Education for sustainability: lessons from living systems governance

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Abstract To survive that is *'to eat and not to be eaten'*. Whatever its spatial and temporal level of organisation, every living system, to survive and *'to itself survive its self'*, owns 7 invariant capacities: *the gauge invariance paradigm* (figure 1). Emerging by embedments and juxtapositions of previous systems, every living *system-of-systems* (figure 2) is both dependent and independent from its new global level of organisation (*endophysiotope*) and past and present local situations of emergence (*ecoexotope*). Mass growth governs growth phase duration (figure 3). Local actors, modules of past, present and new modules of modules (figure 4) become mutually integrated (*percolation process*) into a new global Whole through their merging (figure 5) into an ARMSADA (*Association for the Reciprocal and Mutual Sharing of Advantages and DisAdvantages*). Reversely, *systemic constructal law* (figure 6), the global Whole is integrating the local parceners. Whatever the level of organisation (figure 7), the living systems obey the same principle of evolution and emergence: the volume of the adult system VA (i.e. space scaling) and its time of generation tg (i.e. duration scaling) are linked through a power law $VA^2 = C.tg^3$ (figure 8). The mass controlled duration of acquisition of the reproductive capacity and the volume at the acquisition are always linked by this power law of exponent 3/2 : this *dynamic fractal law* is invariant, "*between and within levels of organisation",* on a 62x62x62x62 dimensions scale (figure 9). As all the sub-systems which live in it, the whole Universe survives into an ecoexotope that it shares with other Universes. *Brownian motion* is the basic phenomenon of control of growth (figure 10) and flows exchange: matter and energy are exchanged at a constant flow rate (figure 11). A Pareto relationship governs limits and limitations interactions (figure 12): *'mutual survival depends on reciprocal limitations', 'for the best and for the worst'* (figure 13); *to survive that is to transform disadvantages into advantages and to avoid advantages turn to disadvantages* (figure 14) through interactive feedbacks (figure 15). [100 references]

keywords ARMSADA, fractal law, gauge invariance, governance, sustainability

1 Introduction

Complex systems, and particularly alive ones, can be represented and analysed as ***networks*** [1]. The availability of large-scale datasets that span the diversity of organisms has made possible to elucidate some of the organisational principles [2] and rules [3] that govern their function, robustness and evolution [4]. Variation in hundreds of species has been the subject of thousands of papers [5] that evidenced laws of practical importance for designing efficient sampling of agricultural pests and insect vectors of human diseases [6]. And log-log plotting may evidence which laws are power laws [5, 7] or not [8].

Figure 1 The *'freedom degrees'* of every living system level of organisation.
Living systems in practice: <u>the gauge invariance paradigm</u>.[17]

Figure 1a The functional capacities that are mutually necessary and sufficient to be a living system.

1. MATTER and ENERGY FLOWS CONTROLS
2. MASS GROWTH
3. REACTIONS TO external and internal STIMULATIONS
4. INNER SPACE-TIME ORGANISATION
5. OUTSIDE INTEGRATION into an ecoexotope of survival
6. MOVEMENTS
- CAPACITIES FOR THE SURVIVAL of the endophysiotope,
- IN ORDER TO ITSELF SURVIVE ITS SELF:
7. REPRODUCTION,
with or without NUMBER GROWTH
[***endophysiotope***: *endo*, internal, *tope,* ***space-time***, *physio,* of functioning;
ecoexotope: *exo*, external, *tope*, space-time, *eco*, of inhabitation (figure 2a)]
(CC-License, Bricage, 1991, 2000)

Figure 1b Example at the genomic level: always 7 sorts of functional genes (grey arrows).

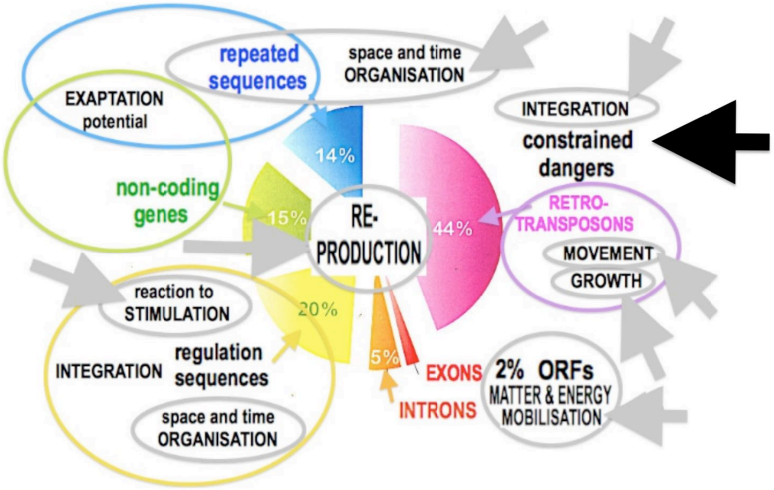


Figure 1c Example at the meta-cellular organisms level (figure 7): some **books by capacities.**

1. MATTER and ENERGY FLOWS CONTROLS
-**Energy forAnimal Life**. (174 p., OUP, Oxford, UK, McNeill Alexander R, 1999)
2. MASS GROWTH
-**Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies, and Companies**. (496 p., Penguin Press, London, UK, West G, 2017)
3. REACTIONS TO STIMULATIONS
-**Avoiding Attack**. **The Evolutionary Ecology of Crypsis, Warning Signals and Mimicry.** (264 p., OUP, Oxford, UK, Ruxton G D, Sherratt T N, Speed M P, 2004),
-**Comparative cognition**. (720 p., OUP, Oxford, UK, Wasserman E A, Zentall T R, 2009)
4. INNER SPACE-TIME ORGANIZATION
-**Rhythms of Life: The Biological Clocks that Control the Daily Lives of Every Living Thing.** (288 p., YUP, Yale, USA, Foster R G, Kreitzman L, 2005),
-Clinical **Anatomy and Physiology of Exotic Species: Structure and function of mammals, birds, reptiles and amphibians.** (272 p., Saunders Ltd, Dublin, Ireland, O'Malley B, 2005)
5. OUTSIDE INTEGRATION
-**The Origin and Evolution of Mammals.** (344 p., OUP, Oxford, UK, Kemp T S, 2004)
6. MOVEMENTS
-**Principles of Animal Locomotion**. (384 p., PUP, Princeton, USA, McNeill Alexander R, 2006)
7. REPRODUCTION, NUMBER GROWTH
-**Size and Gender Roles: Evolutionary Studies of Sexual Size Dimorphism**. (280 p., OUP, Oxford, UK, Fairbairn D J, Blanckenhorn W U, Székely T, 2007),
-**The Origin of Humanness in the Biology of Love.** (227 p., Imprint Academic, Exeter, UK, Maturana Romesin H, Verden-Zöller G, 2009),
-**Embryonic Stem Cells**. (360 p., OUP, Oxford, UK, Notarianni E, Evans M J, 2006)

Figure 2 Mapping functionalism of every living system governance.

Figure 2a How mapping space? : ecoexotope and endophysiotope.

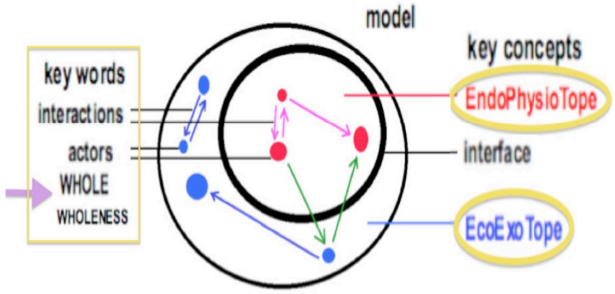


Figure 2c The systemic constructal law.

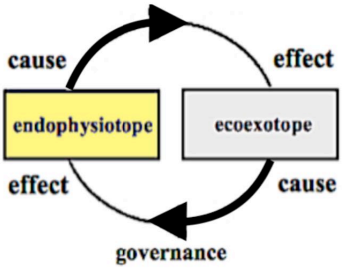
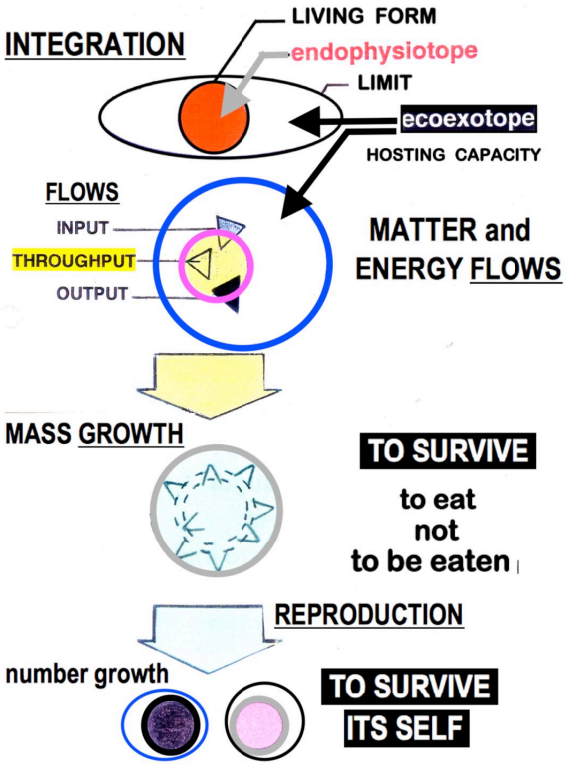
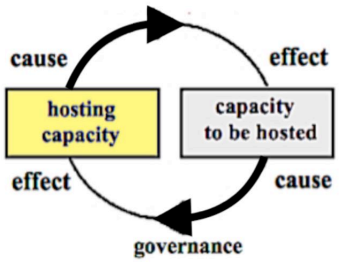


Figure 2b Growth in mass and number (**CC-License**): the life cycle, ***'to eat'.***



the limitations cycle



TO SURVIVE

1. MATTER and ENERGY FLOWS
2. MASS GROWTH
3. REACTIONS to STIMULATIONS
4. INSIDE space and time ORGANIZATION
5. OUTSIDE INTEGRATION
6. MOTION

TO SURVIVE ITS SELF

7. REPRODUCTION [number growth]

Figure 2d The gauge invariance paradigm.

integration and organisation (model and keywords)

A living system is always made of 3 kinds of entities: actors, interactions and the Whole (2a) [2, 9]. Every living system, whatever its organisation level, is integrated into an ***ecoexotope*** of survival (EXO: external, tope: space-time, ECO: of inhabitation) which gives the system e***ndophysiotope*** (ENDO: internal, tope: space-time, PHYSIO: of functioning) an hosting capacity (2b). Changes of the **hosting capacity** result in changes into the **capacity to be hosted**, and reciprocally (2c). Every living system is integrated into an ecoexotope within which it is more adapted, for its **mass growth and reproduction** (2b, 2d), to the interactions network (figure 5) between ecoexotope and endophysiotope, than other systems of systems are (2b). Every effect has a cause and every effect is a new cause for new effects (2c). Changes of the ecoexotope and endophysiotope are overlapping in a loop: ***(hosting capacity)x(capacity to be hosted)=k*** (figure 12). Step by step, by cycling again and again through amplifying loops, ***"a threshold of growth is a requisite for development, a threshold of development is a requisite for growth"***. (CC-License, Bricage, 1991, 2000)

What operational definitions and general paradigms [9, 10] can we use to built a useful model of living systems governance? What rules for their organisation [11] and survival duration can we evidence [12]?

2 Materials and Methods. A meta-analysis of large-scale datasets.

What operational definition for every living system? A theory of living systems must explain simultaneously the adaptive matter and energy flows [13], the control and regulation of behaviour and their changes [14], whatever the space [15] and whatever the time [16].

1) How to define a living system? How to design it as a Whole?

As a Whole, every living system owns 7 functional capacities (figure 1): ***-the control of matter and energy flows***, that eventually allows ***-the mass growth***, ***- the capability to respond to various stimulations***, ***-the ontogeny of an internal organisation***, ***-the capacity of integration into a peculiar ecoexotope of survival***, and ***-the capacity of motion***, that mutually eventually allow it survives enough time to get ***-the capacity of reproduction*** [17]. Structurally, every living system is composed of an ***endophysiotope*** (endo: internal, tope: ***space-time***, physio: of functioning) that is integrated into an ***ecoexotope*** of survival (exo: external, tope: space-time, eco: of inhabitation). The ecoexotope provides ***a hosting capacity*** that allows the survival of the endophysiotope only if it gets ***a capacity to be hosted*** in adequacy: figure 2 [18]. All these capacities are interrelated and linked together into a functional network (figure 3). All together they are mutually necessary and sufficient to be alive. Whatever ***the level of organisation*** of a living system [11], it must, sooner or later, along its life cycle, express all these capacities (figure 2b), which define ***the functionalism of a level of organisation*** [19].

2) The gauge invariance paradigm.

For example, into the genome [20], at the cell level, we can sort the genes into groups expressing these capacities (figure 1b). A lot of books have been written for each of these capacities and for different levels of organization (figure 1c). As a consequence a bee is not a living system but the swarm of bees is the living system [21]. Only the swarm owns the 7 capacities (figure 1a). Indeed an atom is also a living system [11]: fusion is mass growth, fission is reproduction. All the 7 capacities are expressed at the atoms level of organization, but at space-time dimensions and at temperatures that are not ours [22]. ***Other scales but the same gauge invariance paradigm***! Whatever the level of organization of a system, whatever the scale [15], to be alive a system must, as a Whole (figure 2b), sooner or later, express these 7 capacities (figure 2d). ***They are mutually necessary and sufficient***. The gauge invariance paradigm (figure 3a) is the key to define the notion of ***scale invariant*** level of organization. The endophysiotopes of our cells (organization level ***i***) are inhabiting our body endophysiotope (adjacent organization level ***i+1***) which is their ecoexotope of survival (figure 4).

3) What is the keystone paradigm for sustainability?

Look at what a lichen is [23]. A lichen is like *a mille-feuille*. The body of a fungus is ***hosting*** a population of green algal cells. Into the Whole, the lichen endophysiotope, the juxtaposed algal actors are embedded and protected by other actors, the cells of the multi-cellular fungal body. That is a great ***advantage*** for the algal cells, they can survive better than if they were free alone outside the lichens. They can escape the outside dangers of the ecoexotope of the lichen. But that is a ***disadvantage*** for the fungal partner. It must spend a great part of its matter and energy to allow the survival of the algal population partner. So its growth is reduced. For the Whole, that is a ***disadvantage*** [24]: a lichen is a slow-growing organism. But it can survive into ecoexotopes where no other living form can. Lichens are living pioneers. That is a great ***advantage***. But, sooner or later, fungal filaments are catching algal cells and they eat them.

Figure 3 The network of capacities interactions within a level of organisation.

Figure 3a Paradigm of gauge invariance, Bricage's representation [17, 18, 19] (**CC-License**): the functional design of interactions between capacities (figure 1).

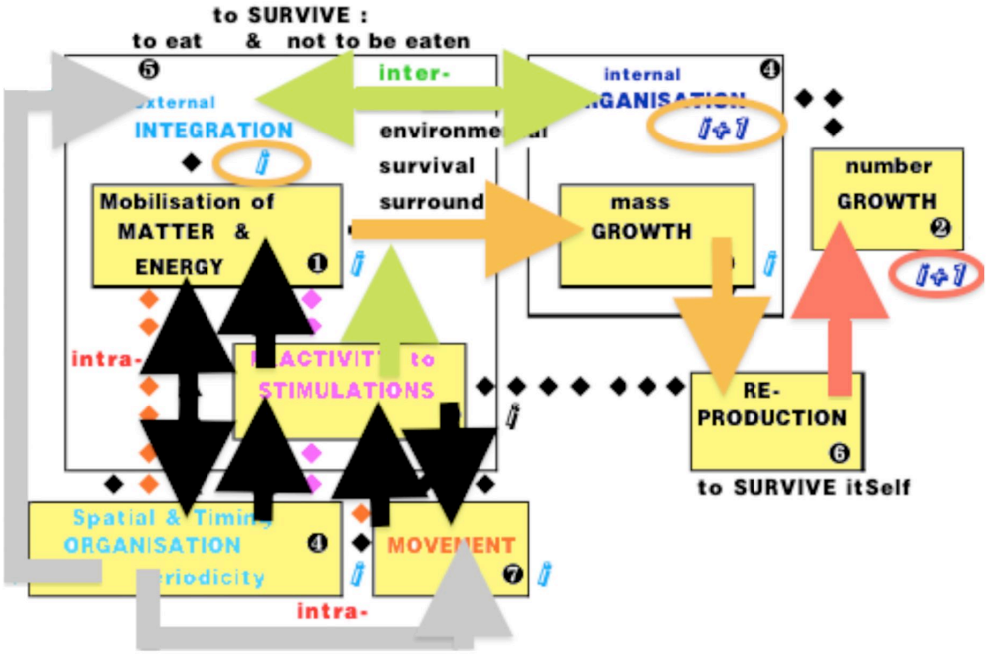
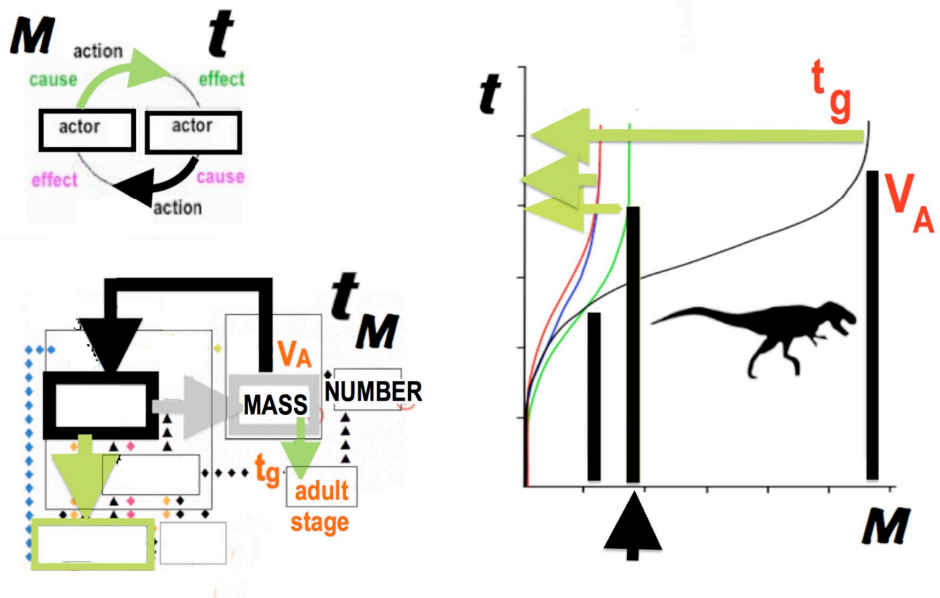


Figure 3b Towards the adult stage: temporal level, the mass governance of growth phase duration.

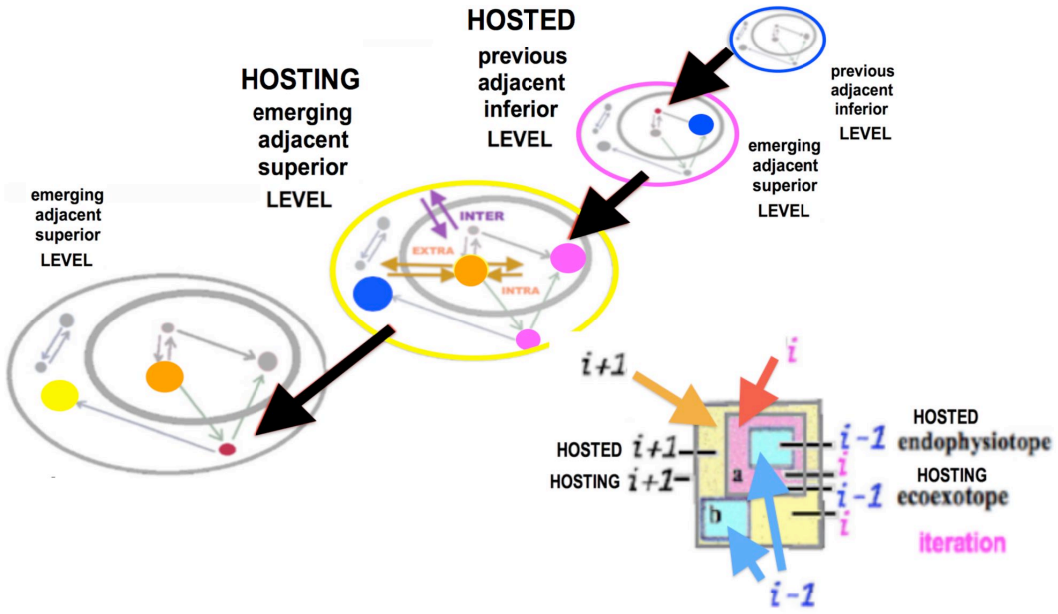


Usually we represent mass growth along time **t**. But indeed we should graph the contrary, whatever the living system, body mass **M** is the governing factor of the duration of growth phase, or time of generation **tg**, which results from attaining a mass threshold, corresponding to the adult volume **VA**.
(CC-License, Bricage, 2013)

Now that is a great advantage for the fungal partner and a great disadvantage for the algal one. ***All that is an advantage for a partner is a disadvantage for the other one and reciprocally***. A lichen is an association between partners of different levels of organisation that are ***fused together in a new whole for the best and for the worst***. A symbiosis [25] is ***never an association for mutual benefits***: advantages and disadvantages are reciprocally shared between local partners and mutually shared with the Whole (figure 5): if benefits they are only for the Whole, the lichen, which is an **A**ssociation for the **R**eciprocal and **M**utual **S**haring of **A**dvantages and **D**is**A**dvantages (in brief: an **ARMSADA**). The same for a green earth newt or a green sea snail which bodies are, like the fungal body of a lichen, hosting a population of green algal cells. ARMSADAs are everywhere [26]. ***There are never advantages without disadvantages.*** A win-win situation is not a systemic one [20]. No living system can be seen outside the ecoexotope of survival it is sharing with other living forms. The partners of the first emergent lichen were ancient free living algal and fungal species that were sharing the same ecoexotope of survival [27]. These founding ancestors don't exist anymore. They disappeared but their progenies always exist into the Whole of the current lichens, and only as lichens, never as free entities. But some brother species are already living freely. They have never met and merged to form a lichen. They probably will never. The fungal and the constrained embedded algal endophysiotopes cannot escape from the lichen. They cannot again be free to survive outside the lichen endophysiotope which is their common shared ecoexotope of survival [21].

Figure 4 Evolution paradigm: ecoexotope and endophysiotope embedments and juxtapositions.
A cyber-systemics view of a living system-of-systems: modelling modularity [11, 30].

Every endophysiotope (blue, red, orange arrows) is both **HOSTED** into an ecoexotope of the same level of organisation (***i-1***, ***i***, ***i+1***) and **HOSTING** endophysiotopes and ecoexotopes of inferior levels of organisation in an iteration process (black arrows): endophysiotopes of organisation levels ***i-j*** (0<j<n) are modules inhabiting endophysiotopes of an organisation level ***i+1*** as their common ecoexotopes of survival (CC-License, Bricage).



4) The ARMSADA paradigm: what really symbiosis is!

Viruses are eating bacteria [28]. Rarely, a virus that invades a bacterium (level ***i-1***) is not able to eat it [29]. This defective bacteriophage is a predator that is unable to kill its prey. Sooner or later bacteriophage-bacterium interactions can give rise to new systems: when the genome of an invading virus is integrated into the bacterial genome, a new endophysiotope emerges in which the virus is embedded,

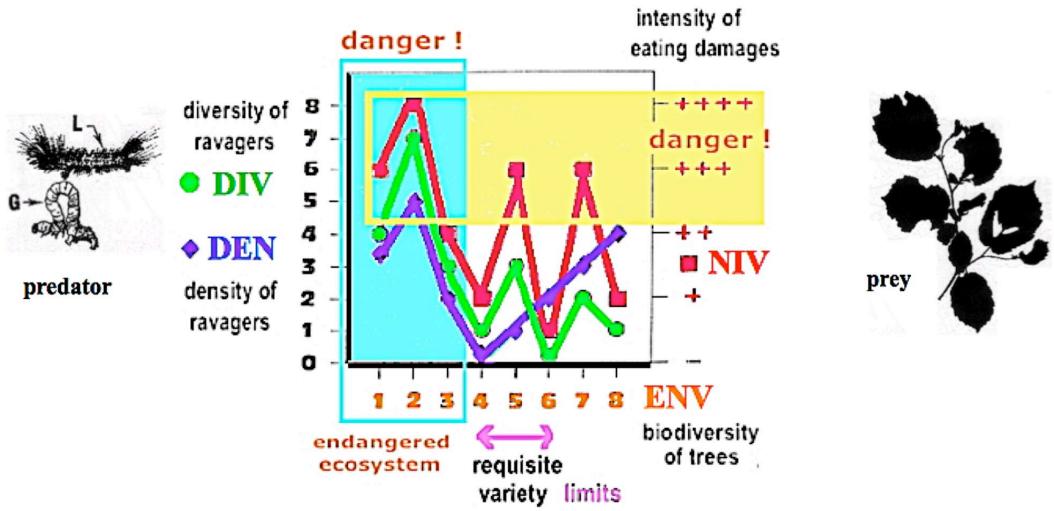
and eventually juxtaposed to other previously embedded viruses. It is a change of scale for the virus. It is now surviving as long as its host survives too. A new system has emerged that is more than a bacterium and a virus. But this integrated Whole can be broken by outside dangers of the bacterium ecoexotope, because the virus is a constrained inside danger that can be released if the bacterial or cell endophysiotope is damaged by other dangers [30]. It is a symbiosis state, as in a lichen or mycorrhizae [31]. ***'To survive that is to eat and not to be eaten'***. For the new Whole to survive both partners must survive: ***for the one to survive***, the virus or the bacterium, ***the other one***, the bacterium or the virus, ***must survive first***.

A cell (i.e. level: ***i***) is an ARMSADA too. The cell probably emerged through the merging of previous partners, of bacterial and archaeal types, from the adjacent inferior level of organisation of the Monera (level ***i-1***), with the help of a RNA viral partner [32]. The cell current endogenous membranes system is the result of that merging. And the fossil of the antic virus is the centrosome that is involved in cell division [33]. Because of the cell origin our cells genome is hosting a lot of genomes of bacterial and viral origins (figure 1b). Cancer disease, which is an advantage for the survival of the cancer cells (level ***i***) and a disadvantage for the survival of the organism (level ***i+1***), is the result of the cell **ARMSADA breakage** [30]. Apoptosis is another kind of breakage, but which an advantage for the survival of the organism and a disadvantage for the survival of the apoptotic cell. Look at the functioning of a forest [34]. Like a viruses-bacteria system it is also a predators-preys interactions network (figure 5a). For caterpillars ***to survive that is to eat*** trees leaves. For trees ***to survive that is not to be eaten*** by caterpillars. To survive that is to eat and not to be eaten, but, ***sooner or later, it is impossible not to be eaten***. The density (growth number) and the species diversity of the caterpillars predators are controlled by the density and diversity of the trees preys. An enough variety of trees species, the preys, is requisite for the survival of the Whole, the forest [35]. If not enough preys or too much the ecosystem is endangered. The Whole survival needs a not too much, not too little, but enough (*meden agan*), species variety. ***A requisite variety interval is the key***. Too much variety can destroy variety. At the ecosystem level (***i+2***) a forest is also a system of systems [36, 37]. Organisms of the bacterial level (***i-1***), the cell level (***i***) and the meta-cell level (***i+1***) are juxtaposed and embedded to make a forest (level ***i+2***) as a Whole and a forest is an ARMSADA too [36].

Whatever the level of organisation we are looking at, ***each living system is an ecosystem of ecosystems***, with embedded and juxtaposed compartmented food networks [20]. Living systems are ***systems of system*****s** that are ***built by embedment and juxtaposition*** of previous less complex systems (figure 4) but according to the same functional law of merging and emergence: the ARMSADA paradigm. In every ARMSADA, like a lichen, a cell or a forest [37], for one actor to survive, all the other ones must survive first. An ARMSADA is ***a 'pluribus unum' organism***. Matter and energy flows are first for the survival of the Whole: ***'unus pro omnibus omnes pro uno'***, ***'in varietate concordia'*** [21]. Into a lichen or a cell every actor gets its own space-time of survival and functioning: ***'a space for each one and each one in its space'*** [38], ***'a time for each one and each one in its time'*** [9]. Into an ARMSADA, advantages for a partner are always disadvantages for other ones and *reciprocally*. If benefits they are only for their Whole, for the *mutual* global association of the local actors: *'reciprocal interactions'* means local interactions between partners, *'mutual interactions'* means global interactions with and within the Whole (figure 5b). All actors and their Whole are making one, in ***a 'unity through diversity' way of survival*** [24]. The merging into an ARMSADA is the result of ***'a percolation process'*** (figure 5c): the same way neurones behave for the emergence and maintenance of neural networks, ***'systems which wired together do fire together'*** and ***'to wire together systems must fire together'***. The percolation process is a metamorphosis [39]: actors and properties of the previous step (before state) are lost, new ones are gained (after, at the end of the process), others are maintained, but transformed during the process. It is not a win-win process [20]. ***There are never winners without losers*** [40]. Every partner is both winner and loser [23, 30, 32, 40, 41]. The only winner is their Whole (figure 5b) [42].

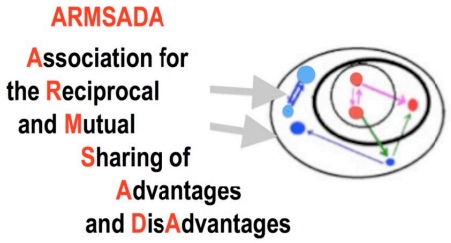
Figure 5 Emergence of every new interactions network by percolation.

Figure 5a Homeorhesis: endogenous balances of a forest ecosystem (CC-License, Bricage, 1991).



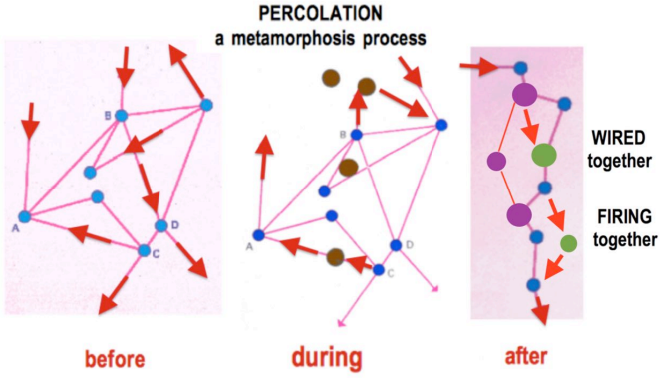
The biodiversity of the plant partners ENV, the biomass producers, the preys, is limiting the diversity DIV and density DEN of their predators (**L**, **G**). The Whole, the forest ecosystem, is endangered either if not enough diversity (**ENV<3**) or if too much diversity (**ENV>8**) ; ***in-between*** (3<<8), ***'meden agan'***, there is enough requisite variety to allow homeo-rhesis from one homeo-static state (**ENV=4**) to another (**ENV=6**) depending on increasing or decreasing changes of the actors requisite variety into the system-of-systems (figure 2a) [17].

Figure 5b ARMSADA (Bricage, CC-License).



Local reciprocal interactions **between** partners (grey arrow) and **global mutual** ones with the Whole and **within** it (grey arrow) are busy together (figure 2c). It is ***a 'synallagmatic' deal, not a win-win deal.***

Figure 5c Homeorhesis: emergence of a new homeostatic network [32] (Bricage, CC-License).



The ***'before'*** homeostatic balanced network (i.e. ***functional steady state***) is changing to another, the ***'after'*** homeostatic balanced new network, through a metamorphosis process: - ancient actors (before, in **blue**) and interactions (**red** arrows) disappeared, - new actors (***during***, in **brown**) have been integrated, - ancient actors are retained but with changes (after, in **green**). Same new functional structures may emerge through different ways: **convergence**. Ancient structures can get new functions: **exaptation** (figure 6).

5) The systemic constructal law and the emergence of new properties.

ARMSADAs are everywhere [43]! Viruses that are inhabiting bacteria, like algal cells are inhabiting the lichen fungus, ***give their host new properties*** that allow bacteria to eat new preys. ***To survive that is first to eat!*** Viruses that are inhabiting bacteria or eukaryotic cells, like our cells, give new properties that allow these bacteria or cells not to be eaten by other viruses or bacteria. ***To survive that is not to be eaten too!*** Endogenous integrated viruses are protecting their host against other viruses. These endogenous integrated constrained dangers (figure 1b) are not only necessary for their host to survive but also for their host to reproduce. And with its host survival, the integrated virus survives too. Living systems are ***systems of systems of adjacent levels*** of organisation. The functional structure, within or between systems, is the result of simultaneous reciprocal interactions: ***'interaction is construction and construction is interaction'***, so, sooner or later, we don't know which are causes or effects: ***systemic constructal law*** (figure 6). For example, root nodules cells (level ***i***) of leguminous plants own a new property of atmospheric nitrogen fixation, but none of the partners, neither the plant organism (level ***i+1***), nor the invading population of bacteria (level ***i-1***) can fix nitrogen from the air [21].

Figure 6 The systemic constructal law.
"interaction is construction, construction is interaction"

Figure 6a Global interactions between endophysiotope and ecoexotope (CC-License, Bricage).

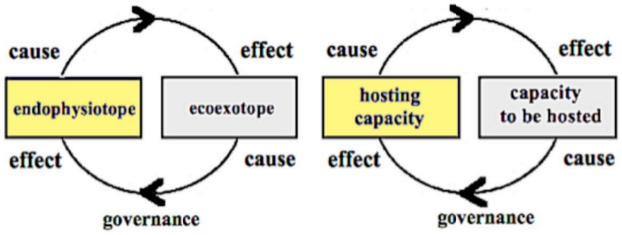
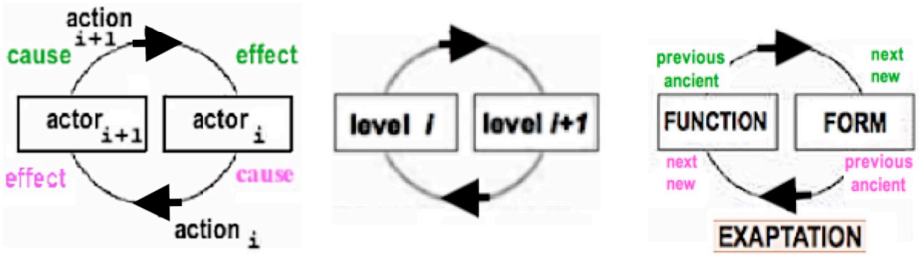
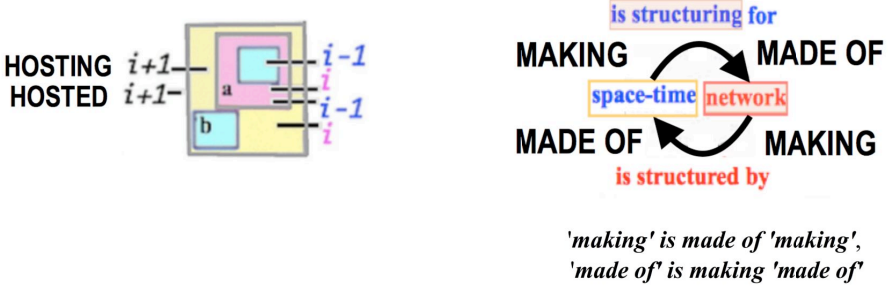


Figure 6b Local interactions between actors into the Whole (figure 2).
Causes give birth to effects that, as causes, give birth to other effects, again and again, in a feed back control cycling way. So ***finally we don't know which are causes and which are effects***. New structures can emerge through metamorphosis (figure 5c). New functions can emerge from ancient structures: ***exaptation***.



within a level **between levels**

Figure 6c Embedment and juxtaposition of levels of organisation (figure 4).



'making' is made of 'making',
'made of' is making 'made of'

3 Results

Either with the leguminous plant nodules formation [44] or with the early cell ontogenesis [32], ***the first step of building an ARMSADA is an emergency situation*** [21]. Free living bacteria (Rhizobium) invade plant roots hair cells. As every parasite, these bacteria eat the plant cells matter. That is a great advantage, they grow in mass, divide and grow in number, killing the cells and moving into the plant body. But ***sooner or later*** the invasion is stopped and the surviving bacteria are sequestered into plant cells vacuoles where they can survive, in the absence of oxygen only by nitrogen fixation. Now that is a great disadvantage. Only the new emerging tumorous nodule as a Whole owns the peculiar property of nitrogen fixation. Nowadays animal and plant oxygen respiratory cells are hosting an ancient free living invading bacterial species which gave rise to the current mitochondrial partner of these cells [38]. The ancient parasitic bacterial ancestor species (level ***i-1***) disappeared but its integrated descent lineage is still surviving within the cellular (level ***i***) and meta-cellular (level ***i+1***) organisms since hundreds millions of years. And it will survive as long as the cell species will survive, the same as for the viruses that are surviving into the cell nucleus (figure 1b) [39, 45].

1) What law of governance does allow living systems of systems ontogenesis and evolution?

Like Rhizobium mutations are regulating the tumorous process of nodule emergence, mitochondrial mutations may give birth to tumorous cells [30]. Mitochondria may be invaded and eaten by viruses, like bacteria are. These viruses look like ancestral viruses that were invading and eating the mitochondrial bacterial ancestors. Nowadays when a cell is damaged, the inhabiting mitochondria will be killed except if they can integrate another hosting cell. Like bacteria, mitochondria always get invading properties and can move from one cell to another. When the mitochondria are damaged, the inhabited cell will be killed. During the apoptosis process, damaged mitochondria are eaten. The whole cell materials are eaten and recycled to make new cells. Into an ARMSADA disadvantages for a partner are disadvantages for other ones, and for the Whole. ***All partners are fused together in a new whole for the best and for the worst.*** Man species is not an exception [41, 46].

The third paradigm is that ***'all new living systems blueprints are emerging by merging of partners into an ARMSADA'*** [24]. A new emergent adjacent superior level of organisation is always hosting previous adjacent inferior levels, that are juxtaposed and embedded in it [11]; ***hosted systems*** are embedded into the new ***hosting system-of-systems*** in which they merged into an ARMSADA. It is an iteration process (figure 4) with feedbacks between and within sub-systems (figure 5) and the system-of-systems (figure 6). The hosted systems are more and more independent of their ancient ecoexotope of survival and more and more dependent of the endophysiotope of their Whole [18], which is their new ecoexotope of survival (figure 6a). Increasing interactions and retro-controls (figure 6c) allow the endophysiotope of a ***i*** level to be the ecoexotope of survival of different ***i-j*** levels (figure 6b). And the ecoexotope of a ***i*** level, sooner or later, will be embedded into the endophysiotope of a ***i+k*** level organism.

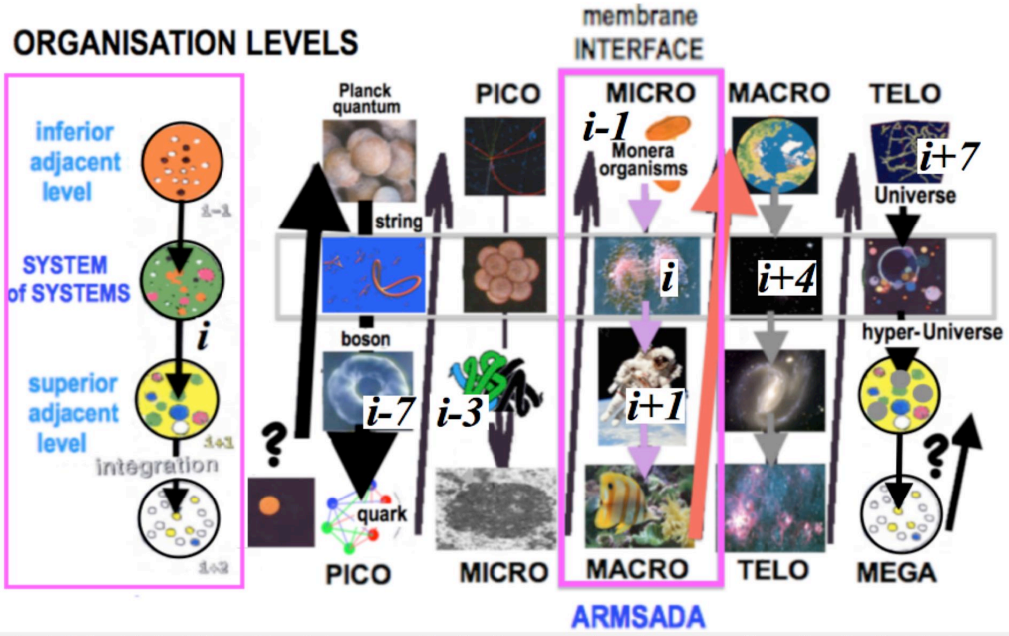
2) A periodic classification chart for living systems.

Due to the ARMSADA process of emerging of new blue-prints, life is not a tree but a coral [7]. A lot of merging allowed new system-of-systems emergences. We can range the current known results in a table (figure 7) according to the scaling invariance [5, 47] for the definition of levels of organisation (figure 1). Each column represents the same kind of way of system-of-systems complexity enhancement and each line represents the same step of systems species evolution. Sub-steps into each step are not represented. For example within the step of Man species there are a great number of kind of societies [42].

3) An invariant scaling relationship between living systems whatever the level of organisation.

According both to ***the gauge invariance paradigm of functioning*** and ***the ARMSADA paradigm of structuration*** we can draw a periodic classification chart of the levels of organisation of all known, or unknown, living systems, from the quantum of Planck to the Universe as a Whole (figure 7) [21].

Figure 7 Living systems of systems periodic classification chart.

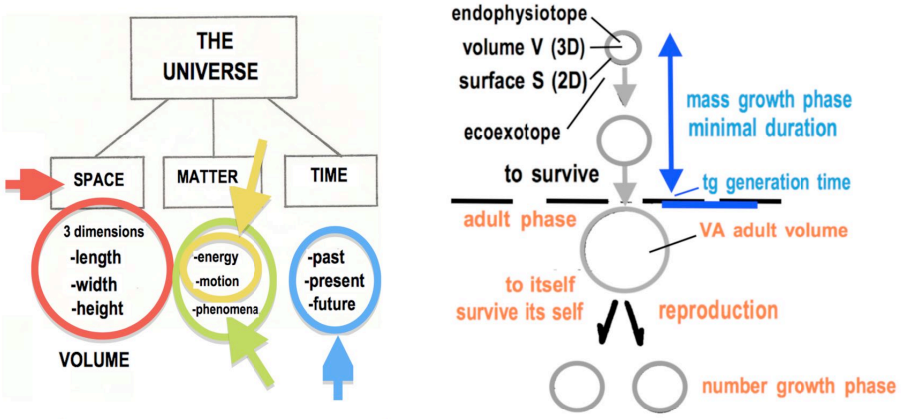


This fractal chart is built by taking into account both -the gauge invariance paradigm (i.e. the fact that any alive system, whatever its level of organisation [e.g. level ***i-1***, level ***i***] owns the 7 mutually necessary and sufficient characteristics: figure 1), and -the ARMSADA paradigm (i.e. the assumption that any level of organisation is a system-of-systems that results from the emergence of an ARMSADA by merging of previous systems). Every box of the chart indicates a level of organisation which is embedding (**hosting**) the previous level(s) and which is embedded (**hosted**) into the next level(s) (as *'poupées gigognes', Matryoshka dolls*). Any level of organisation is both a local actor of a neighbouring upper level of organisation (adjacent superior level) and a Whole which contains actors of lower levels of organisation (adjacent inferior level) (i.e. systemic constructal law: figure 6).
From down to the top, from the quantum of Planck to the whole Universe, the black arrows are indicating ***the 'rising complexity'***, from the infra-microscopic levels (PICO) to the microscopic ones (MICRO), then from the macroscopic levels (MACRO) to the supra-macroscopic (TELO), and above (MEGA). The jump from a level to the following one, indicated by an arrow, is made by the emergence of an ARMSADA, e.g. looking at 'the violet framed column': from ***i-1*** to ***i*** (from the level of Monera to the level of the unicellular organisms), from ***i*** to ***i+1*** (from the cellular level to the meta-cellular level), from ***i+1*** to ***i+2*** (from the level of the meta-cellular organisms to the Earth ecosystems level). All the boxes into the same column include systems ***the actors of which possess the same type of interface*** between their endophysiotope and ecoexotope (e.g. a membrane interface [53], for the violet framed column). Arrows of different columns but on the same place indicate same kinds of jumping process. Systems the boxes of which are horizontally aligned, e.g. the grey framed boxes line, correspond to "same step of evolution" systems but between different kinds of interface (CC-License, Bricage, 2001, 2009).

Every living system-of-systems can be characterised by its time dimension, in seconds, and its space dimension, its volume, in cubic meters (figure 8a) [48]. But due to the dimensional wide scales we must use a logarithmic representation to plot all data (figure 8b) [7]. Our ecoexotope of survival, the Universe, is always in its growth phase, expanding its volume (figure 8c). And every living system-of-systems in it are representatives of different steps of its expanding complexity. For every living species, space growth is governing time flow rate (figure 8c) like mass growth is governing time duration (figure 3b). It is a space-time co-evolution process [7, 49], time is a measure of space, and reciprocally (figure 8d). We may plot together the volume of the system at the end of its growth phase, **VA** the adult volume, at the sexual maturity [50], and the time that is necessary for the system to gain its capacity of reproduction, ***tg*** [51].

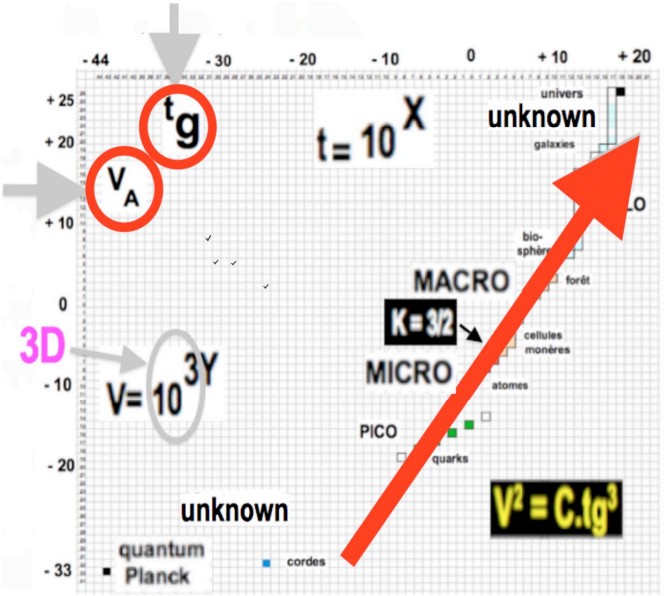
Figure 8 Looking at the Universe growth in powers of 10:
Log-Log plotting of dimensional space-time scale.

Figure 8a Which parameters are the most representative of the fate of a living system?



According to the gauge invariance paradigm, looking at ***space and mass*** we measure ***the volume*** of a system but at its adult step at the end of its mass growth phase, **VA** (figure 2b). We also look at the ***time*** that is necessary for the system to acquire its capacity of reproduction, i.e. the duration of that larval growth phase **tg** (figure 3b).

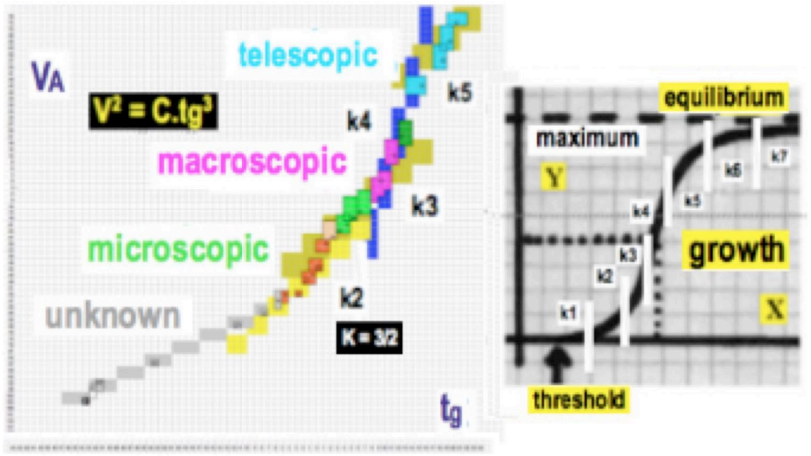
Figure 8b The Universe: a (62x62x62)x62 powers of 10 wide range 4D scale picture [7].



units: **m** meter for space (1D), **s** second for time, slope: 3/2 (CC-License, Bricage, 2009)

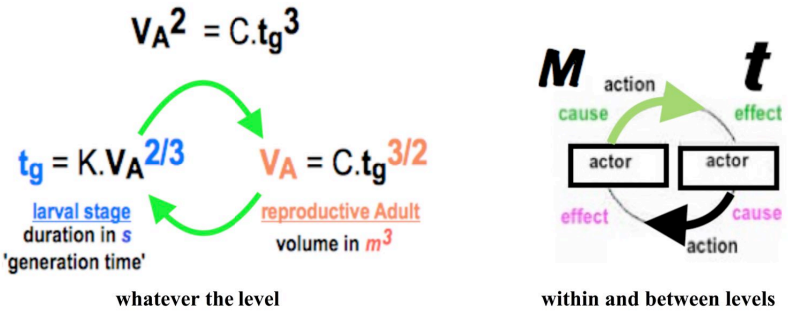
Plotting data from all known levels of organisation with a powers of ten **Log-Log** graph gives a linear relationship between **tg** and **VA**, which slope is **3/2** (with ***tg*** as abscissa). [e.g. orders of magnitude of some spatial dimensions (**1D**), values in powers of ten (62 wide ranging scale): visible diameter of the Universe **+26 m**, of the earth +7 m, of a cell -5 m, of an atom -10 m, of an atom nucleus -15 m, of a proton or neutron -16 m, of an electron -17 m, of a quark -18 m, of a string -34 m, length of Planck **-35 m**. Order of magnitude of some temporal dimensions, values in powers of ten (62 wide ranging scale): age of the Universe more than **+18 s**, time of generation of a cell +4 s, life expectancy of a boson or a free quark -24 s, time of Planck **-43 s**; initial size of the Universe -35 m at -43 s]. Look at http://www.armsada.eu/pb/bernardins/phylotagmotaphologie.pdf
Y spatial level of organisation in a 1D scale of powers of 10, the **3D** volume scale is a power of **3Y**, **VA** is the adult state volume; **X temporal level of organisation**, in a powers of 10 scale too, **tg** is the time of generation, the duration of achievement of the grown-up stage (i.e. the duration of the larval phase of growth), slope **K** = + **3/2** [i.e. the relationship between tg and VA is a power law of 3/2 (or 2/3) exponent depending which parameter we assume as X (tg or VA) or Y (VA or tg) in the plotting (systemic constructal law: figure 6)].

Figure 8c A logistic growth for the Whole (CC-License, Bricage, 2009).



Plotting data from all, real and *'virtual'* (i.e. unknown, but *'modelled'*) levels of organisation, with this Log-Log graph (8b) gives a sigmoid curve which is representative of a growth phenomenon of the Whole. As a Whole, our Universe of inhabitation is growing, expanding its volume. It is always in its growth phase and every living system-of-systems, everywhere in it, are representatives of different steps of its expanding complexity. There is a discordance, a breakage, in the line just between the virtual quantic world and the real classic world. We don't know why. Maybe, in the current quantic world models, either spaces are over-estimated or times are under-estimated. **k1** domain of the quantic virtual part of the Universe, an unknown but modelled and simulated world, **k2** domain of the infra-microscopic and microscopic known real parts, **k3** macroscopic domain of meta-cell organisms species (including the anthropic domain), **k4** Earth and stellar systems domains, **k5** telescopic domain of the cosmic part of galaxies, a badly known but modelled world, **k6** and **k7** unknown parts of the ecoexotope of survival of the endophysiotope of the whole Universe (figure 9).

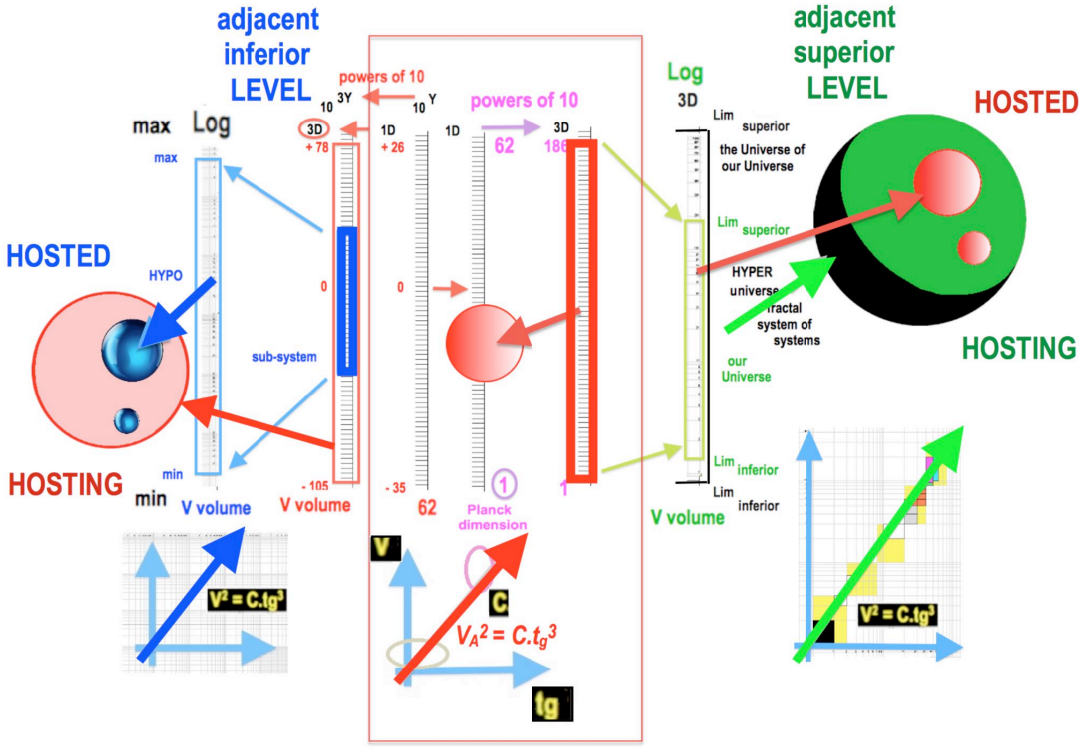
Figure 8d A 4D space-time co-evolution process.



For every living system-of-systems species, time **tg** is a measure of space **VA** and reciprocally (figure 10). Space growth is governing time flow rate like mass growth is governing time duration (figure 3). (CC-License, Bricage, 2009, 2014)

The time of generation, tg, is also the duration of the growth larval phase (figure 3b), in a log-log plot we get a line with a 3/2 slope (figure 8b). If we now take subparts of these data, the sub-systems are governed by the same 3/2 power law that the system-of-systems is (figure 9). And if we plot again all the whole Universe system-of-systems data of the previous log-log plot, using the same log-log plotting we get again a 3/2 slope line (figures 8, 9). So the Universe as a Whole is a sub-system of an hyper-Universe which is governed by the same power law. Thus this power law is ***a scaling invariant fractal power law*** of governance of living systems of systems [36, 52].

Figure 9 A between and within levels of organisation fractal dynamics.
A slope of **3/2** on a (62x62x62)x62 scale dimensions world, fractal law: $V_A^{\,2} = C.t_g^{\,3}$
Units for iterated Log-Log plotting: **m** meter, **s** second, for space and time dimensions.



According to the gauge invariance paradigm (figures 1, 2), looking at ***space and mass*** we can measure ***the volume*** of a living system but at its adult step, at the end of its mass growth phase, **VA** (figure 3). We can also look at the ***time*** that is necessary for the system to acquire its capacity of reproduction, i.e. the duration of the larval growth phase **tg**. The relationship between **tg** and **VA** is a power law of **3/2** exponent (figure 8). On the scale of the whole Universe (right in the middle red frame: **red** scale, graph and volume; organisation level **N**), - as on the scale of its sub-systems parts (blue scale on the left: **blue** graph and volume; adjacent inferior levels **N-j**) **hosted** into the **hosting** Whole, - as in a scale beyond our Universe (on the right place: **green** graph and volume; adjacent superior level **N+1**, **hosting** our **hosted** Universe), - either when we go down in organisation or when we go up (figure 4), - whatever is the role and location of the local or global actors (figure 5), - whatever is the degree of embedment fitting and juxtaposition (figure 8), the time of generation **tg** (the mass controlled duration of acquisition of the reproductive capacity) and the adult volume **VA** (the volume at acquisition of the reproductive state) are always linked by the same power law of exponent 3/2 [13, 49] (CC-License, Bricage).

4) A hidden cryptic fundamental phenomenon of governance: the Brownian motion.

Brownian motion is a time dependent geometrical process that structures the Universe, from down to the top [7], according to a **3/2** power law of time (figure 10). We can notice that $V_A^{\,2/3} = C.\,tg$ and, whatever the dimensional units, **2/3** is often a threshold value in the phenomena of percolation (figure 5). Brownian motion structures 3/2 or 2/3 power laws of co-relation (figures 10, 11).

5) Matter and energy controlled limits and limitations.

We can also say that all living systems, at their interfaces, along their life cycle as a Whole (figure 11a), are exchanging matter and energy [53] at an average constant rate (figure 11b) and in a stochastic Brownian motion way of flows control (figure 11).

Figure 10 Brownian motion governance of structures:
Brownian motion structures 3/2 or 2/3 power laws of co-relation.

Figure 10a Mathematical definition as a power law dependence of space and time [61, 64].

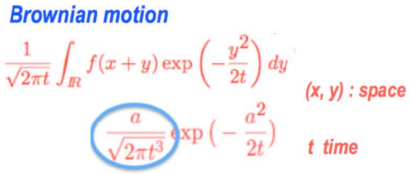
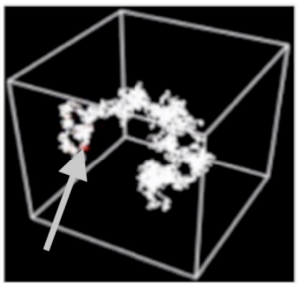
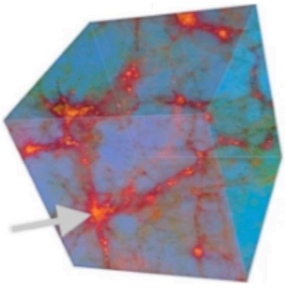


Figure 10b Brownian motion simulations of organisation levels [52].

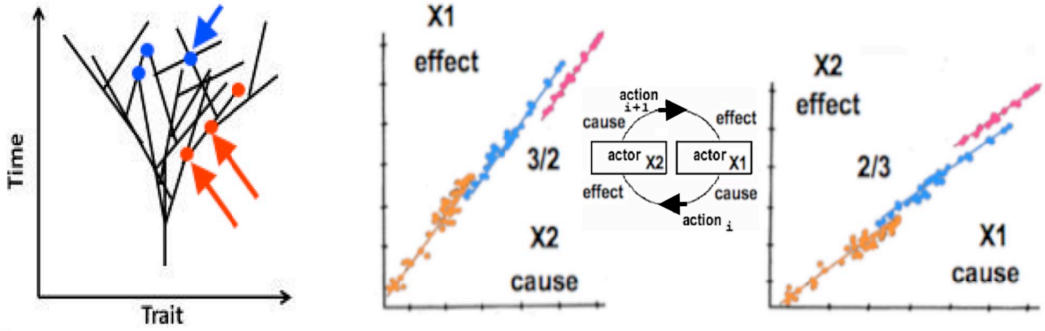


3D simulation of **free particles** (***i-5*** **level**) Brownian motion



3D simulation of the **Universe structure** (***i+7*** **level)** : a virtual spongy structure [7]

Figure 10c Brownian motion co-evolutionary processes modelling (CC-License, Bricage, 2014).



a stochastic way of emergences by fission and fusion [11]

equivalent 3/2 or 2/3 power laws of reciprocal co-relation [52]

We can notice that $V_A^{2\,x1/3} = C.t_g$ and we know that **1/3** is the limit of a convergent series ***of powers of 2*** which is evoking ***the series of divisions of a sub-system*** (figure 2b), for example a stem cell (level ***i***) which gives a growing-up system, a meta-cellular organism (level ***i+1***), during the growth phase of its cycle of development. Applied to a biological **trait** evolution, Brownian motion modelling results in 'a coral like' stochastic way of new species emergence, speciations by fission (red arrows) and fusion (blue arrow), like the ones we know by current processes functioning (i.e. ARMSADA emergence: blue arrow) and fossils records observation (e.g. graduation and sexual or geographical speciation: red arrows) of exaptation (figure 6) [7].

Figure 10d Modelling processes using the golden ratio?

$$\frac{a+b}{a} = \frac{a}{b} = \varphi \qquad 1 + \frac{1}{\varphi} = \varphi$$

In mathematics, 2 quantities **a** and **b** are in the golden ratio if ***their ratio is the same as the ratio of their sum to the larger of the two*** quantities. The Greek letter **φ** (*phi*) represents the golden ratio, which is an irrational number with a value of **1.618**0339... (near from 3/2 = 1.500).

Figure 11 Matter and energy constant flow rates. Brownian motion laws of co-relation.

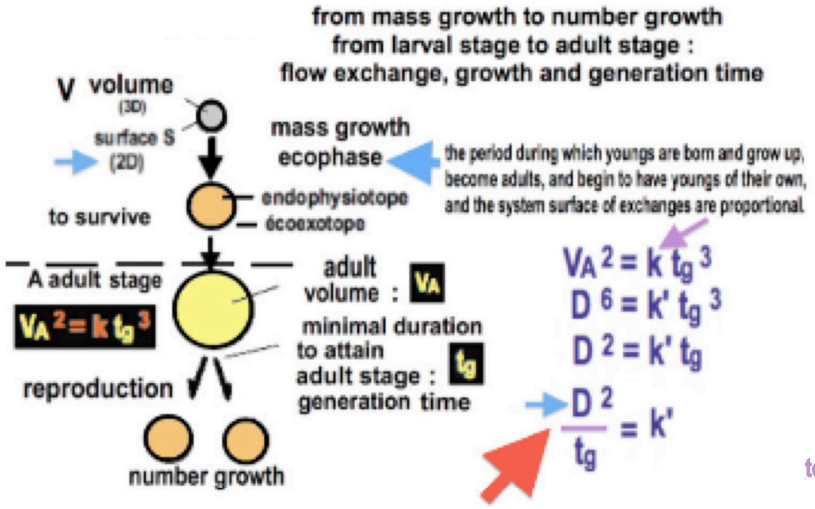
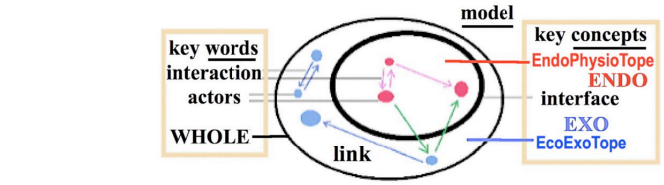


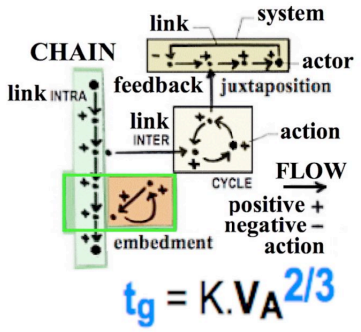
Figure 11a Life cycle. **Figure 11b** Exchanges rate. **Figure 11c** Flow chain.

Figure 11a Life cycle: a **gauge invariance constraint** (CC-License, Bricage).
To survive (figure 2b) and with a threshold of ***mass growth*** (figure 3b) is the prerequisite step for a life form (figure 5) to itself survive itself with eventually ***number growth*** (figure 1a) [7].

Figure 11b $V_A = C.t_g^{3/2}$ consequences:
because D is the linear space dimension, the flow of exchanges at the surface of exchange D^2 is a constant **k'**, i.e. **just-in-time exchanges** are the common rule; **3/2** is not just the true exponent that describes an optimum constraint: ***"the ratio of surface area to volume in a sphere"*** [52].

Figure 11c Flow chain limits and limitations (CC-Licence, Bricage).
Whatever the local inner processes of regulation, the interface constant flow rate (INPUT and OUTPUT) is the global limiting process. Thus *the 'to be hosted capacity' of the endophysiotope* and *the 'hosting capacity' of the ecoexotope* are in a Pareto relationship (HOSTING LIMITS)x(to be hosted LIMITATIONS) = C (figure 12).





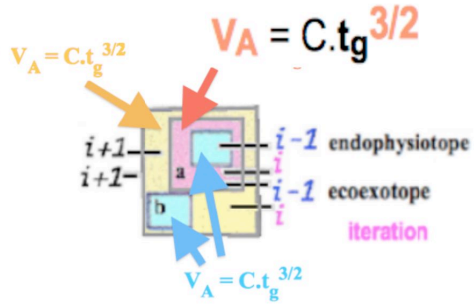


Figure 11d The space limited duration of flows. **Figure 11e** The system-of-systems iteration process.

We have noticed that $V_A^{2/3} = C.t_g$ (figure 8d) and we know that **2/3**= 1/(**3/2**) whatever the dimensional units, and 2/3 is often a threshold value in the phenomena of percolation (figure 5), as forest fires. For every living system-of-systems species, its time **tg** is a measure of its space **VA,** and reciprocally (figure 8d). The spaces embedment and juxtapositions emergence (figure 10) is ***a space-time co-evolution process*** (figure 9). So we can represent spaces embedment and juxtapositions either from a kinetic point of view (figure 11d) or from a geometric point of view (figure 11e). ***Mass is limiting duration*** (figure 3b) and ***mass growth is controlled by flow rate limitations*** (figure 11b). So, ***sooner or later, depending on interactions levels a threshold of growth allows the emergence of a new space*** (figure 4) ***which allows the emergence of a new time*** [13].

4 Discussion

There are never advantages without disadvantages: when new abilities are gained, previous ones are lost. ***The new Whole results always from a percolation process*** (figure 5): ***every Whole is always both more and less than the sum of its parts*** [9]. A neurone which expresses all capacities excepted the capacity of reproduction is not a new level of organisation, during its ontogenesis it gained new emergent properties, due to its new organisation, but it lost the capacity of division (figure 2b).

1) Modularity is the common rule for designing new Wholes and hosting ancient ones.

Juxtaposition and embedment are ***both the cause and the result*** of modularity (figure 4). Cell organisms (level ***i***) are made of modules of Monera like structures (level ***i-1***): the cell organites. These organites are made of clusters of macromolecules (level ***i-2***). Macromolecules (level ***i-3***) are embedding juxtaposed modules of atoms (level ***i-4***) (figure 7). For example the starch grains of a plant cell which grow in number during the cell mass growth are made of an accumulation of starch molecules layers. Mass growth and number growth of different levels of organisation are linked together ***within and between levels***. In terms of modules (figures 4, 11), we can consider ***either the spaces*** of interactions (figure 11e), to describe every living system-of-systems in terms of volumes (compartments space or mass), ***or the times*** of interactions (figure 11d), to describe in terms of time (process durations, flow rates) [49]. There are a minimum number (a threshold value) and a maximum one, of actors, of modules, of states, that are necessary for a controller (the Whole) to control a system (the Whole) which survival is depending from a limited number of interactions between the endophysiotopes of the actors as controllers of their common ecoexotope of survival (figure 5a).

2) Are power laws the common rules for governance control and homeorhesis?

Depending the way we are looking at the retro-action (feed-back) processes we may get inverse slopes, we can exchange the slopes, 2/3= 1/(2/3), but it is the same phenomenon of governance we are looking at (figures 8a, 10c). We can consider either the space or the time as a cause or an effect (figure 6). We can either consider the space if we look at the embedment and juxtaposition processes of ontogenesis of the subsystems into a new Whole (figure 4), or the time if we look at the flows of matter and energy (figure 11c), but it is the same phenomenon of governance and ontogenesis we are looking at (figure 8d).

We know a lot of such a kind of power law: -the Kepler's third ***law of motion governance***, that relies the cube of the space dimension (the semi-major axis) and the square of the time dimension (the orbital period) *in our solar system*, -the ***law of matter and energy governance***, law of irradiance that relies the mass to luminosity ratio of an object to its distance *in our whole Universe system*, which slope is 3/2 or 2/3 depending on what factor we suppose to be the cause or the effect (systemic constructal law), -the ***law of mass and number growths governance***, between the endophysiotopes of species sharing the same ecoexotope of survival, an allometric scaling law between population density and energy use [54], or the ***law of organisation governance*** of predator-prey communities across terrestrial and aquatic biomes [55], and again, depending which factor we consider as the cause or the effect we get a 3/2 or 2/3 slope power law [52] (figure 10). Other similar power laws are governing the relationship between the hosting capacity and the capacity to be hosted of every living system (figure 6): for example, -the space linear dimension and the duration time of food networks extension in the boreal forest (***matter and energy use and mass and number growths governance***), and ***'Man is not an exception'***, -the number of people and the time turnover of a society [20, 56] obey the same power law. Whatever the system-of-systems, the same power law is evidenced. This scaling invariance is expressing a modular fractal organisation (figures 9, 10c).

We usually represent mass growth within time flowing. But indeed mass is controlled by matter and energy flows (figure 3b) and is controlling time duration of growth [13]. Mass is determining time! There is a mass threshold for the system to acquire its capacity of reproduction [57]. Because to reproduce its self and eventually to grow in number (figure 2) has a cost which is paid by mass growth: mass growth stops and flows of matter and energy are invested into number growth. The Kleiber power law means the same [58, 59]. Mass is determining the metabolic rate with the same relationship independently of the level of organisation: a slope of 3/4 on a 18 dimensional world for animal livings [13]. All the metabolic processes in a cell obey power laws of different exponents. And the mean value [13] of all these measured processes is 3/2. These power laws are evidenced whatever the kind of metabolism. A power law of exponent 2/3 is representative of the simultaneous governance of nitrogen and phosphorus concentrations which are limiting factors of proteins and DNA metabolism [60] and of matter growth and energy availability in plant cells [51].

To survive is a game of chance. You need to be lucky, to be at the right place at the right time [4, 9, 39]. ***Before the time is not the time but after the time is no more the time***. How a system might increase durably either the hosting capacity of its ecoexotope of survival or the capacity to be hosted of its endophysiotope, to survive and live on? How to free its self, at least for a moment, from the space and time constraints? How to escape, at least for a moment, from the violence of the struggle for life [3, 24]?

3) Brownian motion is the key governing process.

Brownian motion was first observed, in 1827, by Robert Brown [61]. Through the microscope, he observed the motion of pollen grains (microscopic ***i+1*** level) in water, but he was unable to provide an explanation. Brownian motion provided the evidence of molecular motion (picoscopic ***i-3*** level) and the existence of infra-microscopic systems (figure 7) governing the functioning of macro-scopic living systems [62]. Norbert Wiener gave, in 1918, the mathematical definition and properties of the stochastic process (figure 10a), as the Wiener process [63]. Brownian motion emphasises the physical aspect of the process [64]. But, indeed, in 1900, Louis Bachelier had introduced the limit of random walk as a model for prices evolution on the Paris stock exchange and he is really at the origin of the Brownian motion mathematical model, now always occasionally found in financial literature [65].

For every living system-of-systems species, its time **tg** is a measure of its space **VA,** and reciprocally (figure 8d). The spaces embedment and juxtapositions emergence (figure 10) is a space-time co-evolution process (figure 9). So we can represent spaces embedment and juxtapositions either from a kinetic point of view (figure 11d) or from a geometric point of view (figure 11e). Whatever the scale, Brownian motion is structuring the geometry and rates of matter movements and interactions. Brownian motion can be described as a phenomenon of a 3/2 exponent of time (figure 10c). At the level of the Universe, the slope of the regression line between the distance of a light source and its red wavelength shift, which allows the experimental determination of the Hubble cosmological constant, is 2/3, or 1/(**3/2**). During their growth living systems exchange matter and energy at an average constant rate at interfaces (figure 11b). The 3/2 power law controlled flow is globally representative of the optimal ratio of the volume to surface area in a sphere. The big bang initial singularity is representative of an isotropic closed system [66]. Simulations of Brownian motion models at different scales (figure 10b) get pictures of living structures, from the quantum world to the whole Universe [52]. Looking at giant living systems they usually originate from tiny ones! Referring to the gauge invariance paradigm (figure 1), -mobilisation of matter and energy is flow motion, -mass growth is volume motion, -reaction to stimulations is information motion, -movement is motion, -organisation genesis is space-time steps motion, -integration is interactions motion, -reproduction is generations motion. ***Motions governance is Brownian motion governance!***

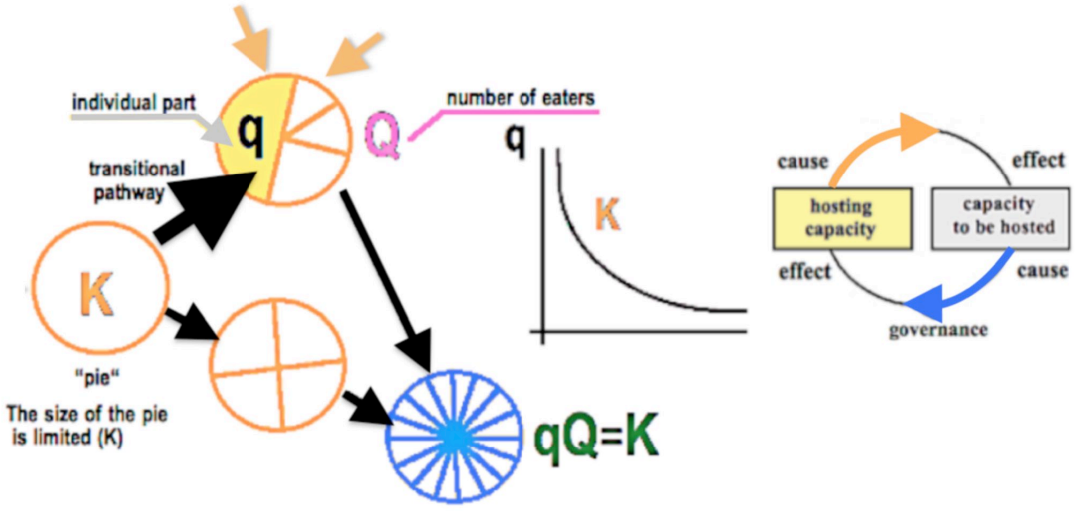
4) Why no other laws than a power law?

Looking at the sizes distribution (figures 8b) we must to question how to differentiate empirically a power law [67], a Log normal distribution and a Pareto distribution [68, 69, 70]. Power laws has been discussed largely with income distribution [71, 40], Zipf-Auerbach city sizes [72], Zipf-Estouf word frequency, Lotka bibliometrics and Mandelbrot information theory [73]. In a Pareto distribution the Log-complementary cumulative distribution function is exactly linear. Pareto has a linear Log-density. That is not the case (figure 8c). In a power law function, an infinite mean/variance is possible. That is the case in time evolving living systems. In a Log normal distribution the mean/variance is finite. Log-normal are more relative to multiplicative processes. But size changes rarely by a random multiplicative factor at each step [58]. It is often claimed that living systems are thermodynamically optimised. The Zipf law [74], sometimes called the continuous Pareto distribution is observed when looking at frequencies. Sorting (figures 7, 8) may be looked either in an increasing or a descending order of **VA**. Zipf plot is a type of log-log scales plot diagram for the data sorted in the descending order, where the abscissa axis presents the value of a quantity, and the ordinate shows its rank. But neither the adult volume **VA** is sorted by classes nor the time of generation ordinate **tg** is expressing frequencies. We got a fractal organisation (figure 9). Either the fractal Mandelbrot model [73] or the Zhu model are optimisation based [75]. But [13], ***living systems optimisation is not the rule!*** Endophysiotopes are functioning in an interval of values (homeostasis) and are surviving in an ecoexotope with an interval of values too (homeorhesis), i.e. *'meden agan'* (figure 5). The values are ***the most dependent of chance***, *'to be at the right place at the right time*', and *'not to be at the wrong place at the wrong time'* [49]. Every living system is an open system-of-system, so, at every time, homeorhesis [76] and exaptation are the results of the percolation network dynamics of interactions (figure 5) between ecoexotope and endophysiotope [18]. When processes are limited, with inferior and superior bounds, as that is always the case for every level of organisation (figure 4), Log-normal model easily pushed to a power law. So Brownian motion is a good model for a not trivial representation of a changing by chance process, it is consistent with the observed data and predictions (figures 8, 9, 10). And observations and experimentations cannot impact outcomes.

5) Another view about the significance of the golden number!

The *golden ratio* (*golden mean* or *golden section*, which symbol φ is the Greek letter *"phi"*) is *a number* approximately equal to 1.618 which appears many times in geometry (figure 10d). It is commonly found in mathematics (e.g. Fibonacci series), nature sciences (e.g. the spiral arrangement of plant parts), and is very popular in art, architects or designers [77, 78] have proportioned their works to approximate the golden ratio (especially in the form of the *golden rectangle*, in which the ratio of the longer side to the shorter is the golden ratio) believing this proportion to be the most pleasant. Its value, very near the ratio 5/3 (i.e. 1.666), is not far from **3/2** (i.e. 1.500), values that are difficult to distinguish through experimental plotting (figure 8). The golden ratio φ and inverse golden ratio $1/\varphi$ have a set of symmetries that preserve and interrelate them. Preserved by the fractional linear transformation, they are reciprocal and symmetric by interchanges, as cause and effect in the systemic constructal law (figure 6). So people could suggest the observed 3/2 slope value (figure 8) could be the golden ratio. But we could also say that *phi* is a mathematical *artefact*, it is *'man made'* [79]. Brownian motion is a real natural process, everywhere, at every time, in the background from the origin of the Universe, even we don't know why it is like this. Maybe that is the reason why looking at Brownian motion controlled processes (i.e. b=1.50 or 1/b=0.66 values) we may think they are golden ratio designed ones (i.e. φ=1.618 or $1/\varphi$=0.618 values), because the differences (between b and φ or 1/b and $1/\varphi$) are between 5% and 10%, i.e. they are masked by the biological variability. But the reality is Brownian motion, not golden ratio, for eternity. Now we know the golden ratio is only *'a pleasant model'* that is a consequence of *'the Brownian motion controlled process of governance*' of the functioning of every level of organisation of living systems of systems [80].

Figure 12 Limits, limitations and interactions, a Pareto like relationship:
(hosting LIMITS)x(to be hosted LIMITATIONS) = C



Changes of the ecoexotope and endophysiotope are overlapping in a loop:
(hosting capacity)x(capacity to be hosted)=k (CC-License, Bricage, 2011)

5 Conclusion

The ultimate objective of the study of living systems is to find a general theory of Life that can explain and predict the dynamics of human and non-human systems [49, 81, 82, 83, 84]. The ARMSADA paradigm has allowed to built a very realistic general dynamic theory [46].

1) ARMSADA: the keystone for emergence and sustainability.

Ten thousands years ago, in different locations, Man species created different ARMSADAs with various wild species partners, ARMSADAs were ***emerging*** with the domestication of plants and animals. ***All the species partners simultaneously lose the ability to kill the other ones***: an ***ARMSADA is long lasting as long as 'for the one to survive, the other ones must survive first'***. But nowadays with Man species number growth and mass industrial agriculture, these ARMSADA deals are broken and Man is an endangered species because of its increasing parasitic behaviour [20]. ***Symbioses are long lasting 'as long as they are supportable for every partner and supported by every partner'***: i.e. advantages and disadvantages are mutually shared and benefits are only for the Whole. Partners don't exist outside of their Whole. Symbioses are neither associations for mutual benefits [85] nor win-win deals; win-win is not a long lasting solution but rapidly a problem [20]. ARMSADA is the key paradigm for sustainability [4, 9].

2) ARMSADA: a fruitful predictive paradigm.

Cancer is the result of an uncontrolled cell growth. Tumour like structures as legumes nodules, and cancer cells, are controlled by viruses, either viruses from the ecoexotope that are damaging cells or endophysiotope constrained viruses that are freed. AIDS and cancer processes are similar in terms of hosted virus and hosting cell interactions [30]. Exceptionally a new whole may ***emerge in the emergency situation*** of viruses killing cells (level ***i***) or cancer cells killing the organism (level ***i+1***). Even if the probability is the lowest one, sooner or later, an ARMSADA balance will ***emerge from an emergency situation***. Vaccine processes were proposed as a result of gauge invariance and ARMSADA paradigms: -a HIV curative vaccine, using stem cells cultivation and transplant technology with HIV auto-engineered

selected HIV resistant stem cells [38] and a cancer curative vaccine methodology with exogenous and endogenous lytic viruses [30]. They have been proved to work [86], and a procedure was patented by jennerex. As the result of billions years of sharing a common ecoexotope of survival, the Earth [76], the ARMSADA process is the key way for societal sustainability [42]. It is ***a way of system management which aims to be the most open possible*** (requisite variety) in order to use in common shared resources, but with sharing both advantages and disadvantages, as within the forest ecosystem (figure 5). The collective management by the community (the actors and their Whole) has established rules of governance ***with the aim of protecting and perpetuating resources***, everyone has the right to use it but within limits [20, 35]. These resources are a joint common property. They are necessary for the gauge invariance capacities (figure 1): -matter (air, water, food) and energy, for growing in mass and number, for moving, for reacting to changes (e.g. ecoexotope changes like climate change), -structures (of the every day life), for an harmonious compartmentation of spaces and times of actions, -information (***creative commons***), for the memory of the good and bad, past, interactions between the ecoexotope hosting capacity and the endophysiotope capacities to be hosted: ***'interaction is construction, construction is interaction'*** (figure 6). Nowadays numerous parts of the joint property are threatened. They are removed from the Common, marketed and destroyed in an irreversible economical, without limits and limitations (figure 12), way of Nature and Life continuous destruction (figure 13a) [41].

3) Sustainability is variety, but not too much variety.

Sustainability needs an optimal interval balance, allowing an homeorhesis (figure 5), in-between efficiency and resilience. Too much efficiency and the predator (a virus, a caterpillar, man species) will kill too much preys (bacteria, trees, ecosystems) and die from hunger. For the predator to survive the prey must survive first. ***It is a who wins loses game***. Too much resilience and actors (a cancer cell, an apoptosis cell) will not die and the Whole will die. ***It is a who wins loses game***. ARMSADA is the key (figure 14). Indeed it is the core of the Taoism philosophy. ***There are never advantages without disadvantages.*** Limitations and control sharing (figure 15b) is the price to pay for surviving as a complex system (figure 15): to stay in-between, *meden agan*, in a window of viability (figure 5a) [87, 88, 89].

4) Interactions between the hosting capacity and the capacity to be hosted: a selective screening.

Our ecoexotope of survival food volume and water and energy availability are limited. All the water of the Earth is only a droplet on a pebble [35]. The hosting capacity of the ecoexotope is limited.To increase always the hosting capacity of the ecoexotope of survival is not a solution but a problem. To increase the capacity to be hosted is the key [20]. Limitations allow to survive only the endophysiotopes that get a capacity to be hosted in adequacy with the available capacity of hosting. Not enough water to use or too much use of water and no more survival. Too much plant density and no flowering, so no fruit, no seed and the plant population will die [21, 35, 88, 89]. Dying is the rule for species which capacity to be hosted is not in adequacy with its ecoexotope hosting capacity [26, 41]. Whatever the size of the pie (figure 12), the numbers and sizes of the parts are limited according to an hyperbolic power law, as it is the case for supply-demand models (figure 12). You cannot eat the pie and have the pie. You cannot get both a high quality and a high quantity. Only a high capacity to be hosted allows the survival of endophysiotopes in weak hosting capacity ecoexotopes. That is a trivial rule in Nature, number growth and mass growth are limited by growth rate which is limited by the ecoexotope hosting capacity. We have to chose which capacity to be hosted we can express in which hosting capacity of the ecoexotope we want to support (figure 13a). It is a hosting-hosted co-evolution process like the host-parasite or predator-prey arms race [30, 38] (figure 14).

Figure 13 Sustainability: the 12 commandments for every system-of-systems governance.

Figure 13a System actors are ***taking, making, wasting, but recycling***, matter, energy and processes.

1 - **convergence**: ***many causes can get the same effect***, several ways of interactions can achieve the same result, '***interaction is construction, construction is interaction'*** (figure 6).

2 - **contingence**: the endophysiotope survival is always limited by constrained dangers, ecoexotope boundaries, barriers, and adverse situations (figures 14, 15).

3 - **emergence**: ***'stressful emergency situations are situations of emergence'*** of new structures, processes, functions (i.e. exaptation), or actors; an emergency situation is always ***the first step of an ARMSADA emergence*** (figure 5).

4 - **solidarity:** ***'e pluribus unum'*** and ***'in variatate concordia'***, ***'there are never advantages without disadvantages***', good and bad choices are for everyone and the Whole. Everyone's growth is limited by that of all the others (local dependence) and the Whole (global dependence). ***"For the one to survive the other one must survive first"*** (figure 14).

5 - **resilience**: the resilience capacity is due to indispensable ***keystone*** actors, networks and situations (figure 5), but they can be identified only when they disappear.

6- **recycling**: recycling processes, ***by embedment and juxtaposition*** into a new space-time, is a method of governance (figure 7).

7 - **systemic constructal law** (figure 6): when the capacity of hosting or the capacity to be hosted is changing, reciprocally the capacity to be hosted or the capacity of hosting must change too (i.e. **homeostasis**), to fit, the governance must eventually change to a new state (i.e. **homeorhesis**) (figure 5).

8 - **sustainability:** only the establishment of an ARMSADA allows the emergence, ***'for the best and for the worst'***, of a sustained and sustainable governance, because it is ***sustainable for everybody and sustained by everyone***, due to the everybody knowledge of the advantages and disadvantages flows, i.e. ***'e pluribus unum'*** (figures 4, 5).

9 - **co-evolution**: every ecological, economical and educational system-of-systems and systems of governance is the result of a systemic interactive co-evolution process, i.e. ***'interaction is construction, construction is interaction'*** (figures 5, 6).

10 - **'meden agan'**: 'over the limits there are no more limitations', ***'mutual survival depends on reciprocal limitations', to survive that is to transform disadvantages into advantages and to avoid advantages turn to disadvantages, 'for the best and for the worst'*** (figures 12, 14).

11- **'meden agan'**: ***'no mass or number growth can increase without limits'*** (figure 3).

12- **'meden agan'**: ***'too much growth is killing growth'*** (figure 14).

Figure 13b Transposition: what principles for education in systems thinking? [91, 92, 93]

1- **convergence**: several ways, more or less long, or effective, can achieve the same result.

2 - **contingence**: acquisitions of new skills and expressions of new competencies are limited by previous competencies limitations and unexpected adverse situations.

3 - **emergence**: stressful emergency situations may boost emergence of new pedagogic interactions, concepts and skills.

4- **solidarity**: good and bad choices are for everyone (students and teacher) and their Whole (the class, the school, the enterprise, the social group).

5 - **resilience**: the resilience capacity is due to indispensable keystone actors, networks and situations (figure 5), but they can be identified only when they disappear.

6- r**ecycling**: recycling trans-disciplinary methods is a method of governance.

7 - **systemic constructal law**: when the capacity of hosting or the capacity to be hosted is changing, reciprocally the capacity to be hosted or the capacity of hosting are changing too, to fit, the governance must change to a new state. Whatever the cause an effect is needed.

8 - **sustainability:** ***'e pluribus unum'***, the birth of an ARMSADA allows the emergence, ***for the best and for the worst***, of a sustainable and sustained governance, because it is supportable for everybody and supported by everyone, due to the knowledge by everybody of the advantages and disadvantages for everyone, i.e. ***'in variatate concordia'.***

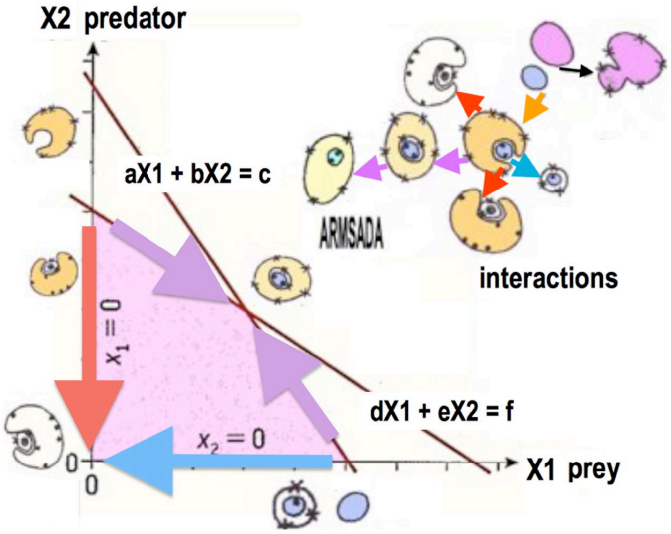
9 - **co-evolution**: every ecological, economical and educational system-of-systems or system of governance is the result of a systemic interactive co-evolution process, ***'interaction is construction, construction is interaction'.***

10- **'meden agan'**: ***'mutual co-existence depends on reciprocal limitations'***, ***for the best and for the worst***', to survive that is to transform disadvantages into advantages and to avoid advantages turn to disadvantages.

11- **'meden agan'**: no process, no governance load can grow without limits.

12- **'meden agan'**: 'too much power is killing power'.

Figure 14 The simplex graph representation of the predator-prey balance.



To survive that is to eat and not to be eaten. You can both be a **predator** and a **prey** depending on what you are eating and which can eat you: e.g. an amoeba is a predator which eats moulds and bacteria, but an amoeba may be a prey for bacteria, and giant viruses. ***Sooner or later it is impossible not to be eaten!*** Phagocytosis is a great advantage for amoebas and for our white blood cells (level ***i***) that are eating bacteria (level ***i-1***) that could eat our organism (level ***i+1***) (figure 7). But some bacterial species that are engulfed by an amoeba, or a white blood cell, can resist to digestion, persist, eat the cell and grow: e.g. Mycobacterium species, responsible of human diseases like tuberculosis or leprosy. ***There are never advantages without disadvantages. To survive that is to avoid advantages turn to disadvantages, and to turn disadvantages into advantages.*** In the struggle for life between a predator species (**X2**) and a prey species (**X1**) if the predator always wins, and kill its prey, sooner or later, no prey will survive (X1=0) and the predator (red arrow) will die too (X2=0). [猎物尽走狗。] The ecosystem global variety will decrease: -2 (i.e. blue then red arrows). If the prey always wins the predator will not survive (X2=0) and life variety will also decrease: -1 (only red arrow). In order to preserve the global variety, as in the forest ecosystem (figure 5), neither the predator nor the prey must die and it depends on a balance between variations of the 2 species number growths (Lotka-Volterra equilibrium). Merging into an ARMSADA (pink arrows), with the emergence of a new life form, allows the increase of the whole ecosystem variety: +1.
[22, 35, 41] (CC-License, Bricage).

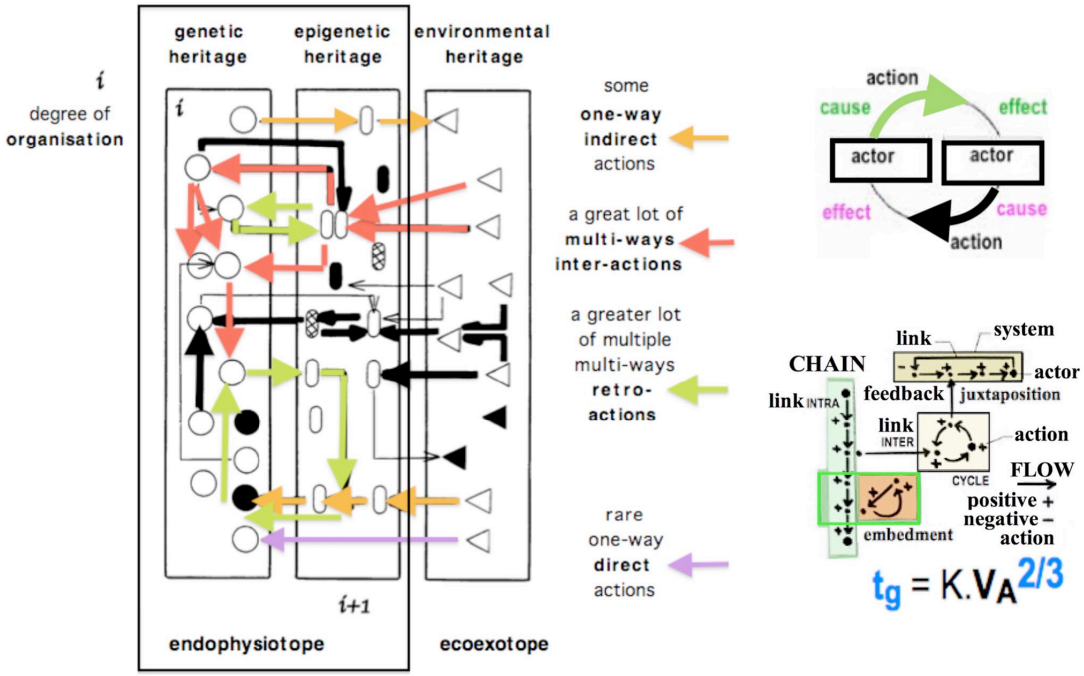
5) Teaching systems thinking is the true key road for sustainability.

Nature seems very various but ***'unity through diversity'*** is the rule. Reality is the result of necessity but chance is the law [90]. To enter an ARMSADA is a way for a system (a species, a society) to limit the consuming of its hosting capacity and to increase its capacity to be hosted [42, 46, 87]. ***It is 'an examination' every species has to pass sooner or later, again and again, for ever, and when failing only one time it is eradicated***. Only will survive species that are embedded into an interactive ARMSADA network of ARMSADAs. Teaching *'systems thinking'* is the key [46, 91, 92, 93]. According to the 2020 Strategic Framework for European Cooperation in Education and Training [94], systems thinking is a key competence to further develop and promote education for sustainable development. We need teachers of teachers [35] to seed systems thinking everywhere [95] in an interdisciplinary way (figure 13b) [96], not only to train youngest in systems thinking approach practice [92] but first for a better human healthcare [93] and welfare [97], not only to know Living systems history (figure 15a) [98, 99] and fate [100].

Figure 15 The system-of-systems iteration processes.

Figure 15a The epigenetic heritage [18, 19].

Figure 15b The systemic constructal law: qualitative and quantitative aspects.



The endophysiotope survival is always limited by the constrained dangers of the **genetic heritage** and the ecoexotope boundaries, barriers, or adverse situations of the **environmental heritage**. The continuous interactions between the capacity to be hosted of the endophysiotope and the hosting capacity of the ecoexotope (figure 6) give birth to an **epigenetic heritage** which is acting both as a buffer and a memory for the survival (figures 1, 2, 12, 14) (CC-License, Bricage, 2002).

References

[1] Almaas E. Biological impacts and context of network theory. The Journal of Experimental Biology, 2007, 210: 1548-1558.

[2] Bricage P. La survie des organismes vivants. Atelier AFSCET Systémique & Biologie, Fac. Médecine, Paris, France, 44 p., 2000. **CC-License**, http://www.afscet.asso.fr/SURVIVRE.pdf

[3] Bricage P. La nature de la violence dans la nature : déterminismes écologique, physiologique et génétique de l'adaptation aux changements aux différents niveaux d'organisation des systèmes végétaux. *In* La Violence. Colloque AFSCET, Andé, France, 7 p., 2000. **CC-License**, http://www.afscet.asso.fr/pbviolW98.pdf

[4] Bricage P. Systèmes biologiques : le jeu de la croissance et de la survie. Quelles règles ? Quelles décisions ? Quels bilans ? La Décision Systémique : du Biologique au Social. Atelier AFSCET, Institut International d'Administration Publique, Paris, France, 6 p., 2000. **CC-License**, http://www.afscet.asso.fr/JdVie1.pdf

[5] Eisler Z, Bartos I, Kertész J. Fluctuation scaling in complex systems: Taylor's law and beyond. Adv. Phys., 2008, 57: 89-142.

[6] Kaltz O, Escobar-Páramo P, Hochberg M E, Cohen J E. Bacterial microcosms obey Taylor's law: effects of abiotic and biotic stress and genetics on mean and variance of population density. Ecological Processes, 2012, 1(5): 1-6.

[7] Bricage P. L'évolution créatrice : métamorphoses et phylotagmotaphologie du vivant. L'évolution du vivant a une direction. Comment est-elle orientée ? 150 ans Après Darwin, 70 ans Après Teilhard : Lire L'Évolution. Centre de Sèvres, Paris, France, 109 p., 2009. **CC-License**, http://hal.archives-ouvertes.fr/hal-00423730/fr

[8] Straatsma G, Egli S. Stretched exponential as one of the alternatives for the power law to fit ranked species abundance data. Matters, 2017, 2: 1-6.

[9] Bricage P. La nature de la décision dans la nature ? Systèmes biologiques: production, consommation, croissance et survie. Quelles règles ? Quels degrés d'exigence ? Quels bilans ? La Décision Systémique: du Biologique au Social. Colloque AFSCET, Andé, France, 2001, 16 p. **CC-License**, http://www.afscet.asso.fr/Decision.pdf

[10] Miller J H, Page S E. Complex Adaptive Systems: An Introduction to Computational Models of Social Life. Princeton Studies in Complexity, PUP, Princeton, USA, 288 p., 2007.

[11] Bricage P. Pour survivre et se survivre, la vie est d'abord un flux, ergodique, fractal et contingent, vers des macro-états organisés de micro-états, à la suite de brisures de symétrie. Atelier AFSCET Systémique & Biologie, Institut International d'Administration Publique, Paris, France, 11 p., 2001. **CC-License**, http://www.afscet.asso.fr/ergodiqW.pdf

[12] Miller J H. A Crude Look at the Whole: The Science of Complex Systems in Business, Life, and Society. Basic Books, New York, 272 p., 2016.

[13] Bricage P. Mobilisation de la matière et de l'énergie, et croissance, aux différents niveaux d'organisation des systèmes vivants : les principes organisateurs d'émergence des systèmes vivants. Thermodynamique du Changement. Aspects Systémiques. Journées Annuelles AFSCET, Andé, France, 63 p., 2013. **CC-License**, http://www.afscet.asso.fr/Ande13/pbAnde2013.pdf, https://hal.archives-ouvertes.fr/hal-00830425
[14] Bricage P. Pigmentation and soluble peroxidase isozyme patterns of leaves of Pedilanthus tithymaloides L. variegatus as a result of daily temperature differences. Plant Physiology, 1982, 69: 668-671.
[15] Bricage P. Isoperoxidases, markers of surrounding and physiological changes, in situ in leaves and in vitro in calli of Pedilanthus tithymaloides L. variegatus: cell compartmentation and polyfunctionality, control of activity by phenols, specific roles. *In* Molecular and Physiological Aspects of Plant Peroxidases, Greppin H et al., eds. Geneva, Switzerland, p. 261-265, 1986.
[16] Bricage P. Chronobiology of the multiple molecular steps and pathways of in situ anthocyanin biosynthesis of Lathyrus macrorhizus Wimm leaves. Bulletin G.E.R.B., 1985, 17: 16-17.
[17] Bricage P. Les Caractéristiques des Organismes Vivants. APIDS, Fac. Sci. UPPA, Pau, France, 44 p., 1991. **CC-License**.
[18] Bricage P. Héritage génétique, héritage épigénétique et héritage environnemental : de la bactérie à l'homme, le transformisme, une systémique du vivant. *In* Évolution du Vivant et du Social : Analogies et Différences. Colloque AFSCET, Andé, France, 20 p., 2002. **CC-License**, http://www.afscet.asso.fr/heritage.pdf
[19] Bricage P. The evolutionary shuttle of the living systems. *In* UES-EUS Congress, Hersonissos, Creta, Greece, Res-Systemica, 2002, 2: 1-6. **CC-License**, http://www.afscet.asso.fr/resSystemica/Crete02/Bricage.pdf
[20] Bricage P. Win-win not a solution. What next? *In* Avant Garde. Blachfellner S, Werner T M, eds. BCSSS, Vienna, Austria, p. 21-24, 2016.
[21] Bricage P. Associations for the Reciprocal and Mutual Sharing of Advantages and DisAdvantages ARMSADA. The way, to be resilient and self-sustainable, the living systems are running through. *In* Governance for a Resilient Planet, ISSS International Congress, Waterloo, Canada, 12 p., 2010. **CC-License**, http://journals.isss.org/index.php/proceedings54th/article/view/1491
[22] Bricage P. Organisation, intégration et espace-temps des systèmes vivants. *In* Intégration du Vivant et du Social : Analogies et Différences, Colloque AFSCET, Andé, France, 31 p., 2003, **CC-License**, http://www.afscet.asso.fr/pbAnde03.pdf
[23] Bricage P. La survie des systèmes vivants. *In* Prendre Soin de l'Homme, MCX20, CHG Pau, Pau, France, 2 p., 1998, **CC-License**, http://web.univ-pau.fr/~bricage/VivantPauMCX20.pdf
[24] Bricage P. A new evolutionary paradigm: the Associations for the Mutual Sharing of Advantages and of Disadvantages. *In* The Creation of a Sustainable Society Depends on Innovative Systems Thinking. 100th Anniversary of Karl Ludwig von Bertalanffy's International Conference on Systems Thinking 'Unity through Diversity', Vienna, Austria, 1 p., 2001.
[25] Margulis L. Symbiosis in Cell Evolution. Freeman W H & Co Ltd, Macmillan Publishers, London, UK, 419 p., 1981.
[26] Bricage P. La semi-autonomie du vivant : pour que l'un survive, il faut d'abord que l'autre survive, et réciproquement. *In* Crises et Réponses Systémiques, UES-EUS Congress, Bruxelles, Belgique, Acta Europeana Systemica, 2011, 1(2b): 1-28. **CC-License**, http://www.armsada.eu/files/pbARMSADA.pdf
[27] Hom E F Y, Murray A W. Niche engineering demonstrates a latent capacity for fungal-algal mutualism. Science, 2014, 345(6192): 94-98.
[28] Chen B, Akusobi C, Fang X, Salmond G P C. Environmental T4-family bacteriophages evolve to escape abortive infection via multiple routes in a bacterial host employing altruistic suicide through type III toxin-antitoxin systems. Frontiers in Microbiology, 2017, 8(1006): 1-11.
[29] Erez Z et al. Communication between viruses guides lysis–lysogeny decisions. Nature, 2017, 541: 488-493.
[30] Bricage P. Cancer is a breaking of the cell's ARMSADA through an aggression that results in a lack of non-autonomy. UES-EUS Congress, APOCOSIS, Lisboa, Portugal, Res-Systemica, 2008, 6: 1-8 p. & 26 p., **CC-License**
[31] Bonfante P, Genre A. Mechanism underlying beneficial plant–fungus interactions in mycorrhizal symbiosis. Nature Communications, 2010, 1(48): 1-11.
[32] Bricage P. The cell originated through successive outbreaks of networking and homing into Associations for the Reciprocal and Mutual Sharing of Advantages and of Disadvantages, between the partners, with a benefit only for their wholeness. UES-EUS Congress, Paris, France, Res-Systemica, 2005, 5: 1-11., **CC-License**, http://www.afscet.asso.fr/resSystemica/Paris05/bricage3.pdf
[33] Bricage P. Les systèmes agoantagonistes : l'origine endosyncénotique de la cellule. *In* La Gouvernance dans les Systèmes. AFSCET, Polimetrica, Milan, Italy, p. 67-72, 2007, **CC-License** , http://www.afscet.asso.fr/resSystemica/Paris05/bricage3.pdf & http://www.afscet.asso.fr/resSystemica/Paris05/bricage.pdf
[34] Bricage P, Duverger-Nedellec A, Larroche D. Appraisement of the defoliator Lepidoptera associations in a hardwood forest. Acta Entomologica Vasconae, 1990, (1): 5-26.
[35] Bricage P. Thinking and teaching systemics: bio-systemics in higher education. *In* Proceedings of the 2010 General Assembly of The International Academy for Systems and Cybernetic Sciences. Gu J, Xu J, eds. The Sichuan University at Chengdu, PR China, p. 1-14, 2010.
[36] Bricage P. Approche systémique de l'évolution du vivant. Teilhard Aujourd'hui, 2010, 33: 31-39, **CC-License,** http://hal.archives-ouvertes.fr/docs/00/42/37/30/PDF/phylotagmotaphologie.pdf
[37] Bricage P. Évaluation des interactions entre les densité et diversité des chenilles de lépidoptères et les diversité et degré de défoliation des feuillus d'un bois. Mesure de la polyphagie et prédiction des pullulations potentielles. Acta Entomologica Vasconae, 1991, 2: 5-21.
[38] Bricage P. Le langage du vivant : plurilinguisme, transfrontaliérité et associativité. Congrès national ANLEA, UPPA, Pau, 9 p., 2005, **CC-License**, http://www.abbayeslaiques.asso.fr/BIOsystemique/ANLEA05PauPB.pdf
[39] Bricage P. The metamorphoses of the living systems: the Associations for the Reciprocal and Mutual Sharing of Advantages and of Disadvantages. 6th European Systems Science Congress Proceedings, workshop 4: BioSystemics. Res-Systemica, 2005, 5: 1-10. **CC-License**, http://tinyurl.com/pbmeta1
[40] Bricage P. Living and banking systems comparison. Prisoners' dilemma "win-win" is not the solution. Advances in Systems Science and Applications, 2015, 15(2): 150-165.
[41] Bricage P. About man Interventions in the living networks: modelling with a qualitative animated semiological holistic point of view, a systemic approach, an holistic way of education to explain the issues of the fighting steps and the escalade of violence between mankind and the wild. UES-EUS Congress, Bruxelles, Belgique, Social Responsibility IASCYS Workshop, Acta Europeana Systemica, 2011, 1(3u): 1-25, **CC-License**, http://aes.ues-eus.eu/aes2011/iascysWS_Bricage_text.pdf

[42] Bricage P. An approach of organizations and management: systemic ethics, democracy and sustainability. Associations for the Reciprocal and Mutual Sharing of Advantages and DisAdvantages. International Journal of Public and Private Management, 2014, 1(1): 90-113.
[43] Bricage P. Local versus global and individual versus whole competition between and within living systems. ARMSADA emergence and breaking. Acta Europeana Systemica, 2014, 4(2): 1-15.
[44] Madsen L H et al. The molecular network governing nodule organogenesis and infection in the model legume Lotus japonicus. Nature Communications, 2010, 1(10): 1-12.
[45] Bricage P. L'organisation spatiotemporelle des systèmes vivants. Temps et Systèmes, AFSCET, Andé, France, 25 p., 2015, **CC-License**, http://www.afscet.asso.fr/Ande15/pbTimesAnde2015.pdf
[46] Bricage P. Living networks of networks: the societal and environmental responsibility of humanity in the fight between humans and the wild. *In* Social Responsibility Beyond Neoliberalism and Charity. Dyck R G, Mulej M, eds. Bentham Science, New York, USA, 2014, 3: 257-277.
[47] Barabási A L, Bonabeau É. Les réseaux invariants d'échelle. Pour La Science, 2003, 314: 58-63.
[48] Bricage P. Agoantagonisme, rétrocession et émergence : organisation des systèmes vivants, éducation à la systémique, santé et sociétalité. Hommage à Emmanuel Nunez, AFSCET-AEIS, CNAM, Paris, 15 février 2014, Res-Systemica, 2014, 10(11): 1-19. **CC-License**, http://web.univ-pau.fr/~bricage/ResSystemica2014nunez.pdf
[49] Bricage P. Modelling space-time-action modularity and evolution of living systems. *In* Advances in Complex Societal, Environmental and Engineered Systems. Nemiche M, Essaaidi M, eds. Springer, Berlin, Germany, p. 269-297, 2017.
[50] Lee A H, Werning S. Sexual maturity in growing dinosaurs does not fit reptilian growth models. PNAS, 2008, 105: 582-587.
[51] Bricage P. Lathyrus macrorhizus : influence des facteurs stationnels sur la floraison in situ. Canadian Journal of Botany, 1984, 62: 241-245.
[52] Bricage P. Loi puissance d'invariance spatiotemporelle des systèmes vivants. Revista Internacional de Sistemas, 2014, 19: 5-33.
[53] Hulbert A J et al. Life and death: metabolic rate, membrane composition, and life span of animals. Physiol. Rev, 2007, 87: 1175-1213.
[54] Marquet P A, Quiñones R A, Abades S, Labra F, Tognelli M, Arim M, Rivadeneira M. Scaling and power-laws in ecological systems. The Journal of Experimental Biology, 2005, 208: 1749-1769.
[55] Kant S, Kumar V. Dynamics of a prey-predator system with infection in prey. Electronic Journal of Differential Equations, 2017, 209: 1-27.
[56] Bricage P. Man next challenge for survival: Associations for the Reciprocal and Mutual Sharing of Advantages and DisAdvantages. Las Asociaciones con Ventajas e Inconvenientes Recíprocos y Partidos. *In* Los Valores del Quijote, Giménez Chornet V, Colomer Viadel A, eds. Universitat Politècnica de València, p. 263-273, 2017.
[57] Tzur A et al. Cell growth and size homeostasis in proliferating animal cells. Science, 2009, 325: 167-171.
[58] Lloyd D, Legendre S, Harremöes P. Evolutionary entropy: a predictor of body size, metabolic rate and maximal life span. Bulletin of Mathematical Biology, 2009, 71: 800-818.
[59] Dodds P et al. Re-examination of the 3/4-law of metabolism. J. Theor. Biol., 2010, 209: 9-27.
[60] Nasir A, Kim K M, Caetano-Anollés G. Phylogenetic tracings of proteome size support the gradual accretion of protein structural domains and the early origin of viruses from primordial cells. Frontiers in Microbiology, 2017, 8(1178): 1-18.
[61] Kahane J P. Le mouvement brownien et son histoire, réponses à quelques questions. Images des Mathématiques, CNRS, octobre 2006, http://images.math.cnrs.fr/Le-mouvement-brownien-et-son.html
[62] Di Rienzo C, Piazza V, Gratton E, Beltram F, Cardarelli F. Probing short-rang protein Brownian motion in the cytoplasm of living cells. Nature Communications, 2014, 5(5891): 1-8.
[63] Dunbar S R. The definition of Brownian motion and the Wiener process. Stochastic Processes and Advanced Mathematical Finance. Lincoln, Nebraska, USA, 17 p., 2014, http://www.math.unl.edu
[64] Perrin F. Étude mathématique du mouvement Brownien de rotation. Ann. Sci. Ec. Normale Super. #3, 1928, (45): 1-51.
[65] Schilling R L, Partzsch L. Brownian Motion. An Introduction to Stochastic Processes. De Gruyter Textbook, Berlin, Germany, 408 p., 2014.
[66] Robredo J F. Le big bang, une idée tombée du ciel. La Recherche, 2018, HS 24: 40-43.
[67] Clauset A, Shalizi C R, Newman M E. Power-law distributions in empirical data. SIAM review, 2009, 51(4): 661-703.
[68] Pareto V. Un applicazione di teorie sociologiche. Rivista Italiana di sociologia, 1971, 1901: 402-456.
[69] Almaas E, Barabási A L. Power laws in biological networks. *In* Power Laws, Scale-Free Networks and Genome Biology, Koonin E V, Wolf Y I, Karev G P, eds. Springer, Korea, p. 1-11, 2006.
[70] Dan Y. and T. Moriya (2011) Analysis and simulation of power law distribution of file types in file sharing systems. The Third International Conference on Advances in System Simulation, SIMUL, p. 108-113, 2011.
[71] Reed W J, Hughes B D. From gene families and genera to incomes and internet file sizes: why power laws are so common in nature. Physical Review, 2002, 66(6): 67-103.
[72] Auerbach F. Das Gesetz der Bevölkerungskonzentration. Petermanns Geographische Mitteilungen, 1913, 59: 74-76.
[73] Mandelbrot B. Les objets fractals : forme, hasard et dimension. Flammarion, Paris, 212 p., 2010.
[74] Zipf G K. Human behaviour and the principle of least effort. The Economic Journal, 1950, 60(240): 808-810.
[75] Zipf G K. Human Behavior and the Principle of Least Effort: An Introduction to Human Ecology. Martino Fine Books, New York, 588 p., 2012.
[76] Margulis L. The Symbiotic Planet: A New Look at Evolution. ScienceMasters, Phoenix Press International, Washington D.C., USA, 176 p., 2001.
[77] Van Mersbergen A M. Rhetorical prototypes in architecture: measuring the Acropolis with a philosophical polemic. Communication Quarterly, 1998, 46(2): 194-213.
[78] Padovan R. Proportion: science, philosophy, architecture. Nexus Network Journal, 2002, 4 (1): 113-122.
[79] Markowsky G. Misconceptions about the golden ratio. College Mathematics Journal. Mathematical Association of America, 1992, 23(1): 2-19.
[80] Perez J C. Codon populations in single-stranded whole human genome DNA are fractal and fine-tuned by the golden ratio 1.618. Interdisciplinary Sciences: Computational Life Science, 2010, 2(3): 228–240.
[81] Newman M E J. Power laws, Pareto distributions and Zipf's law. Contemporary Physics, 2005, 46: 323-351.
[82] Snooks G D. A general theory of complex living systems: exploring the demand side of dynamics. Complexity, 2008, 13(6): 12–20.

[83] Bricage P. Time management by living systems: time modularity, rhythms and conics running calendars. Methodology, theory and applications. System Research & Behavioral Science, 2013, 30(6): 677-692.
[84] Naryzhny S, Maynskova M, Zgoda V, Archakov A. Zipf's law in proteomics. J Proteomics Bioinform, 2017, 10(3): 79-84.
[85] Martin F M, Uroz S, Barker D G. Ancestral alliances: plant mutualistic symbioses with fungi and bacteria. Science, 2017, 356(6340): 1-9.
[86] Germain M. Une thérapie génique contre la drépanocytose. La Recherche, 2018, 531: 76-77.
[87] Bricage P. Les communautés en Vic-Bilh : associations matrimoniales et patrimoine associatif. Journées Européennes du Patrimoine. Centenaire des Associations Loi 1901, Bull. Association ALBA, 2001, 17: 1-4.
[88] Bricage P. Sémiologique graphique de l'espace-temps-action du vivant : bilan épistémologique et praxéologique de sa modélisation systémique, co-déterminisme global, prédictibilité locale et imprédicativité glocale. Vers Une Nouvelle Systémique ? AFSCET, Andé, France, 34 p., 2010, **CC-License**, http://www.afscet.asso.fr/Ande10/pbETAvivant10.pdf
[89] Bricage P. Un aspect de la flore et de la faune de la côte sableuse et rocheuse des mamelles. Quelques aspects des rapports entre les êtres vivants et leur milieu de vie: exemples d'actions des facteurs du milieu sur les êtres vivants. Bulletin A.A.S.N.S., 1976, 55: 17-41.
[90] Thuan T X. Le Chaos et l'Harmonie : La Fabrication du Réel. Gallimard, Paris, France, 603 p., 2000.
[91] Bricage P. Guide Pour l'Enseignement de la Biologie Dans les Écoles Africaines. UNESCO, Paris, France, Author 206925, 120 p., 1981.
[92] Bricage P. La démarche scientifique expérimentale : un langage systémique. Mise en évidence d'une phase critique d'apprentissage. Systémique et Langage, Colloque international AFSCET, Andé, France, 30 p., 2008, **CC-License**, http://www.afscet.asso.fr/Ande08/pbAnde08ExpSci.pdf
[93] Bricage P. Engineering health and social sciences curriculum: governance of the pedagogy, pedagogy of the governance. Social Responsibility: Holistic Education for Holistic Behaviour, IRDO, Maribor, Slovenia, 7 p., 2011, **CC-License**, http://tinyurl.com/HSSengineering
[94] Collective Council E.U. Recommendation On Key Competences For Lifelong Learning. European Commission, Brussels, Belgium, 18 p., 2018.
[95] Bricage P. The International Academy for Systems and Cybernetic Sciences, Revista Internacional de Sistemas, 2014, 19: 01-04, https://www.uv.es/sesgejd/RIS/19/1.Bricage.IASCYS.pdf
[96] Lawrence R J. Interdisciplinary science: a coming of age? New-York Academy of Sciences Magazine, p. 18., 2016.
[97] Bricage P. Use of chronolithotherapy for better individual healthcare and welfare. J. Syst. Sci. Syst. Eng., 2017, 26: 336-358.
[98] Jeong H, Tombor B, Albert R, Oltvai Z N, Barabasi A L. Organisms from all domains of life are scale-free networks. Nature, 2000, 407: 651.
[99] Bricage P. Danger des représentations non-systémiques et pouvoir de prédiction des représentations systémiques en Sciences de la Vie. Les Représentations au Crible de l'Approche Systémique. Journées annuelles AFSCET, Andé, France, 39 p., 2006, http://www.afscet.asso.fr/pbAnde06txt.pdf
[100] Bricage P. The modelling of the time modularity of the living systems: the time delay, time duration, time lag and the rhythms. UES Congress, Paris, France, Res-Systemica, 2005, 5: 1-11. http://www.afscet.asso.fr/resSystemica/Paris05/bricage2.pdf