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Power laws spanning controls of living systems growth and development

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### Power Laws Spanning Controls of Living Systems Growth and Development.

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Abstract-The spatial and temporal structure and functioning of living systems are associated with scaling independent qualitative characteristics (gauge invariance) and quantitative laws (power laws). This is allowed by the emergence of new blueprints through previous living systems merging into 'Associations for the Reciprocal and Mutual Sharing of Advantages and Dis-Advantages' (ARMSADA). Starting from the qualitative concept of the gauge invariance of living systems and the evidence that living systems, whatever their level of organisation, are iteratively, through a fractal process, built by encasement and juxtaposition of previous embedded and juxtaposed living systems, a periodic table of living systems-of-systems evolution was proposed. Various physiological processes of a lot of living systems, whatever their scale, from the quantum of Planck to the whole Universe, were investigated in various ecological environments. Representations of the relation between the [growth phase duration] i.e. the [duration of time before the acquisition of the adult reproductive state] or [generation time] tg and the [volume of the grown-up stage] or [volume at this growth larval phase end] i.e. the [3D size] VA evidenced a +3/2 exponent power law, or a +2/3 exponent power law, depending on the chosen tg and VA log-log graph, because 2/3 = 1/(3/2), for every living system whatever its scale. Such a two-third power law for curved movements provides a strict constraint on optimal control models that narrows down the cost of functioning for example. This Kepler's third law like equation for the evolution governance and the emergence of new living systems is the result of an universal phenomenon: Brownian motion.

*Keywords: ARMSADA*, capacity to be hosted, ecoexotope, endophysiotope, fractal, *gauge invariance*, growth mass, growth phase duration, hosting capacity, keystone species, organisation levels, percolation network, periodic table, power laws, system of systems, *systemic constructal law*, time of generation

#### 1. Introduction

What is a living system? How to define every living system [53]? Can we get a definition which is independent not only of the space dimensions and time scales, but also of the system structure, its level of organisation and its degree of evolution, its functional complexity [10, 12, 33]?

The first paradigm is "*the gauge invariance of living systems*": whatever a living system is, it can be defined by 7 functional capacities (figure 1) [7]. Every living system can be defined as an *endophysiotope* (ENDO: internal, tope: space-time, physio: of functioning) integrated into an *ecoexotope* of survival (EXO: external, tope: space-time, eco: of inhabitation). The EXO is providing a **capacity of hosting** (HOSTING) and, to survive, the ENDO must express a **capacity to be hosted** (HOSTED) that is fitting with it [4, 5, 6, 11, 12]. These properties define what is a level of organisation, whatever the system complexity and size [12].

How do new blueprints, new organisation levels, of living systems emerge?

#### 2. How Are Living Systems Working?

Whatever its organisation level, a living system is defined with 7 functional characteristics, that are in interaction [7]: **figure 1**. The capacity of moving matter and energy flows is the first, it allows the capacity of mass growth. Both are controlled through the capacity to respond to stimulation. All of that is possible because the system endophysiotope (ENDO) and the system ecoexotope (EXO) exhibit a correlated organisation into the space, through the time, and in action. The EXO furnishes the ENDO a capacity of hosting (HOSTING). Reversely, only can be hosted an ENDO that possesses an appropriate capacity to be hosted (HOSTED). This is the process/capacity of integration. Sooner or later during its life cycle, a living system expresses a capacity of movement. All these 7 capacities/capabilities are mutually necessary and sufficient for the survival, which has only one goal: the reproduction of the same life form [8]. Every living system is running through 2 phases of development, firstly a MASS GROWTH survival phase (a *"to eat and not to be eaten"* phase), during which matter and energy INPUT, THROUGHPUT and OUTPUT flows allow growth, then a phase of reproduction that eventually allows NUMBER GROWTH [11, 12].

#### Systemic constructal law: interaction is construction, construction is interaction

Causality is circular (**figures 1, 2**): each living system-of-systems is integrated into an EXO within which it is more adapted to the interactions network than other ENDO systems-of-systems could be [1, 13]. EXO changes, like climate changes or communities changes [42], and ENDO changes are overlapping and in a loop. The HOSTING changes, in quality or in quantity, particularly due to recycling, are controlling the growth and constrained contingent changes in the functional, spatial and temporal organisation of the HOSTED [11, 12].

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Figure 1. How to define every living system level of organisation? -KEY CONCEPTS-

A living system is a WHOLE of modules (parts, actors, sub-systems) that are sharing interactions. Whatever its organisation level, *i*, *i*+1, and its actors network, every living SYSTEM-of-SYSTEMS is made of an **endophysiotope** (*endo*: internal, *tope*: space-time, *physio*: of functioning) that is hosted by an **ecoexotope** (*exo*: external, *tope*: space-time, *eco*: of inhabitation). Whatever the flows of matter, energy or information, the endophysiotope (ENDO), whatever its ecological job, is encased into its ecoexotope (EXO) of survival. The ENDO and EXO are reciprocally interacting together, allowing their common survival only if the CAPACITY TO BE HOSTED of the ENDO is fitting (**integration**) with the HOSTING CAPACITY of the EXO, both interacting together. Actors from a sub-system can inter-act with actors either from encased (hosted) adjacent inferior or encasing (hosting) adjacent superior systems. Whatever its organisation level, every living system owns 7 capacities (*the gauge invariance paradigm*), that are, sooner or later, expressed during its life cycle, to allow its survival, first to gain a mass threshold (growth phase) which is a prerequisite for reproduction (adult phase). - **C.C. free**, adapted from Bricage [7, 9, 10, 11, 12] -

That itself feedback is controlling the growth and the development [14]: "(hosting capacity)x(capacity to be hosted)=k".

Interactions networking [2] (figure 2) results in power laws of governance [3, 27, 34]. Step by step, by cycling through amplifying loops, "a threshold of growth is a prerequisite for development, a threshold of development is a prerequisite for growth". For example, whatever the system-of-systems, the number growth X and mass growth Y are correlated and limiting each other according to a power law XY=K. When the number of parts of a pie is increasing, we know that the size of each part is decreasing. That is a well-known economic law: e.g. when quantity Q increases, quality q decreases, Qq=C [19].



Figure 2. Systemic Dependence Law: iteration of mixing controls between actors or systems. Every initial cause is hidden behind successive interactions. Every effect is a cause of another effect. Every actor, event or process X1, X2 can inter-act (arrows) either directly on the other one (external or extra-control, retro-action), or on itself (internal or intra-control), or indirectly (postcontrols). Controls are iteratively juxtaposed and embedded in space and in time (either through a priori or a posteriori post-controls. The X1.X2 interdependence obeys a power law of governance (with  $\mathbf{k}$  as constant and  $\mathbf{p}$  and  $\mathbf{n}$  as exponents) which is a functional relationship representative of their mutual iterative retro-actions. To define or measure complexity within a system-of-systems is not easy. There are at least 3 kinds of complexity: - space-complexity (actors are juxtaposed and embedded (encased) in different spaces), - time-complexity (as spaces are, times are juxtaposed and embedded too), - actions and interactions-complexity. Whatever the organisation level, the 7 functional capacities (figure 1) are interacting together. Could we evidence a power-law of interaction for every couple of capacities, or a global power-law that could be independent of the organisation level i? Organisation levels are interacting together in a circular way and because of the continuous reciprocal interactions between EXO and ENDO new function or new form may emerge from previous ones: EXAPTATION. - C.C. free, adapted from Bricage [22, 23, 26] -

#### The living systems-of-systems organisation levels: definition

Each organisation level of every living system-of-systems, whatever the spacetime scale, is defined by these 7 mutually necessary and sufficient functional characteristics, that are in interaction [5].

The survival [4] has only one goal: the reproduction of the same life form [8].

Organisation levels are interdependent [13], e.g. free-swimming larvae of benthic marine animal populations recognise cues from surface-bound bacteria to settle and metamorphose, e.g. a bacterium (*Pseudoalteromonas luteoviolacea*) is producing arrays of bacteriophage tail-like structures that trigger metamorphosis of a tubeworm (*Hydroides elegans*). This new form of virus-bacterium-animal interaction that explains how marine biofilms can trigger ecosystems development, is **an ARMSADA** [8, 9, 13, 17, 21, 36].

What is an ARMSADA? Why are ARMSADAs everywhere [14, 15, 17]?

#### How are all living systems functioning since billions of years?

South penguins have no reason for walking fast [25]. On the south pole there are no predators to eat them. But there are no preys too and nothing to eat for them and it is very cold. *There are never advantages without disadvantages* [9]. They are surviving very difficultly in that EXO with an extremely low HOSTING. To survive they would need an ENDO with an extremely high HOSTED. But they can lay their eggs there and their offspring can grow if they will have enough to eat. So penguins have always at least 2 reasons for swimming very fast : *"to eat" and "not to be eaten"* [18, 20, 21]. The sea water is an EXO with a high HOSTING! There are a lot of preys to eat for them. But there are predators too. There are never advantages without disadvantages ! To survive south penguins need *"to be lucky !": "to be at the right place at the right time and not to be at the wrong place at the wrong time"* [4, 8, 25].

But "sooner or later it is impossible not to be eaten." Like they are eating fishes, penguins are eaten by killer whales. They are belonging to a same food network. To survive that is "to avoid advantages turn to disadvantages and to transform disadvantages into advantages." Every living system, a cell [6, 13], a forest [8], is a wholeness, made of actors with their interdependent links (figures 2, 3). The stability and resilience of the system, while facing to changes of its ENDO and its EXO, is depending on the number of actors and the percolation process of their interactions (figure 3) [17].

What sort of governance does allow the sustainability [15]?

#### How do new blueprints, new organisation levels, of living systems emerge?

The EXO is furnishing HOSTING to the ENDO which survival is depending on its HOSTED. Both must fit in adequacy, which needs limitation or adaptability to limits changes. Out of limits there is only one solution: systems merging into new system-of-systems, new blueprints, in which all partners and their WHOLE are sharing advantages and disadvantages, in which they are both winners and losers [13]. Every ARMSADA emergence (figure 3) depends on the ecological, economical and genetical history, on the location of every actor into the system [8, 14, 33], on the global network of interaction and its local fate [24, 29].



#### Figure 3. The ARMSADA paradigm. What is an ARMSADA? (examples).

**From parasitism to mutualism:** the nodules of leguminous plants: Rhizobia are free living moving bacteria (1a) that are able to invade the roots of plants (1b). They grow in mass and number into the plant ENDO, to survive that is **first to eat**, **in order to reproduce its self**. That is an emergency situation for the plant survival (1), to survive that is **not to be eaten**! After a while, new plant organs emerged, nodules (2), that result from a special merging of the Rhizobia population with a root plant cells population. Into nodules, bacteria have changed their behaviour, they are now subdued to the plant metabolism. Both partners, the plant meta-cell organism and the bacteria population are sharing together advantages and disadvantages for the survival of their new WHOLE. Nodules grow in mass and number. Bacteria that are sequestered into vacuole-like compartment are growing in mass too.

The phenomenon is a metamorphosis that results from a percolation process: A new actor (the bacteria population) has been integrated into the pre-existing plant cells network (before). As in every metamorphosis, previous actors are lost/destroyed (lysis), other are conserved but transformed and new actors are integrated (after). Every plant cell is an ARMSADA: All compartments of a plant cell, mitochondria, chloroplasts, peroxisomes, the cytoplasm and nucleus are derived from initially free living Monera that are now making a WHOLE, sharing metabolites in a TAKE-MAKE-WASTE but RECYCLE process: every waste product is a food for other compartments.

- C.C. free, adapted from Bricage [11, 13, 17] -



Figure 4. The living systems-of-systems organisation levels: the life's rising periodic table. This fractal chart is built by taking into account both -the gauge invariance paradigm (i.e. the fact that every living system, whatever its organisation level [i-n, i+j] owns the 7 mutually necessary and sufficient characteristics (figure 1), and -the ARMSADA paradigm (i.e. the assumption that any new level of organisation is a system-of-systems that results from the emergence of an ARMSADA by merging of previous systems (figure 3)). 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 following level(s) (as Matryoshka dolls). Every 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) (systemic constructal law). From down to the top, from the quantum of Planck to the whole Universe, the black arrows are indicating the complexity rising, 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 MICRO-MACRO 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 ENDO and EXO, e.g. a membrane interface for the i-1 ... i+1 column. Arrows of different columns but on the same place indicate same kinds of jumping process. Systems the boxes of which are horizontally aligned correspond to "same step of evolution" systems but with different kinds of interface.

- C.C. free, adapted from Bricage [10, 13, 14, 16, 21, 22, 23] -

#### The emergence of an ARMSADA is a global response to local survival crises

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Do look for example at viruses [28, 32]. Bacteriophages [36] are predators that eat bacteria as preys. But when all bacteria are eaten, there is no more matter and energy, no more living system, to produce any virus. When there is nothing to eat, the viral species will disappear. It is *a 'who wins loses game'*! To escape from this game, living systems-of-systems developed ancestral alliances [39] that emerged after predator-prey struggles [35], like the viruses-bacteria struggle for life [13, 36]. Alliances allowed mutual survivals of the enemies by their merging into a WHOLE, *a new blueprint*, an **ARMSADA**, that emerged only when both simultaneously lost the capacity to kill the other one [9, 13, 20].

"For one to survive, the other one must survive first." [13, 17, 36]

Let's look at a lichen. The lichen body is the body of an ancestral free living fungal species. Into its body, a population of an ancestral free living algal species was hosted. The fungal partner furnishes HOSTING to the algal guest which owns HOSTED in adequacy. The ENDO of the fungus is the EXO of survival of the ENDO of the algal cells [7, 9, 17]. It is a great advantage for the algal cells that are protected against drought, viruses and bacteria by the fungal body. But it is a great disadvantage for the fungus which must take a great part of its matter and energy to allow the survival of the algal cells. But, sooner or later, fungal filaments are catching algal cells and eat them. Now it is a great advantage for the fungal part 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. There are never advantages without disadvantages. The greater the advantages, the greater the disadvantages. Both are winners and losers too. It is not an association for mutual benefits, but an ARMSADA. If benefits, they are only for the WHOLE, the lichen. And for the Whole to survive, each partner must survive first and reciprocally. Growth in mass and number of both the parts and the Whole are long lasting as long as they are supported by every partner and supportable for every partner and the partner-of-partners too. Only reciprocal rewards stabilise cooperation [38] but "win-win situations" don't exist [11, 17, 18]. You can never always be a winner! Sooner or later, you will be a loser too; sooner or later, the greater the advantages, the greater the disadvantages [14].

ARMSADAs are everywhere (**figures 3, 4**); in all living, past, present, and future blueprints: endogenous bacteriophages, endogenous retro-viruses into the nucleus of cells [32], plant cells endogenous compartments, legumes nodes, lichens, ecosystems. Man species was able to enter into ARMSADA deals with plants and animals species at the origin of agriculture [24].

The ARMSADA process is the only living systems keystone solution to allow ENDO maintenance in a no-changing EXO, to allow ENDO resilience when EXO changes are deleterious and to allow the emergence of new blue-prints when HOSTING-HOSTED are no more fitting together [17, 18].

#### 3. How Are Living Systems Interrelated ?

#### The living systems-of-systems organisation levels: classification

The cell is the adjacent inferior level of organisation of that of a meta-cell organism. And the ENDO of the organism is the EXO of survival of the cells (figures 1, 3). Every life form, whatever its level of organisation, as a SYSTEM-OF-SYSTEMS (figures 2, 4), is integrated into a superior adjacent level of organisation, an ecosystem, that it shares with other organisms: **figure 4** [4, 8].

A cell (level i), which is as an *endosyncenosis* of Monera (level i-I) is built as an ecosystem (level i+3) is [6, 12, 13].

#### The living systems-of-systems organisation levels: fractal modularity

A lichen which is both an organism and **an ecosystem**, a cell which is also an ecosystem and **an endosyncenosis**, both are an ARMSADA [14]. The eukaryotic cell [13] has emerged from the help of a RNA virus from a microbial mat of Monera. The nitrogen fixing legumes [17] emerged also from the fusion of a population of Monera with -and within- an organism (figure 3) "Every living system-of-systems is indissociable from its EXO. Permanently it must re-build its organisation and re-create its autonomy; it is unceasingly dependent on the EXO in which it continuously has to regenerate itself its self, its ENDO. In that EXO which it is sharing with other life forms it takes matter, energy and information, integrated within a food web. Before being able to survive itself in its progeny, it must first stay alive and survive, by extending its existence beyond the unbearable events which can result in its disappearance." [9, 11, 12, 13].

What is the relationship between growth, survival and reproduction [4, 7]?

Whatever its level of organisation, a living 'system of systems' emerging by embedments and juxtapositions of previous ones [10], effectively functions in 4 dimensions with -VA: the Adult system Volume and -tg: the time of generation, the duration that is necessary to acquire the capacity of reproduction [16].

Whatever the system complexity, it always runs through 2 phases: -a larval phase, which is a growth phase (of persistence and resilience), and "*if the self of the system survives long enough to attain a mass threshold*", -an adult phase, which is the reproduction phase, during which "*the system, itself, survives its self*". Indeed the describing parameter is not time [29]: the governing parameter is the mass [21]. Mass growth is determining time duration. If we represent in a loglog plot the relationship between the Volume of the system in its Adult phase VA and its time of generation (e.g. the duration of the growth phase needed to gain the reproductive capacity) **tg**, we get a line with a 3/2 slope [16] (**figure 5**).

A unique power law is thus linking together all the interconnected systems of systems of our Universe as a WHOLE:  $VA = C.tg^{3/2}$  [16].



Figure 5. The living systems-of-systems developmental power law of control.

Every living system-of-systems, whatever its organisation level, can be defined by 2 parameters: - its volume, resulting from its MASS GROWTH, but at the end of its larval phase, when it just acquires the reproduction capacity, i.e. its adult volume VA (in m3) and -the duration that is necessary for growth before to be adult, i.e. the minimal duration between 2 successive generations, allowing eventually NUMBER GROWTH, its time of generation, tg (in sec). In a log()-log() graph, from the **picoscopic** level to the teloscopic one, the relationship between these 2 parameters is quasi-linear with a slope K of 3/2 which represents a unique systemic dependence law:  $VA^2=C.tg^3$ . Indeed, from the quantum of Planck to the whole Universe, the graph is more a sigmoid (with a threshold and a plateau) than a line, but we don't know really well the values of the parameters at the ends of the scales. Nevertheless such a sigmoid is what we know about the working of a growth process, but in a Log-Log scale. Is this power law independent or dependent of the scale we are looking at?

- Adapted from "phylotagmotaphology", C.C. free, Bricage [16, 22, 23] -

Indeed, every sub-system we get from the whole Universe system obeys this same power law. And, if we iterate the graph, again with the same kind of log-log plotting, we observe the same line, i.e. our Universe is a subsystem of a hyper-Universe in which it is embedded and probably juxtaposed with other Universes (**figure 6**). This unique power law is the fractal law of functioning of all living beings, whatever are their complexity, size or time scales, and origin [27].

But what does mean a 3/2 exponent power law?

Many power laws have been evidenced in the functioning of living systems [34, 50].  $VA = C.tg^{3/2}$  is the same as  $VA^{2/3} = k.tg$ . What does that mean? If we look at the physical dimensional scales,  $VA^2 = C.g^3$  is the same as  $D^2 = K.tg$ , e.g. the global flows of matter and energy exchanges are at a constant speed K at the surface interfaces ( $D^2$ ) within a system and between adjacent systems.



Figure 6. The fractal modularity of living systems-of-systems inter-dependence and emergence. In 10 exponents, tg in seconds (X), is growing from Dimension -43 to +18 and VA in cubic meters is growing from Dimension (-35)^3 to (+26)^3. To know if the previous log().log() law (figure 5) is dependent of the scale we are looking at (figure 4), we can look only as every part of the WHOLE Universe. For example at either the MICRO- or PICO- or MACRO- scopic level (only MICRO is shown): at every level we find the same relationship with the same slope 3/2. Dimensions are so extended that we can also graph a log( log().log() plot of the previous log().log() one. Again we find the same power law with a 3/2 exponent. That is to say, our Universe is both a fractal systemof-systems containing sub-systems and a sub-system part of a fractal upper-system-of-systems. - C.C. free, adapted from Bricage [16, 21, 22, 23] -

A lot of 2/3 (or 3/2) power laws are known for many processes [26] at different biochemical and biophysical scales, like the 3<sup>rd</sup> Kepler's law [16, 44]. Life emerged and evolved from basic physical processes through laws of holistic governance that can now be modelled [22, 27].

The living systems-of-systems power law of governance  $VA^{2/3} = k.tg$  is expressed as a similar 2/3 power law as Brownian motion, the basic physical phenomenon of our Universe, is [43]; even if we don't know why [22].





The gauge invariance paradigm (figure 1) means that 45 interactions are governed by power laws at every 18 organisation levels (figure 3). Obviously not all are easy to measure. Nevertheless it appears that the interactions between **METABOLISM** (mobilisation of mater and energy) and **MASS** growth obey a power law of exponent varying from 3/2 (i.e. total dependence of Brownian motion or optimal flow at the exchange interface?) to 1 (i.e. limiting factor) and 0 (i.e. independence) (figure 9). And the antagonist interactions between **MASS** and **NUMBER GROWTH** obey a power law of exponent varying from -2/3 to -3/2 = 1/-2/3 whatever the organisation level.

- C.C. free, adapted from Bricage [22, 23, 26, 27] -

#### 4. Why are power laws everywhere?

In 1997, Enquist, Brown and West [34] suggested a universal extension of the 3/4 scaling power law for living systems that was proposed in 1932 by Kleiber [37]. That not only explained the relationship between resting metabolism (i.e. matter & energy mobilisation) and body size (i.e. mass growth) [40, 50, 51] but also many other body size-physiological process scaling patterns that could be multiples of 1/4. For instance, in mammals, life span scales to body weight with a +1/4 exponent power law and heart frequency scales to body weight with a -1/4 exponent power law. Consequently, no matter how large a mammal system is, all of them have a constant number of heartbeats over their lifetime (figure 8) [3, 26].

XY=k are frequent governing laws of chemical, physical and living systems.





As mass growth (VA) and growth duration (tg) interaction of the ENDO is controlled by a power law (figures 5, 6, 7), relative size (M) and number growth (N) also obey a XY=K power law (i.e. from leguminous nodules growth (figure 3) [42]), that means that the slope of the plot depends of what plot  $\log(N)=K.\log(M)$  or  $\log(M)=1/K.\log(N)$  we are choosing: 3/2 = 1/2/3; the negative slope means antagonism between N and M (NM=K) [52]. When a positive slope, whatever the choice, 2 other kinds of interaction controls can be evidenced whatever the X1, X2 parameters (figure 2: X1^p=k.X2^n): X1=+K.X2 means that X2 is a limiting factor of X1 and reciprocally, and X1=C =C.X2^0 means that X1 is a constant factor whatever X2 [3]. Because of the interaction between the ENDO and EXO, changes and relationships between the X1 and X2 parameters are depending from and evidencing the interactions between the HOSTING capacity of the EXO and the capacity TO BE HOSTED of the ENDO. Whatever the mass growth or the HOSTING increase, sooner or later HOSTING LIMITS (the plateau of the sigmoid curve) lead to a HOSTED LIMITATION. The relationship between the HOSTING of the ENDO obeys also a power law which slope, k or K, evidences the ARMSADA sharing of ADVANTAGES and DIS-ADVANTAGES between the parts, that are functional partners for the living system-of-systems survival.

- C.C. free, adapted from Bricage [22, 23, 25, 26, 27] -

The idea rooted in the concept that the surface area  $(D^2)$  and volume  $(D^3)$  of a system, whatever its internal or external interactions networks [14] (figure 3), are critical thresholds for *the geometric flow functioning* [22, 44].

#### Local power laws

A meta-analysis of a database of interactions of the living systems ENDO steady-state and their EXO changes allowed to quantify  $45 \times 18$  allometric [7] relationships (**figure 7**) and to evidence *a pool of local governing power laws*: -invariant independent processes (power-laws with exponent  $\in = 0$ ), -simultaneous limiting interactions regulation processes ( $\in = +1$ ), -feedback ( $\in = -1$ ), -competition between actors ( $\in = 1/2$ ) and -optimal exchanges flow ( $\in = 2/3$ ) processes (**figure 8**). The 3/4 and 3/2 (or 2/3) scaling laws are effectively holding local controls.

Why is the 3/2 power law also holding global control (figures 6, 7)?

#### What does mean a 2/3 or 3/2 power law?

The difficulty was in the choice of useful units and valid experimental reference situations [16, 21]. A lot of researchers used mass or volume [34, 35, 37], other used lifespan [45]. With VA, **the volume of every adult living system**, regardless of its organisation level, in cube meters, and with tg, the generation time, the time required to reach the threshold of the mass sufficient to acquire the reproductive capacity (*i.e.*, **the duration of the larval phase** which is specialised for mass growth), in seconds, then, for every living system of our Universe, all results experimentally obey a power law with a 3/2 exponent, a line with a 3/2 slope, with an exceeding 90% probability, along 62x62x62 dimensions of space and 62 dimensions of time (figures 5, 6).

Priority was given to biological phenomena not to statistics! [26, 27]

From geometric and biological points of view, 2/3 (or 3/2) is the hallmark of an optimised, spherical, interface for flow exchanges: the relationship VA^2/3=k.tg or tg=K.VA^2/3 (figure 9) is the mark of a constant average flow of exchanges at the interface between ENDO and EXO. A two-third power law for movements or metabolites exchanges [44, 46] (figure 1) provides a strict constraint on optimal reciprocal control models (figures 9, 10) that narrows down the cost of ENDO physiological functioning and optimise ENDO-EXO interactions (figure 10) like answers to stimulation and integration (figure 1) [22].

The flows at the interface between ENDO and EXO are, locally and globally, controlled. These inter-actions between flows and within space-time, and their co-interactions, are giving birth to rhythms, emergent properties are born, determinism is imposed on chaos [22]! So everything happens as if to the chaos of the EXO of survival, the ENDO is imposing power laws of order by increasing its spatial and temporal complexity (figures 2, 7, 9) and reciprocally (figure 9).

#### The omnipresence of the Brownian motion background

Researchers are "*rediscovering*" the basic omnipresence of Brownian motion, an unpredictable, stochastic process (Wiener process), but systemic structuring phenomenon, even in biology [31, 46], maybe at the genome level too [47].



Figure 9. <u>Reciprocal power laws geometrical controls of volume and number growths</u>. The same power law is governing both the geometric fractal flows of evolution and emergence of new blueprints (ENDO exaptation) and new organisation levels, i.e.  $VA=C.tg^{3}/2$ , and the temporal flows of functioning within every ENDO, i.e.  $tg=KVA^{2}/3$ . Whatever the organisation level, spaces are embedded and juxtaposed as times are too.

- C.C. free, adapted from Bricage [22, 26, 27] -





VA^2=C.tg^3 with tg generation time, VA adult volume (3D), surface is 2D, line is 1D, V^2 is D^6. The 3/2 coefficient is a hallmark of a Brownian mechanism of constant flowing, k', at the surface, because 2/3 = 1/(3/2) is the dimensional ratio of the surface (2D) to the volume (3D) of a sphere. - C.C. free, adapted from Bricage [16, 22, 26, 27] -

Brownian motion, which is also described by a 3/2 exponent power law of time (**figure 11**), is itself an invariant fractal phenomenon, that could be the continuous link between all organisation levels whatever is the jump [12] from every previous system-of-system to a an emerging new one (figure 4).



Figure 11. <u>A basic inherited control phenomenon of structuration: Brownian motion.</u> Brownian motion [31, 43, 46] is a stochastic 3D phenomenon (arrows) that obeys a time 3/2 exponent power law. The 3D simulations of Brownian motion of free particles (*i-5 level*) and of the whole Universe (*i+7 level*) (figure 7) give the same 3D virtual convergent spongy-like structure. The evolutionary emergence (Time) of new ARMSADA blueprints also obeys a stochastic 2D tree of fission and fusion processes allowing the emergence or the increase of species biodiversity (Trait). - C.C. free, adapted from Bricage [22, 23, 26, 27] -

#### 5. Discussion & conclusions

Living systems are not only modules that are embedded and juxtaposed into more complex ones but they are also embedding previous less complex ones, which are juxtaposed, in a fractal iterated way, just like Matryoshka dolls are (figures 1, 6). My second paradigm is "each jumping step from a previous blueprint to a new one is the merging into an Association for the Reciprocal and Mutual Sharing of Advantages and DisAdvantages", an ARMSADA (figure 3) [12, 13, 15, 17].

#### Researchers are rediscovering what symbiosis is [41]

The endogenous viruses, into our genome [32], are *constrained dangers* that can be freed when our cells are endangered, like the symbiotic hosted bacteriophages are released when their hosting bacterium is endangered [15]. The *un-controlled*, *de-controlled* dangers induced damaged cancer cells proliferation.

A forest is an ecosystem in which dangers, like caterpillars, are damaging trees, eating their leaves [8]. It is also *a who wins loses game*. If too much leaves are eaten, trees will die and the butterfly species will disappear. Through forests evolution a balance arose between predators (the caterpillars) and preys (the trees). A sufficient biodiversity is needed for the survival of a forest: *enough but not too much: "meden agan"*. When HOSTING is increasing, usually by making a field of trees, pest dangers increase too. A single pest species can kill this field of only 1 plant species. When engineers are cutting an old or planting a new tree species, if they don't know the forest balance -which is unique for every forest [8]-, they usually don't know what could be the result for the forest survival [8, 9]. Depending only on the local forest structure, that could be *the best or the worst*. The sustainability in economic processes obeys the same laws as in ecologic processes. That is the core of the Taoist Chinese philosophy which describes an optimal reciprocal balance between *yin-yang* as did the ancient Greek philosophy: "*meden agan"*. *Excess is always unbalance!* [15, 17]

#### Ecology is the economy of Nature, economy should be ecology first

The ARMSADA deals between Man species and Earth domestic plants and animals were broken with Anthropocene industrial mass production. HOSTING was carried too far, without limits. So, because HOSTINGxHOSTED=k (figure 8), HOSTED decreased to the worst [25, 27]. Man controlled ecosystems have the most productive capacity, with a very low latency, but the least biodiversity and only 1 keystone species: Man. Anthropo-systems' health is highly poor with only a local man-dependent autonomy. Wild ecosystems are ancient, with a high biodiversity, a high resilience capacity. They are robust; as ARMSADA they are experienced in life survival, but they have enough production only for their own, not for Man which is an invading species [19]. Limits and limitations are controlling all the partners growth, in mass and number: HOSTINGxHOSTED=k. Every living system-of-systems is an ecosystem in which the partners are making an "E PLURIBUS UNUM", "IN VARIETATE CONCORDIA", and "UNUS PRO OMNIBUS, OMNES PRO UNO" society. Matter and energy processes are open in Take-Make-Waste- but Recycle ways (figure 3). In their WHOLE, partners are linked together for the best and for the worst [14, 17].

*Examples of de-controlled dangers are numerous*: e.g. excess in mass industrial breeding led to the emergence of more and more new influenza viruses in pigs and hens breedings, with more and more frequent flue epidemics in men. With more pigs and hens to eat for men, there are more and more pigs, hens and men to eat for the virus [19, 20], e.g. by cutting the equatorial wild forests, in Africa, Man species induced the emergence of eating man viruses, as the Ebola virus which EXO was destroyed through forests destroy and which next EXO could be Man ENDO. Since billions of years, at any time, to survive, every living systems has to enter into an ARMSADA. It is an exam every living species has to pass, sooner or later, again and again. If it fails, even only once, it is eradicated!

Currently, Man species is failing [18, 19, 20]. Maybe the new ARMSADA model is on the way, but without us! The emergence of the CoViD-19 coronavirus does allow us to ask questions [23, 28, 29, 30].

#### Every ARMSADA is a partnership for mutual sharing of profits and injuries.

Every ARMSADA emerges due to the fact that the 2, or more, partners are not simply juxtaposed but are combined and interpenetrated to form a new whole (figure 3). They metamorphose themselves simultaneously in a new, unique, different, whole "ecosystem like" organism [4, 13], an *endo-syn-cenosis*. The half-autonomy of the partners and the new independence/dependence of their whole is built on the interdependence of the parts and the whole [6].

The growth and development of a vertebrate embryo (meta-cell organism: i+1 organisation level) (figure 4) involve tightly regulated cellular (cell: i level) processes with molecular (i-2 level) instructions informing the proliferating embryonic cells about their identity and behaviour. The opposite gradients of two ago-antagonist proteins are sufficient to induce the molecular and cellular mechanisms required to organise morphogenesis [22]. But, depending on its variants and interactions, the same molecule may have different roles. To survive that is to use the simplest way to control both the maintenance, modulation and changes of structure and function (like in the metamorphosis of an organism).

#### What are the rules and the laws? [1, 2, 49]

When the number of parts of a pie is increasing, we know that the size of each part is decreasing. That is a well-known economic law: when quantity Q increases, quality q decreases, Qq=C. Sooner or later, "It will be very difficult to maintain the supply of food and raw material." (James Lovelock). If we want to survive, "We need to reconsider both our relationship with Nature and our relationship with ourselves, with our society." (Edgar Morin) [27]. Everywhere Man species is able to increase its EXO HOSTING. It has be done, and is still going on, more and more [18, 19, 20]. But there are never advantages without disadvantages, and the greater the advantages, the greater the disadvantages [17, 21]. Man species activities are increasing more and more climate change. Drought and pollutions in air, waters and soils, are increasing. Domestic plants and animals species are endangered. And Man species is endangered too [19]. But things are not changing! "Conflict between Man and Nature has been increasing to an extent likely to undermine the very foundations of Life on Earth." (Mikhaïl Gorbachev) [25].

Man is a very endangered species [19]! Can we do something about that? Matter and energy are used without limits by Man species, to produce more and more men, and only for Man species survival! "We have to understand that we are approaching a bottleneck." (Edgar Morin). Can we do something to slow down this process? What are the lessons we can study from Nature [1, 27, 29]?

#### In a systems-of-systems world win-win process don't exist.

For more than hundred years, symbiosis [39] has been defined as an association for mutual benefits. That it is not what it is! We are rediscovering what it is [8]: it is an ARMSADA! Whatever the actors and the interactions into a system -as a Whole-, "there are never advantages without disadvantages". "All that is an advantage for a partner is a disadvantage for another one! If there are some benefits they are only for the Whole." Whatever the kind of structure, type of functioning and level of organisation, of both the partners and the Whole, all living systems (bacteria, cells, multi-cell organisms, ecosystems... (figure 3)) are ARMSADAs [13]. With only 2 paradigms we drew a periodic table of living systems classification according to their organisation levels (figure 4). These 2 paradigms are falsifiable and fruitful. The ARMSADA paradigm allowed assumptions that has been proved in AIDS and cancer curation research [14, 15].

**To sum up**— LOG scaling appears a more fruitful way for the representation and understanding of natural phenomena (figures 5, 6) and the discovery of Life's complexity (figure 8). The gauge invariance characteristics (figure 1) are interrelated and controlled by power-laws relationships (figure 7). Whatever the evolutionary jumping process [12] that allows, sooner or later, emergences of new blueprints (figure 4), of new ARMSADAs (figure 3), ENDO-EXO interactions (figure 2) and HOSTING-HOSTED limitations (figure 8) are controlled either by local power laws (figures 7, 8) or a global scale-free, fractal, 3/2 (or 2/3) exponent power law (figures 6, 9) which optimises the local and global flows of exchanges (figures 9, 10). The underlying phenomenon that does force living systems-of-systems to obey this law slavishly is the Brownian motion process (figure 11).

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