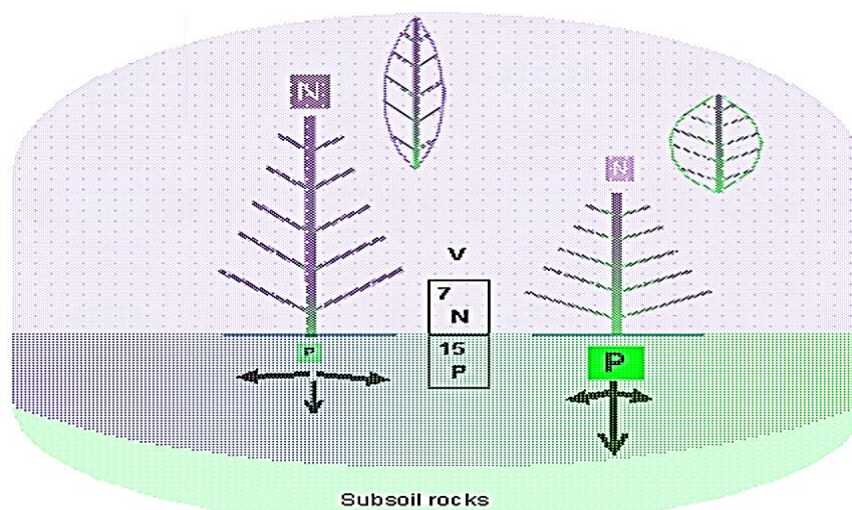


Fig. 6. Polar syntonic structuring of nature (A) and whole-plant fractal polarity (B):

A. Polar syntonic structuring of the atomic, organismic and planetary levels of organization.

Nitrogen (N) and Phosphorus (P) are respectively represented in purple and green colors.

Thus, at the planetary level, P is shown to be abundant in the subsoil rocks, and N in the atmosphere, but they coexist in the soil and the biomass, which can be more abundant in either element. At the atomic level, N and P belong to subsequent periods in group V of Mendeleev's table of the chemical elements (shown at the center of the Fig.). At the organismic level, N abundant soils promote shoot development, while P abundant soils promote root development.

B. Whole-plant fractal polarity.

Polar fractal model of the plant. From left to right, the root/shoot ratio at the whole-plant level correlates inversely with shoot and leaf apical dominance. Framed in syntonic structuring around the N/P tandem, the model assumes that N abundant soils correlate with higher N/P ratios at the organismic level and with their associated fractal morphology, whereas P abundant soils have the opposite effect. This allows talking about the integral polarization of ecosystems.

Рис. 6. Полярное синтоническое структурирование природы (A) и фрактальная полярность целого растения (B):

A. Полярное синтоническое структурирование на атомном, организменном и планетарном уровнях.

Азот (N) и фосфор (P) представлены соответственно фиолетовым и зеленым цветами. На планетарном уровне P в изобилии содержится в материнской породе под почвой, а N в атмосфере, но они сосуществуют в почве и живых организмах, в которых может преобладать любой из этих элементов. На атомном уровне N и P относятся к последовательным периодам V группы таблицы химических элементов Менделеева (в центре рисунка). На организменном уровне, почва, богатая азотом, способствует развитию побегов, а богатая фосфором – корней.

B. Фрактальная полярность целого растения.

Полярная фрактальная модель растения. Слева направо соотношение корней и побегов на уровне всего растения обратно пропорционально апикальному доминированию верхушки побега. В рамках синтонического структурирования соотношения N/P, в этой модели предполагается, что почвы, богатые азотом, коррелируют с более высоким соотношением N/P на организменном уровне и с сопряжённой с ним фрактальной морфологии, в то время как обилие фосфора в почве дает противоположный эффект. Можно говорить об интегральной поляризации экосистем.

6. The generative properties of nature and the principle of syntonic structuring

From an epigenetic standpoint, the notion of self-organization around robust morphogenetic processes (Goodwin, 1994) may contribute interesting insight into *SDpa*, since branching and invagination can be approached as the two poles of a gradient between which bauplan-defining morphogenesis is seemingly constrained in nature. Furthermore, the polarization of morphogenetic fields can be understood as an extremely simple and, hence, correspondingly ubiquitous and hardly observable generic form-driver in nature. These notions are synthesized around the concept of “syntonic structuring”, which states that nature – both physical and biological – is generally built around robust morphogenetic attractors. One of such attractors corresponds to the formation of polar gradients.

The clearest and most outstanding example of syntonic structuring is provided by the nitrogen/phosphorus (N/P) polar tandem, which structures nature from the molecular, through the organismic, to the planetary level. In effect, N and P belong to subsequent periods of group V in Mendeleev’s table of the chemical elements (*i.e.*, they are essentially similar, just varying in their degree of electronegativity). At the organismic level, N promotes shoot (*i.e.*, *aerial*) growth, while P promotes root (*i.e.*, *underground*) growth. Furthermore, at the planetary level N tends to evaporate, thus being abundant in the atmosphere, while P tends to precipitate and is abundant in the subsoil rocks. In this way, through their contrasting physico-chemical properties, these two elements determine the earth/sky polarity of the planet and its organisms (Fig. 6A).

6.1. Whole-plant polar fractality

Syntonic structuring has an interesting bearing on plant structure and, therefore, on *P&A SDpa*. Said connection, however, only comes clear after comparing the shoot to the root and the leaf. In the case of root and shoot, we can go beyond their contrasting tropisms, to see how their anatomy and growth dynamics also run on polar grounds, as is also the case of their branching patterns. In effect, cross cuts of these organs (Groff & Kaplan, 1988) reveal how their vascular strands form an *external* ring in the shoot and an *internal* core in the root. Likewise, new organs are formed *externally* on the shoot, and *internally* in the root (Fig. 13). Figuratively speaking, it is as if the root was an inside-out version of the shoot. These observations support the current claim that the root is morphologically opposimilar to the shoot. Furthermore, continuity between these purported opposites is also suggested by Arber’s (1950) notion that the root is a “partial shoot”, in the sense of the common dendroid pattern of these two organs.

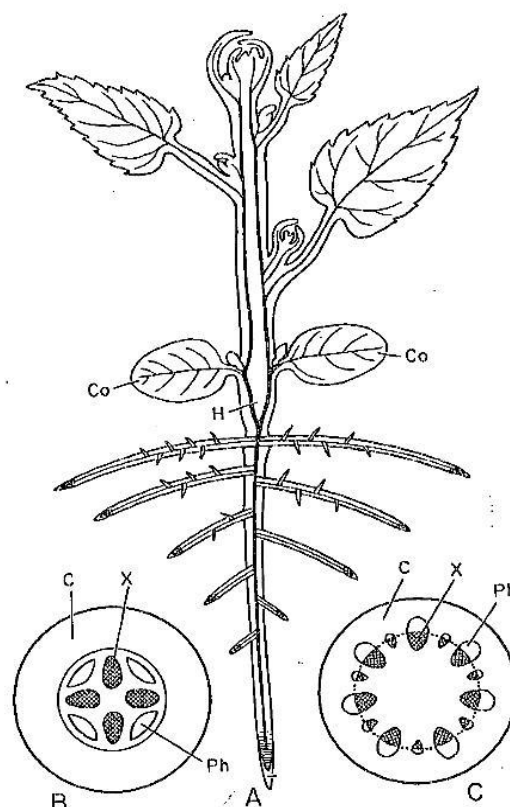


Fig. 7. Topological comparison between root and shoot:

The central and peripheral positions of vascular bundles and new lateral elements of root and shoot, respectively, are shown in longitudinal (A) and cross (B and C) cuts.

X – xylem; Ph – phloem; C – cortex; H – hypocotyl; Co – cotyledons

Р и с . 7. Топологическое сравнение корня и побега:

Центральное и периферическое расположение сосудистых пучков и новых латеральных элементов корня и побега показаны соответственно на продольных (А) и поперечных (В и С) срезах. X – ксилема; Ph – флоэма; C – кора;

H – гипокотиль; Co – семядоли

For their part, leaf and shoot can also be understood both phylogenetically and ontogenetically as contracted/expanded versions of each other, thus constituting the alternative phases of a cycle that the plant continuously reiterates as it grows, since shoots (the expansive phase) produce leaves (the contractive phase), which, in turn, produce shoots. This appreciation is mostly explicit through the position of leaf and shoot meristems, which are *peripheral* in the latter and *central* in the former (Fig. 8). A detailed topological comparison between leaf and shoot has been invoked by several authors (Sachs, Uittien, Goethe, Kant Dresser, cited in Arber, 1950, pp. 73 and 74; De Candolle, A.P., cited in Arber, 1950: 80-81).

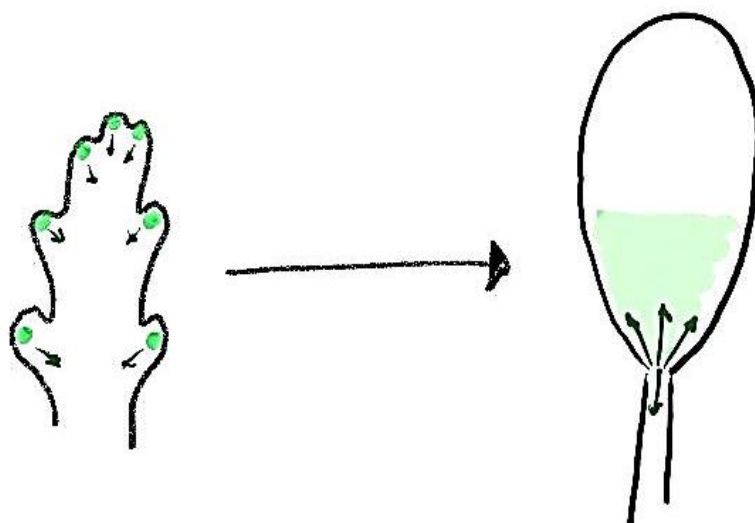


Fig. 8. Topological relation between leaf and shoot:

On the vertical plane, shoot meristems are located peripherally, while the leaf's basal meristem is rather central. Growth is specified centripetally in the shoot (therefore, the structure grows centrifugally).

The leaf follows the opposite pattern. Prepared by the authors.

Fig. 8. Топологическая связь между листом и побегом:

На вертикальной плоскости, меристемы побега расположены на периферии, в то время как базальная меристема листа занимает скорее центральное положение. Рост побега происходит центропетально (следовательно, структура растет центробежно).

Лист соответствует противоположной схеме. Рисунок авторов.

By integrating the former leaf, shoot and root comparisons, these three structures appear as topological transformations of each other. The leaf can be seen as a shoot which has undergone centripetal meristem displacement on its vertical plane, through the evolutionary process described by the telome theory (Zimmermann, 1976). For its part, the root can be interpreted as a shoot which has also undergone centripetal meristem displacement, but on its horizontal plane (Fig. 13). As a result, the evolutionary development of leaves and roots can be said to be the result of the morphogenetic polarization of the shoot, on contrasting geometrical planes.

6.2. Whole plant parallelism: Fractal polarity

Plant component systems seem to be evolving in parallel, under tight physiological controls. Thus, we are introducing a fractal polarization model of the whole-plant structure is based on the aforementioned topological similarities between leaf, shoot and root, to which it adds certain parallel trends. In other words, the whole plant and its main components are

understood as an integrated series of nested topological and constructional polarities. As a result, these plant components are said to not only exhibit transformed versions of the positional assembly of their subcomponents (organization), but also concomitant changes in the relative proportions of those parts (construction). Said series of nested correlations are explained, on the one hand, by leaf and shoot homology (cf. Floyd, Bowman, 2010), which makes their parallelism an expectable consequence, and on the other hand, by a simple root/shoot resource allocation model. As it can be observed in Fig. 6B, when biomass allocation at the plant level is polarized towards the root, this is assumed to be mainly expressed by an increase in length of the central axis of this system, which, in turn, increases its apical dominance. At the same time, biomass withdrawal from the shoot, (mainly expressed by its central axis, according to the model), results in apical dominance reduction in this system. Finally, the resulting changes in shoot apical dominance are transferred to the leaf via their shared regulatory (homologous) mechanisms. On these grounds, *the model in question basically states that the polarity of the whole-plant (as expressed by its root/shoot ratio) correlates directly with root apical dominance and inversely with those of the shoot and the leaf.* This fractal parallel variation might take place at different scales in time, be they evolutionary, phenotypic or physiological.

As to the empirical support of this model, only preliminary observations are available, although not at the expense of their very suggestive qualities. These correlations can hardly be observed through static forms, although cases like those of *Schefflera* spp. and *Cecropia* spp. constitute notable exceptions. Instead, more widespread evidence seems to come from parallel evolutionary variation. The entire model can be appreciated already in the genus *Smallanthus* (tribe Helianthidae of the family Asteraceae), where we have preliminarily observed a clear contrast from abundantly tuberous to pivotal roots associated to the mentioned shoot and leaf apical dominance features, including an insertion angle correlation between leaf and shoot. We are currently studying the connection between root/shoot ration and leaf apical dominance in a series of *Oxalis* spp. (Fig 9 and Fig. 10), wherein preliminary observations suggest that plants with relatively larger roots tend to exhibit shoot, leaf and leaflet lateral dominance, and viceversa. This parallelism would be affecting not only apical dominance, but also characters like branching angles (Fig. 9). Parallel variation between plant components may not be restricted to evolutionary processes, but also to physiological changes, as suggested by preliminary observations in *Smallanthus sonchifolius* (Fig. 11), or genetically engineered mutations, as in lettuce plants (Fig. 12).



Fig. 9. Shoot and leaflet morphocline in section

Holophyllum of the genus *Oxalis*, subgenus *Thamnoxyis*:

Modified from drawings published in Lourteig (1994). Visual inspection shows how shoot and leaflet apical dominance increase concomitantly from *O. impatiens* (I) through *O. mandioccana* (II) to *O. kuhlmannii* (III).

Even the insertion angle of the leaflets apparently correlates with that of their secondary veins

Р и с . 9 . Целое растение, побег, корень и листочек в секции *Holophyllum* рода *Oxalis* подрода *Thamnoxyis*:

По рисункам Lourteig (1994), с изменениями. Визуальный осмотр показывает, как отношение корень/доля (по оценкам соотносительных областей на рисунке) увеличивается от *O. impatiens* (I) через *O. mandioccana* (II) к *O. kuhlmannii* (III) и обратно коррелирует с соотношением побегов и листовых зачатков при апикальном доминировании. Даже угол отхождения листочков, по-видимому, сопоставим с углом расположения вторичных жилок.

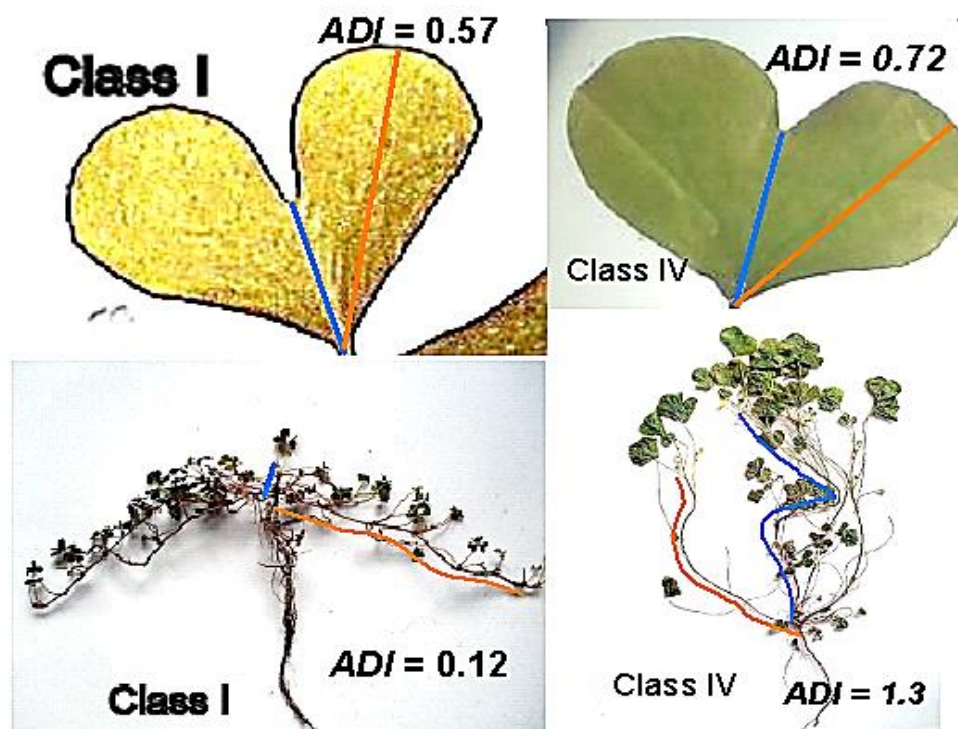


Fig. 10. Whole-plant, shoot, root and leaflet parallel variation in *Oxalis corniculata* ssp. *corniculata* vars. *atropurpurea* and *corniculata*. The Label "Class I" corresponds to variety *atropurpurea*, while "Class IV" corresponds to variety *corniculata*. Data obtained from an ongoing study on self-similarity between shoot and leaflet in *Oxalis corniculata*.

ADI – Apical dominance index calculated as the quotient between central axis length (blue lines) and average length of the lateral axes (red lines). Leaflet and shoot ADI data calculated from a sample size of 30 plants cultivated under uniform soil and climate conditions. Root and whole plant data estimated directly by visual inspection on these photographs (no statistical morphometric data are currently available for these parameters). From left to right, the root/shoot ratio inversely correlates with shoot and leaflet apical dominance.

Р и с . 1 0 . Параллельное изменение целого растения, корня и листочка у *Oxalis corniculata* подвида *corniculata*, разновидности *atropurpurea* и *corniculata*.

Изображение "Class I" соответствует сорту *atropurpurea*, "Class IV" – сорту *corniculata*. Данные, полученные в ходе продолжающегося исследования самоподобия между побегом и листом у *Oxalis corniculata*.

ADI – индекс апикального доминирования, рассчитываемый как частное между длиной центральной оси (синие линии) и средней длиной боковых осей (красные линии). Данные листочка и побега ADI рассчитаны на основе выборки из 30 растений, культивируемых в однородных почвенно-климатических условиях.

Данные о корнях и растениях в целом оцениваются непосредственно путем визуального контроля на этих фотографиях (статистические морфометрические данные по этим параметрам в настоящее время отсутствуют). Слева направо соотношение корней и побегов обратно коррелирует с доминированием верхушки побега и листочка.

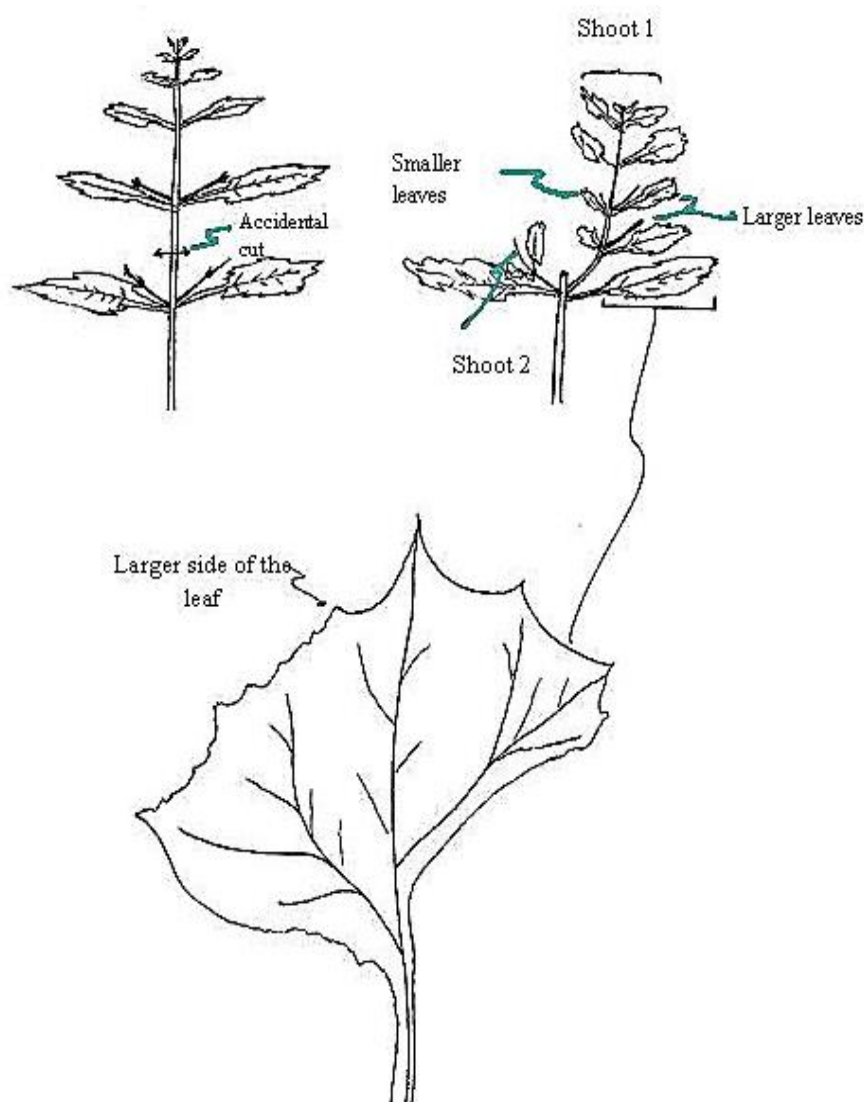


Fig. 11. Accidental cut in *Smalanthus sonchifolius*, revealing identical leaf and shoot morphogenetic processes:

After an accidental cut of the primary stem, shoot 1 reiterates the monopodial branching pattern of the species, while shoot 2 grows smaller. In turn, shoot 1 produces more developed leaves and branches on one side, while those on the opposite side grow smaller. Furthermore, the leaves exhibit bilateral asymmetry, since one side grows more than the other one.

Р и с . 11 . Случайный отрезок *Smalanthus sonchifolius*, раскрывающий идентичность морфогенетических процессов листьев и побегов:

После случайного среза первичного стебля побег 1 повторяет вид моноподиально нарастающих структур, а побег 2 становится меньше. В свою очередь, побег 1 производит более развитые листья и ветви с одной стороны, в то время как те, на противоположной стороне растут меньше. Кроме того, листья проявляют двустороннюю асимметрию, так как одна сторона растет активнее другой.

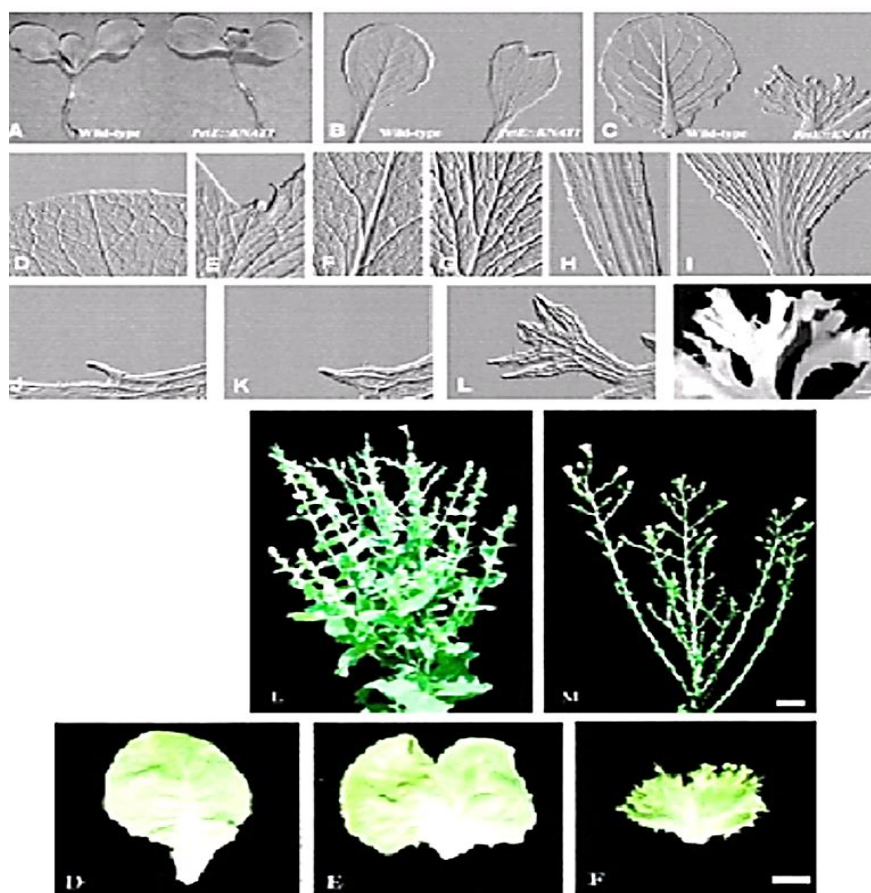


Fig. 12. Overexpression of the homeotic gene *KNAT1* in lettuce plants: A generalized shift towards lateral dominance can be observed from shoot through leaf shape to leaf venation minute details. Except for pictures A, B and C, which are self-explained, the letter sets below the pictures label the wild type (actually mutant plants resembling the wild phenotype) on the left and the actual phenotypical alterations (mutant plants classified as either mildly or severely altered) on the right. Grey pictures: A, seedlings; B and C, first and eighth leaves, respectively; D (wild) and E (mutant), leaf tip; F and G, leaf midvein; H and I, leaf base. J through M illustrate the progressive formation of a lobe-like structure in a severely mutated leaf. Colored pictures: L and M are flowering shoots; D, E and F, natural leaf and two degrees of mutation. Adapted from Frugis et al., 2001.

Р и с . 1 2 . Гиперэкспрессия гомеотического гена *KNAT1* у растений салата:

Можно наблюдать общее смещение в сторону латерального доминирования от побега через структуру листа к мельчайшим деталям жилкования листа.

За исключением рисунков А, В и С, которые объясняются самостоятельно, буква под изображениями соответствует ярлыку дикого типа (мутантные растения, напоминающие дикий фенотип) слева и фактические фенотипические изменения (мутантные растения, классифицированные как слегка или сильно измененные) справа. Серые картинки: А – проростки; В и С – первый и восьмой листья, соответственно; Д (дикий) и Е (мутант), кончик листа; F и G – срединная жилка листа; H и I – основание листьев; J – M – иллюстрируют постепенное формирование структуры сильно видоизмененных листьев. Цветные картинки: L и M – цветущие побеги; D, E и F – типичный лист и две степени мутации. С изменениями по: Frugis et al., 2001.

The current fractal polarization whole-plant model allows talking about two polar extremes in plant construction, namely “earth” plants (featured by relatively higher root/shoot ratios and their corresponding fractal architecture) and “sky” plants, with the opposite overall architecture (Fig. 6B). By coupling this model to the fact that nature is organized around the N/P polar binary, it can be hypothesized that “earth” plants are associated to lower N/P ratios both in their tissues and in the soils they grow on, whereas “sky” plants follow the opposite trend.

By integrating *SDpa* into the analysis, a pattern starts to emerge, seemingly permeating all life expressions, which appear to be just polar topological transformations of each other. This is observed intra-organismically within plants and inter-organismically when they are compared to animals. Thus, branching and invagination can be viewed as the two poles of a developmental and evolutionary avenue constraining both kingdoms, in which it extends intraorganismically. Although the corresponding analysis in animals is still pending, their many topological and physiological connections with plants constitute a promising research field in this sense.

On the other hand, this notion is perfectly aligned with the principle of “minimum complexity increase” (Saunders , Ho, 1981), which assumes that *it is evolutionarily more advantageous to build new additional complexity on the basis of formerly acquired features*, instead of building entirely new structures requiring largely complex novelty. In this sense, topological transformations and self similarity as depicted by *SDpa* would have been an advantageous morphogenetic option.

Finally, what is most significant in syntonic structuring is its appealing simplicity, which makes it a very likely event and explains its widespread distribution in nature, to the point of suggesting that *biological complexity is actually the iteration of simplicity* (e.g., *polarity*). However, polar morphogenesis is just as simple as conspicuous, which contributes to explaining its having been overlooked for so long.

This attributed simplicity of nature also allows coining the metaphor of the morphospace as an “urban epigenetic landscape”, in the sense of its constriction by the mentioned polar morphogenetic and evolutionary avenues. Furthermore, the fractal iteration of polarity and its intraorganismic parallelism indicates the likeliness of an integral adaptive capability of organisms. This stance may fruitfully complement the notion of organisms as rather complex puzzles of individual characters, which has pervaded biological thinking for so long.

7. Syntonic adaptiveness

Actually a corollary of syntonic structuring, the notion of syntonic adaptiveness simply highlights that both the organism and the environment

are structured around polarity. If this is so, the problem of natural selection is reduced to fitting the degree of polarization of a given character to that of the environmental factor that affects it. For instance, autotrophs are certainly confined within branching morphologies, which optimize photosynthesis by maximizing the light absorption surface of the organism (i.e., autotrophy). Consequently, all invaginated organisms are somewhat forced heterotrophs through fagotrophy (nutrient absorption through internal body surfaces), which is not a good autotrophic adaptation. Nonetheless, this does not prevent the existence of branching heterotrophs, namely fungi and some colonial animals, or even invaginated (i.e., carnivorous) plants. Hence, the purported branching - invagination evolutionary avenue within which nature would be morphogenetically constrained seems to be functionally segmented (from autotrophy to heterotrophy), thus leaving autotrophs "locked up" in the branching direction and invaginated organisms also fixed on heterotrophy.

Figuratively speaking, syntonic adaptiveness can be compared to a chess game in which both the board (the environment) and the pieces (the organisms) range from black to white through different tones of grey. Under these conditions, all an organism needs to do is to find the part of the board that fits its tone of grey, which is much more likely than the Darwinian natural selection mode.

Another likely case of syntonic adaptiveness seems to result in the context of phyllotaxy. A mathematical and physical model of leaf distribution on the shoot proposed by Douady and Couder (1992) accounts for the golden ratio spiral observed in the phyllotactic pattern of most plants. The former authors interpret the process of biomass allocation to leaf primordia at the SAM in terms of mutual repulsion between them. That is to say, leaf primordia would need to keep minimum distances between them in order not to enter an excessively competitive dynamics for too little biomass. Interestingly, however, this notion of mutual repulsion is equally applicable to light distribution to the leaves, which is also optimized by the golden ratio spiral (King et al., 2004). In effect, mutual shading in the presence of abundant (not excessive) light is something from which leaves tend to stay away through golden ratio spirals. Thus, mutual repulsion among elements competing for resources (biomass or light) comes to be the common place between the respective internal and external dynamics of leaf arrangement. Hence, the structuring process and its corresponding selective pressure seem to be quite analogous (*sensu lato*), thus conferring phyllotaxy a certain degree of pre-adaptedness, reducing the need for natural selection and evoking a less changing nature, as it is further commented in this section.

Finally, syntonic adaptiveness can be mathematically summarized. The probability of existence of a given structure (P_s) in nature can be

roughly estimated as the quotient between its adaptive value (w) and its variation potential (vp): $P_s \cong w/vp$ (modified from Saunders, Ho, 1976). Since vp tends to infinite (all forms are equally likely) under the Darwinian paradigm, P_s tends to zero. For that reason, both life and its complexity have seemed so unlikely for two hundred years. Yet, under the syntonic adaptiveness paradigm vp tends to 2 (the two poles of a "black and white" morphogenetic gradient), while w (which, by definition ranges from 0 to 1) can be said to average 0.5 (given a certain structure, and since the ecological factor that affects it is also polarized along the simplest of gradients, the odds of w being 1 are 0.5). Consequently, by calculating P_s we obtain 0.25 under these "ideal" conditions.

7.1. Elaborating on the fractal polarization of functional gradients

As we have seen, the aforementioned interorganismic evolutionary avenue linking $P\&A$ is seemingly paralleled by a functional counterpart ranging from autotrophy to heterotrophy. Likewise, parallel functional avenues appear to accompany the intraorganismic extensions of said epigenetic landscape, to which we have attributed the fractal systems we are studying.

The second iterations of the fractal systems of $P\&A$ would be much more likely if their functional requirements were also polarly constrained. The notion of leaf and shoot parallelism allows observing that, during the evolutionary development of angiosperm leaves, *the more leaf and shoot differentiated structurally and functionally from one another, the more a common requirement arose for the resulting whole (the shoot) and its parts (the leaves); i.e., the need to provide support and irrigation for their corresponding photosynthetic components.* The latter correspond to the leaves in the case of the shoot, and to the photosynthetic portion of the leaf blade, in the case of the leaf. An identical analysis can be applied to the digestive system (see sections 0 and 0).

As it can be observed, the fractal segregation of the morphospace is seemingly paralleled by the fractal segregation of the functional space, all of which can be considered to be a further complexation (fractalization) of syntonic adaptiveness. This functional "pre-design" of the self-organizational aspects of form calls into question the very dialectics of structure and function, which has traditionally been the center of the Darwinian paradigm. Just as well, and paraphrasing Stephen Jay-Gould (1980), this pre-adaptedness of nature contradicts the panglossian paradigm and fits both the structural integration and syntonic adaptiveness concepts; only that, according to the latter, the spandrels of San Marco would be somewhat older than ordinarily assumed. In fact, they would constitute the manifestation of a timeless, immanent property of nature.

7.2. A less changing nature?

Syntonic structuring provides a sensible explanation of an observation that has been somewhat overlooked, if we take into account its importance. In a study in the Virginia Piedmont (North America), each of a series of studied plant functional guilds was found to be made up of phylogenetically related taxa, in turn associated to close relatives apparently belonging to the same guild around the world (Givnish, 1987). This is attributed by the author to unknown phylogenetic constraints that would be stabilizing the morphofunctional characters of each guild, thus preventing its evolutionary drift towards other guilds' morphospace and ecological niches.

In these plants, apical dominance correlates inversely with light availability, while leaf width correlates directly with temperature. These features can be explained by the factors they correlate with, since light scarcity stimulates plant height, while leaf size is a good adaptation to warm temperatures (Givnish, 1976). From the standpoint of syntonic adaptiveness, the evolutionary stability of these functional guilds can be attributed to the purported robustness of their polar structural gradients, coupled to the polar environmental gradients in which they fit. This may have been enhanced by the occupied-to-available niche dynamics and the possible adjacent constriction detailed in section 8. In sum, this notable discovery reasonably fits the morphofunctional space exploration dynamics as depicted in the current work, and its concomitant notion of a less changing nature than ordinarily assumed.

Nevertheless, the Darwinian paradigm continues to play a role in the framework provided by these new explanatory veins. In the formation of the fractal systems of *P&A*, either simple genetic drift or contingent selective pressures (i.e., typically Darwinian elements) would have been enough to propel both kingdoms in opposite directions of their evolutionary spectrum, namely the second iterations of their PFSs, which certainly rendered much more efficient energy harvesting activities, and would have produced another evolutionary "lock-up" effect (also see section 8). Precisely these elements of the Darwinian paradigm play an interesting articulation role within the structural and functional polar constraints that appear to have framed and propelled *SDpa*, as it is explained in the next section.

8. Exploring the morphofunctional space (and putting it all together)

The dynamics of morphofunctional space exploration is likely to introduce certain directionality into the evolutionary process, especially in the context of polar epigenetic landscapes wherein characters with highly adaptive values are fixed through their fitting into polar functional landscapes. In other words, if evolution is simplified by syntonic adaptiveness, the

specifics of morphofunctional space exploration seemingly confer it directionality and “concentration”, in what appears to be an orderly series of evolutionary steps, as it is explained below. Said exploration, as indicated by its name, can be approached structurally and functionally.

Table 5

Morphofunctional space exploration dynamics

Таблица 5

Динамика освоения морфофункционального пространства

MORPHOSPACE			FUNCTIONAL SPACE		
General framework	Inter-organismic structural gradients	Intra-organismic structural gradients	Intra-organismic functional gradients	Inter-organismic functional gradients	General framework
Current forms	Branching	Leafless plants	Integrated support and photosynthesis	Autotrophy	Niche occupation
Genetic drift		Leafy plants	Segregated support and photosynthesis		Niche constriction
Adjacent possible variants	Invagination	Non-coelomic animals	Integrated locomotion and digestion	Heterotrophy	Potential new niche availability
		Coelomic animals	Segregated locomotion and digestion		

Note. The columns specify the segmentation of the structural and functional gradients that, under the assumptions of syntonic adaptiveness, are said to have fit into one another. Thus, columns with the same color indicate the fitting of the morphospace into the functional space, which is approached as a general evolutionary framework and at the inter- and intraorganismic levels of plants and animals.

Примечание. Столбцы определяют разделение структурных и функциональных градиентов, которые, согласно предположениям о синтонической адаптивности, вписываются друг в друга. Таким образом, колонки того же цвета указывают на установку морфопространства в функциональном пространстве, которое рассматривается как общие ориентиры и на внутри- и надорганизменных уровнях у растений и животных.

From a structural standpoint, morphospace exploration dynamics is likely to be affected by the fact that *a given morphology can only be attained on the basis of certain pre-conditions*. Such has seemingly been the case of most leafy plants, which had to develop shoots in the first place, in order to support their leaves. Just as well, flowers could only be developed on the basis of leaves. In a general sense, it can be said that the morphospace offers infinite possibilities, but a given morphological condition reduces such possibilities to a set of *adjacent possible variants* (cf. Kauffman, 2000). As

a result, the broad set of evolutionary possibilities attributed to genetic drift by the traditional paradigm appears to be narrower due to their actual availability.

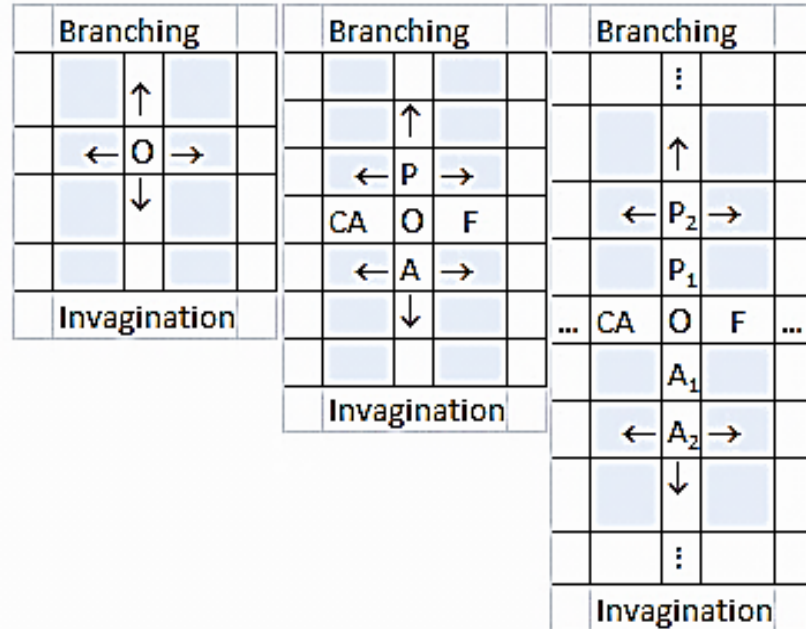


Fig. 13. General evolutionary dynamics of plants and animals integrating syntonic adaptiveness and morphofunctional space exploration:

Sequential evolutionary steps are depicted from left to right.

O – Hypothetical ancestor of plants and animals. CA – Colonial animals. F – Fungi. P – Plants. A – Animals. The blue fringes illustrate the constrained evolutionary avenue that goes from branching to invagination. The arrows represent adjacent possible variants at each step (P₁, P₂; A₁, A₂). In this extremely simplified scheme, only one adjacent variant along the “non-trivial” evolutionary avenue is available at each evolutionary step. These steps likely correspond to the sequential iterations of the primary and secondary fractal systems of plants and animals. Fungi and colonial animals are represented as lateral variants since they combine branching and invagination.

Р и с . 13 . Общая эволюционная динамика интеграции синтонической адаптивности и освоения морфофункционального пространства у растений и животных:

Последовательные эволюционные шаги изображаются слева направо.

O = гипотетический предок растений и животных. СА – колониальные животные. F – Грибы. P – Растения. A – животные. Синие полосы иллюстрируют ограниченный эволюционный путь от ветвления к инвагинации. Стрелки представляют смежные возможные варианты на каждом шаге (P₁, P₂; A₁, A₂). В этой чрезвычайно упрощенной схеме на каждом эволюционном этапе доступен только один смежный вариант по «нетривиальному» эволюционному пути. Эти шаги, вероятно, соответствуют последовательным итерациям первичной и вторичной фрактальных систем растений и животных. Грибы и колониальные животные представлены в виде боковых вариантов, так как они сочетают ветвление и инвагинацию.

From a functional standpoint, current morphological variants at any point in evolutionary history constitute occupied ecological niches which can be said to prevent, to a certain extent, backward steps. Thus, evolution may have been propelled “forward” to develop novelty by niche constriction (i.e., by contingent selective pressures of the Darwinian type) or “attracted” from ahead by new ecological niche availability resulting from the ecological interaction between *P&A* (see section 0). For example, an invaginated organism (probably an animal) may have been compelled by the aforementioned set of conditions (morphospace exploration dynamics, the principle of minimum complexity increase, contingent selective pressures and new niche availability) to further develop invagination as a means to improve fitness to the environment. Under these conditions, *P&A* would be somewhat directed towards the development of fractality. Table illustrates the specifics of morphofunctional space exploration dynamics.

This assumed idea of the general directionality of evolution can be illustrated by an analogical model in which sand progressively accumulates by vertical deposition on a flat surface. In this way, higher levels of complexity can only be reached on the basis of lower ones. Thus framed, the case of *P&A* is represented by two sand piles growing in straightly opposite directions (e.g., on antipodal positions on earth), which represent branching and invagination as main body plan themes.

For the sake of simplicity, these relations can be deployed on a two dimensional square grid wherein each group’s evolutionary chances can be clearly represented (Fig. 13). There, successive “layers” of adjacent possible variants can be seen as concentric circles which have been crossed by the evolutionary history of *P&A*. Said evolutionary dynamics can also be compared to an expanding circular wave propelled forward by the occupied-to-available-niche polar dynamics, frontally contained in its expansion by actually accessible variants, and “chanelled” by polar syntonic structuring, which is represented as a laterally constraining force. There, the evolutionary wave is “locked-up” when the character is fixed by fitting into its polar functional counterpart (Table 5).

8.1. Non-trivial coevolution?

A closely related notion to developmental constriction and the consequent evolutionary avenues was developed by Russian scientist Serguei Meyen as early as 1988. He coined the notion of “non-triviality” for phenomena like predictable leaf evolutionary transformations. Nowadays, genomics and developmental genetics, coupled to morphological progress such as the one introduced in the present work, have led to a clearer understanding of these and other phenomena. Yet, the field of *P&A* coevolution as framed in syntonic adaptiveness deserves the label “non-

trivial", since the current one is just a very preliminary attempt to approach a rather unknown field.

To provide a general conceptual framework for this analysis, let us recall that energy in the organisms we are studying is overly employed to propel internal movement, which, in turn, facilitates external movement, *i.e.*, open growth in plants and locomotion in animals (section 0). And the evolution of these features has implied the morphofunctional innovations we have been dealing with, namely the primary and secondary fractal systems and, within (upon) the former, the reproductive systems. In this context, it can be generally stated that the vertical evolutionary innovations of plants facilitated the horizontal developments of animals, and vice-versa, as if building a spider's web all around the planet. Thus, better energy capture strategies on the part of plants supported animal locomotion progress, and vice-versa.

For instance, herbivory may have constituted a selective pressure for plants to develop more efficient photosynthetic strategies, which, in turn, may have offered new potential ecological niches for animals. Conversely, animal locomotive improvements surely were the basis of many cross-pollination and seed dispersal strategies, which, in turn, may have offered additional food availability and, therefore, new niches for animals. On these grounds, an evolutionary dialectic between niche availability and occupation, mediated by typically Darwinian selective pressures, may have polarized the functional space of *P&A* evolution, as it is clarified in the lines that follow.

Thus framed, syntonic adaptiveness facilitates some fruitful speculation on leaf origins and hence, *SDpa*. The functional inter-modeling of autotrophs and heterotrophs may have been mediated by the resistance offered by a rather elastic nature (as opposed to the plastic one depicted by the Darwinian paradigm) that actually canalizes change according to (polar) developmental constraints.

One might consider, then, that foraging or grazing on leafless plants such as the *Rhyniophytes* necessarily led to the decapitation of their apical meristems. This, in turn, surely made it difficult to restart growth somehow. Under these conditions, the chances of meristem decapitation diminished if the meristem was located less distally and more proximally. This simple selective pressure probably led plants to the centripetal meristem displacement that characterizes leaves.

This transition toward the leaf could be reasonably attributed to the *PETROSELINUM* genetic system, since it seemingly specifies the alternation between stem growth and leaf inception in the shoot apical meristem of angiosperms. This genetic system is considered to produce alternate pulses of *KNOX* and *JAG* proteins, which are respectively responsible for stem and leaf development (Ichihashi et al., 2014). A simple

repolarization of this system from its *KNOX* pole to its *JAG* one may have been enough to provoke the displacement of the meristem in question. At the morphogenetic level, this transition depends on whether new cells at the meristem are formed centripetally (as in the shoot) or centrifugally (as in the leaf). Even a saltationist switch is a sensible hypothesis for this process, since it mainly revolves around which of two cells resulting from mitosis is going to remain meristematic.

In this particular case, the polar evolutionary avenue to which we have referred in a rather abstract manner actually materializes in the constituent telomes of the proto-leaves along which the meristems migrated. At the proximal end of those proto-stems were the leaves which, until then, were no more than a potential adjacent variant. Through grazing, animals may have literally pushed proto-shoots away from existence, thus propelling their change toward their potential counterpart: the leaf.

A new polarity arises at this point, namely actual vs. potential, physical vs. conceptual or metaphysical. The coming section, after analyzing fractality as framed in *SDpa*, brings things close to an intense, but temporary *finale*, as we will see.

The shoot/leaf – plant/animal connection

The fractal systems of *P&A* resonate with a widespread (though scarcely considered) phenomenon of nature, known as pseudocyclic similarities (Gaussen, 1952; Notov, 2016a, b, 2017b) i.e., similar structures found at different organizational levels within the same organism. An example is provided by the inflorescences of the Asteraceae, which very precisely resemble their constituent flowers (Gaussen, 1951). This condition is often reached by aggregation of structural units into higher and higher levels of organizational hierarchy, as if forming a spiral. Each cycle of the spiral leads to the same structure, but a higher organizational level. Therefore, the term “pseudocycle”.

However, and as commented in section 0 the evolutionary development of leaves and roots can be said to be the result of the iterative polarization of the shoot on contrasting geometrical planes. This, in turn, allows interpreting plant evolution as a case of pseudocyclic similarity, one in which the modules are not the growth units produced in the meristems, but the opposite topological transformations represented by leaves and shoots (at the shoot level) or the root and the entire primary shoot (at the whole plant level). In other words, the repeated module is polarity itself and its constituent poles.

Another likely example of pseudocyclic similarities as affected by polarity may correspond to the case of conifers, where the phenomenon is rampant (Mathyukin, 2017). In effect, these plants often exhibit extreme leaf size reductions, a condition to which the mentioned author attributes certain loss of the evolutionary plasticity of this organ (*ibid.*). In response, some

shoot systems have been aggregated into phyllodes (i.e., they have assumed several leaf traits). In some groups, this process has been repeated several times along evolutionary history, thus exhibiting several pseudocycles (ibid).

From a structural standpoint, the notion of leaf and shoot parallelism may contribute to explaining pseudocyclic similarities in conifers, since they not only exhibit leaf reduction but internode shortening (probably an integral adaptation to cold environments) as well. By understanding leaf and shoot as homologues, leaf "nodelets" and "inter-nodelets" come to be seen as homologues of shoot nodes and internodes. In this way, the internode reduction one observes in the shoot of conifers is likely to account for the (parallel) reduction in leaf size. Hence, the parallel evolution of a polar character such as internode length is likely to be affecting pseudocyclic similarities in these plants.

The involvement of polarity in pseudocyclic similarities has an important bearing on the present endeavor to explain *SDpa*. While the case of leaves is precisely that of *aggregation* of modules (telomes) into higher order structures, the digestive system actually results from *segregation*. This observation provides new insight into the nature of modularity (usually associated to repeated morphogenesis and open growth) and, therefore, fractality.

As shown by *SDpa*, repeated morphogenesis is widely distributed in unitary animals, not only through longitudinal segmentation (e.g., the gill arches), but also through the SFS – PFS ($2' - 2''$) module described in section 0, which is an opposimilarity of *P&A*, as it is also the case of iterative invagination/branching.

The widespread distribution of repeated morphogenesis in *P&A* suggests that the modularity of plants is not exclusive of organisms with open growth, but has been turned inwardly in unitary animals, despite their closed growth. In this way, modularity appears as a unifying principle underlying both open and closed growth, which come to be opposimilar developmental strategies revolving around it.

The packing of open growth modularity into closed growth is not exclusive of the plant/animal (*p/a*) system, since it also features the leaf/shoot system. This is reinforced by several other characteristics linking the two components of both systems, which are featured by the contrast between radial (the plant and its shoot) and bilateral symmetry (leaves and animals), the latter accompanied by dorsiventral polarity. Likewise, and provided that the primary shoot corresponds with the aerial part of the plant, its top-bottom polarity shows similar contrasts with the proximo-distal and antero-posterior polarities of leaves and animals, respectively. In sum, leaves are animal-like at a glance.

Additionally, while leaves and shoots are contracted/expanded

versions of each other, *P&A* are inside-out versions of one another. Along these lines, while leaf and shoots are considered homologue structures (Floyd, Bowman, 2010), *P&A* satisfy several homologation criteria (namely, topology, complexity and congruence), as largely detailed in the results of the current work. For another thing, while *P&A* exhibit palindromic series of elements, so do leaves and shoots. The latter opposimilarity results from the fact that the leaf grows from the center, while the shoot grows from the periphery. By understanding these structures as circular sectors, new nodes in the shoot are placed at the apex, whereas new “nodelets” in the leaf are placed basally. Hence the newer-to-older growth series run in opposite directions in the two structures.

Table 6
Morphological relations between the plant/animal and leaf/shoot systems

Таблица 6
Морфологические отношения между растениями и животными,
листовой и побеговой системами

Feature	Plant/animal system	Leaf/shoot system
Symmetry	Radial to bilateral	
Polarity	Top-bottom to antero-posterior and dorsi-ventral	
Opposimilarity		
Structural relations	Homology suggested by tight opposimilarities	
Constructional relations	Parallelism	Apparent convergence
Palindromic sequences	Newer to older nodes (nodelets) and internodes (inter-nodelets)	SFS – PFS (2' - 2'')*
Matching linear sequences	Center to periphery deployment	Direct similarities between primary and secondary fractal systems

Note. * Notation of the palindromic sequences of *P&A* explained in section 0.

Примечание. * Система обозначений палиндромных последовательностей растений и животных объясняется в разделе 5.

Notwithstanding, since leaf and shoot share the same dendroid pattern, the center to periphery deployment of these circular sectors (and their parallelism constitutes a direct similarity coexisting with the mentioned opposimilarity. Just as well, the *p/a* system exhibits the coexistence of direct similarities (parallelism) and opposimilarities (all the *SDpa* items mentioned in this work, including the palindromic series). Table 6 summarizes the connections detailed above between these two systems.

These observations suggest an enigmatic connection between both systems under study, since the tight links that are being currently revealed for the fractal iterations of plants would have, in this framework, a counterpart between *P&A*.

8.2. The nature of nature

Polarity is but one of what seems to be several metapatterns (cf. Volk et al., 2007), robust self-organizing processes (Wagner, 1994), generic forms (cf. Goodwin, 1994), or syntonic structuring modes, all of which are closely related notions. Other metapatterns are exemplified by the formation of circular or spiral forms (Goodwin, 1994; see section 7 in this work), binaries and membranes, among other structuring modes (Volk, 2007). All of these can be synthetically said to be *generic interaction modes among analog components*, which confers them robustness (they can be attained from different analog components), widespread and recurrent distribution, and spontaneity in both the physical and biological world, the latter revolving around the former. It is probably these generic interactions modes what is behind pseudocyclic similarities and, hence, the fractal systems involved in SD. But, once abstracted, these generic interaction modes appear as rather conceptual in nature, as centrally defining elements of the morphospace explored by nature through evolution. Thus, in the context provided by the current work, nature seemingly shifts from being a “nothing that becomes something”, as in the Darwinian paradigm; to be regarded as a rather *immaterial, timeless, immanent whole that manifests contingently through evolution*.

CONCLUSIONS AND FUTURE RESEARCH PERSPECTIVES

1. In the context set in the current work, there seems to be “continuity of information” between P&A, which actually fits Van Valen’s definition of homology (1982).

2. The widespread distribution of syntonic structuring and its fractal nature, together with the notion of syntonic adaptiveness suggest the existence of certain “intrinsic design” in nature.

3. Morphofunctional space exploration dynamics goes one step ahead, since it suggests a mode of further developing nature’s intrinsic design, under the same “randomness constriction” dynamics.

4. By broadening the modular organization field, SD opens the way for a frontal investigation of the underlying structuring principles of biology in this area. Furthermore, Klein bottle logophysics constitutes an interesting approach to the likely wrapping of the mineral world into the biological one, while the science of metapatterns even proposes the incorporation of the cultural layer into this same broadened view of nature.

5. As a likely materialization of the morphospace, SD has interesting metaphysical implications that deserve being explored through future research.

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СИНТОНИЧЕСКАЯ ДИВЕРГЕНЦИЯ РАСТЕНИЙ И ЖИВОТНЫХ

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Растения и животные представлены как противоположно сходные организмы, поскольку у них реализуются полярно контрастные морфогенетические процессы, базирующиеся на общих принципах. Основные морфогенетические стратегии растений и животных соответствует моделям ветвления и инвагинации. Циклический морфогенез позволяет описать оба типа организации посредством нескольких фрактальных систем и их последовательной итерации. В данном контексте явное морфофункциональное соответствие свидетельствует о том, что эти фрактальные системы выполняют функции обратного сходства у растений и животных. В их числе и чрезвычайно точное топологическое распределение полярных контрастных биохимических эффекторов. Из-за сложности этих противоположностей они до сих пор представляют собой необъяснимое явление, явно выходящее за рамки дарвиновской парадигмы. Фактически требуется пересмотр концепции гомологии, в связи с идеей о существовании некоторой «информационной непрерывности» (см. Van Valen, 1982) между двумя естественными царствами, которые, как полагают, дивергировали от общих одноклеточных предков. Рассмотрены некоторые особенности организации растений и животных, обладающие потенциальной объяснительной силой в отношении этих представлений.

Ключевые слова: *Эволюционная биология, сложность.*

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